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ABSTRACT

This hearing was held to examine the current state of mathematics, science, and engineering education at the undergraduate level by focusing on the demands of a knowledge-based economy. Contents include opening statements by Representative Nick Smith, Chairman, Subcommittee on Research, Committee in Science, U.S. House of Representatives; Representative Eddie Bernice Johnson, Ranking Minority Member, Subcommittee on Research, Committee in Science, U.S. House of Representatives; and Representative John B. Larson, Member, Subcommittee on Research, Committee in Science, U.S. House of Representatives. The witnesses were Dr. Carl E. Wieman, Distinguished Professor of Physics, University of Colorado, Boulder; Dr. Kathleen P. Howard, Assistant Professor of Chemistry, Swarthmore College; Dr. Daniel A. Wubah, Professor of Biology, James Madison University; Dr. Steven Lee Johnson, Provost and Chief Operating Officers, Sinclair Community College; and Dr. James Narl Davidson, Professor of Mechanical Engineering and Interim Dean of Engineering, Georgia Institute of Technology. (YDS)

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ED 473 140

MEETING THE DEMANDS OF THE KNOWLEDGE BASED ECONOMY: STRENGTHENING UNDERGRADUATE SCIENCE, MATHEMATICS AND ENGINEERING EDUCATION

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTH CONGRESS

SECOND SESSION

MARCH 7, 2002

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MEETING THE DEMANDS OF THE KNOWLEDGE BASED ECONOMY: STRENGTHENING UNDERGRADUATE SCIENCE, MATHEMATICS AND ENGINEERING EDUCATION

THURSDAY, MARCH 7, 2002

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:40 a.m., in Room 2325 of the Rayburn House Office Building, Hon. Nick Smith [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
SUBCOMMITTEE ON RESEARCH
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

Meeting the Demands of the Knowledge Based Economy: Strengthening Undergraduate Science, Mathematics and Engineering Education.

Thursday, March 7, 2002
10:30am – 12:30 p.m.
2325 Rayburn House Office Building

WITNESS LIST

Carl Wieman, Ph.D.
Distinguished Professor of Physics
Recipient of the 2001 Nobel Prize in Physics
University of Colorado, Boulder

Kathleen P. Howard, Ph.D.
Assistant Professor of Chemistry
Swarthmore College

Daniel Wubah, Ph.D.
Professor of Biology
James Madison University

Steven Lee Johnson, Ph.D.
Provost and Chief Operating Officer
Sinclair Community College

Nari Davidson, Ph.D.
Professor of Mechanical Engineering and Interim Dean of Engineering
Georgia Institute of Technology

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SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Meeting the Demands of the Knowledge Based Economy: Strengthening Undergraduate Science, Mathematics and Engineering Education

THURSDAY, MARCH 7, 2002
10:30 A.M.–12:30 P.M.
2325 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On March 7, 2002, the Subcommittee on Research will hold a hearing to examine the current state of undergraduate mathematics, science, and engineering education. The hearing will:

- Examine challenges in undergraduate science, mathematics and engineering education at a variety of institutional types;
- Explore examples of undergraduate science, mathematics and engineering programs that address the relevant problems;
- Discuss federal programs that could be developed in the future to fill current gaps or stimulate additional change; and
- Consider H.R. 3130, The Technology Talent Act, and gain recommendations on how this bill could be expanded into a more comprehensive legislative package to address the needs of the undergraduate mathematics and science education community.

2. Background

Workforce Challenges

Institutions across the United States—from community colleges to research universities—are facing a number of challenges in recruiting and retaining ample numbers of highly qualified students to majors in science, mathematics, and engineering. In addition, institutions face the challenge of trying to ensure that all students, regardless of major or career interest, become scientifically literate members of society and capable users of technology.

Recent data suggest a number of important trends regarding the production of the next generation of scientists and engineers. While the overall percentage of science and engineering degrees as a function of the total number of degrees awarded has remained relatively steady across the past 35 years, certain fields have experienced serious declines. Student interest has shifted markedly from the physical sciences and mathematics to the life sciences and computer science. In addition, in a number of technical fields, the percentage of Bachelors degrees that are awarded to foreign students has been steadily increasing.

At the same time, the demand for jobs requiring technical expertise is growing, and indicators point to a mismatch between the supply of scientists and engineers in certain disciplines and the demand for them. For example, the reliance of companies on H1–B visas used to hire foreign scientists—especially in the areas of computer science, engineering and bioinformatics—suggest that corporate America is feeling the pinch of supply and demand for individuals trained in these fields.

Given the demands of our knowledge-based economy, the U.S. needs to increase the number and diversity of trained scientists and mathematicians and facilitate an understanding of basic scientific principles among non-scientists. The Nation's colleges and universities are not meeting these challenges. Some believe it is the institutional structure of these institutions that is to blame, citing examples such as the tenure system and its emphasis on rewarding research over teaching at many colleges and universities. Others cite a lack of attention or funding for education at

the undergraduate level. Still others believe faculty culture and historical practice—such as the use of large introductory lecture classes or the use of teaching assistants instead of professors to teach courses—are the chief culprits. There are as many opinions as there are faculty, students and administrators, but in this hearing we will examine successful models of undergraduate education and highlight key elements of effective programs.

Lack of preparation of students at the high school level

While not a focus of this hearing, national results of student performance on high school science and mathematics assessments clearly suggest that there are simply too few students with the mathematical or analytical skills necessary for college-level math and science coursework. According to a 1996 study conducted by the National Center for Education Statistics, 30 percent of all incoming college freshmen require some form of remedial coursework to prepare them for college-level math and science courses. Currently, all of the Nation's community colleges and 81 percent of four-year higher education institutions offer remedial courses to students. Because students who require remedial education are less likely to consider majors that require mathematics prerequisite courses—such as majors in the physical, engineering and computer sciences—lack of preparation at the high school level clearly plays a role in many students' decisions not to choose a technically based major.

A number of legislative proposals aimed at addressing this problem are in various stages of the legislative process. H.R. 1858, the National Mathematics and Science Partnership Act, was passed unanimously through the Science Committee and was adopted without dissent by the House last year. A Senate companion to H.R. 1858, offered by Senators Rockefeller, Roberts, and Kennedy, S. 1262, awaits action in the Senate. The Senate companion also includes another House bill, H.R. 100, which was authored by Rep. Ehlers and also adopted unanimously by the House. Finally, H.R. 1, the No Child Left Behind Act, was signed into law last year by President Bush, and contains provisions aimed at addressing shortcomings in K–12 math and science education.

Past Science Committee hearings have focused on the critical issue of improving science and mathematics education at the K–12 level. This hearing focuses on the next step—undergraduate education in these disciplines. What follows is a summary of perceived problems and potential solutions—some largely untested, others in practice for years.

The Tech Talent Act—discouraging the 'weeding out' of potential science majors

Stanford Economist Paul Romer, in a 2000 paper entitled *Should the Government Subsidize Supply or Demand in the Market for Scientists and Engineers?*, proposed that it is the traditional 'weeding out' process in science, mathematics and engineering departments—not a lack of interested students—that is largely responsible for the current shortfall of undergraduate majors in science, mathematics, and engineering. Romer asserts that U.S. colleges and universities have institutionalized a culling process, implemented through tough grading policies and a survivalist mentality in introductory courses, that eliminates a large percentage of students who were once interested in science and engineering. Rooted in long tradition, the exclusionary mindset of science and engineering departments has become part of the institutional culture that, along with intense pressure for faculty research productivity, has led to the costly loss of talent and diversity in the scientific enterprise due to student attrition.

While few can disagree that science and engineering programs are highly selective in nature, not everyone accepts Romer's premise regarding the cause of this selectivity—that this weeding out process is simply the institution's way of holding down costs. Romer's proposed remedy to this problem is, in essence, to provide financial incentives—federal funding—to universities that agree to turn out more scientists and engineers. A Canadian program that provides incentives to Ontario universities for each new computer science and engineering student they educate appears to be successful—the participating institutions have seen a collective increase in enrollment of 145 percent for engineering students and 180 percent for computer science students since the program was implemented.

H.R. 3130, the Technology Talent Act, which was introduced last fall by Chairman Boehlert, along with original co-sponsors Mr. Larsen, Ms. Hart, Mr. Honda, and Mr. Udall, builds on the Romer proposal. (The bill is identical to its Senate companion, S. 1549, which was introduced by Senators Leiberman, Bond, Domenici, Frist, and Mikulski.) It authorizes $25 million for FY02 and such sums as necessary for the succeeding years to create a competitive grant program at the National Science Foundation (NSF) that would provide funding and rewards to institutions that develop creative and effective recruitment and retention strategies that bring more

students into science, mathematics, and engineering programs. Congress provided $5 million in FY02 for a pilot program based on the Tech Talent bill, the Science, Technology, Engineering and Mathematics Talent Expansion Program (STEP); the FY03 budget request includes $2 million for continuation of the program.

Improving curricula and faculty training

Another explanation for the 50 to 60 percent attrition rates seen at many universities for first-year students who declare an interest in science majors but later switch to non-scientific fields is that curricula and teaching at the undergraduate level are to blame. Elaine Seymour, a research associate in the Department of Sociology at the University of Colorado, Boulder, suggests that lack of student interest in these fields is often due to "appalling teaching" that is a result of poor curricula and teacher training. However, a number of institutions—often led by one or a few dedicated faculty members—have sought to address this problem head-on, by engaging in extensive curriculum reform efforts aimed at improving undergraduate instruction through curriculum revisions or faculty training.

Project Kaleidoscope (PKAL) has been an innovator in the undergraduate education reform movement. PKAL began in 1989, with support from the National Science Foundation, when academicians from a number of different institutions met to outline an agenda for the reform of science and mathematics at liberal arts institutions. PKAL's charge evolved to include the identification and dissemination of successful practices that transform the learning environment in college and university science and mathematics departments, and to build national networks working toward that end. Over its 10-year history, PKAL has attracted additional funds from the National Science Foundation, the Howard Hughes Medical Institute, and a number of private and corporate foundations. PKAL disseminates information—through workshops, institutes, and publications—about working models to strengthen student interest and success in science. PKAL is now engaged in a new emphasis on catalyzing transformation at the institutional level, wherein institutions that have demonstrated accomplishment in improving undergraduate science and mathematics education over the past five years—by weaving science, mathematics and engineering education into their strategic plan, implementing policies and practices that reward faculty for teaching excellence and scholarly activity, and creating up-to-date facilities that enable research-rich learning environments for students, for example—would expand these efforts across multiple science, mathematics, or engineering disciplines both for majors and non-majors.

The National Science Foundation supports a host of programs aimed at improving undergraduate curricula, facilities, and faculty performance. Undergraduate science, mathematics, and engineering education activities are supported not only by the Education and Human Resources (EHR) Directorate, but also by individual research directorates. Primarily, however, funding for undergraduate education reform comes from the Division of Undergraduate Education (DUE) in the EHR Directorate. While the FY 2002 budget for DUE totaled $142.41 million, the FY 2003 President's budget request cuts funding for DUE by 4.8 percent—down to $135.60 million. A description of current programs operated by DUE can be found in Appendix A.

Private sector efforts to improve undergraduate teaching and curricula. In addition to programs offered by NSF, private-sector foundations, such as the Howard Hughes Medical Institute (HHMI) and the ExxonMobil Foundation, also sponsor programs aimed at improving undergraduate education in the sciences. Targeted mostly toward the biological sciences or interdisciplinary programs linking biology with other sciences, HHMI will provide, in 2002, $80 million in grants to research and doctoral universities and $50 million to bachelor's and master's degree granting institutions (primarily independent liberal arts colleges). The purpose of these grants is to strengthen undergraduate science education and respond to the recent surges in undergraduate enrollments in the biological sciences, as well as to the rapid advances in molecular biology, genetics and related life sciences. ExxonMobil, through its Project NExTNew—Experiences in Teaching—provides a number of opportunities for new or recent Ph.D.s in the area of mathematical sciences who are interested in improving the teaching and learning of undergraduate mathematicians.

Engaging undergraduates through research projects

A popular model for undergraduate education reform, following largely in the footsteps of K–12 education reform, involves the integration of hands-on learning in college-level course work. It is believed that when students participate in the real world of science—by working with research faculty or graduate students during the academic year or summer months—they experience the joy of discovery, develop higher-order cognitive skills, and are attracted to careers in science that, perhaps, they had never even considered before.

A recent survey of 136 liberal arts colleges found that the number of students engaged in research has risen by 70 percent in the past decade. Research universities have always included their best students in undergraduate research opportunities, but like their independent college counterparts, these institutions are looking for new ways to include more students—including non-majors—in some aspect of scientific research. Non-research campuses are also jumping on the research bandwagon by partnering with research institutions that offer summer research experiences to students.

Including undergraduates in research programs is especially difficult in large research universities where thousands of students earn degrees each year and where graduate students and post-doctoral fellows have priority in laboratory placement. At many undergraduate institutions there are no research facilities, and scant budgets to afford supplies or instrumentation. Some institutions are finding novel ways to provide research experiences to students that deviate from the traditional model of having a student work in a single professor's laboratory, such as summer research programs and those that involve partnerships with other institutions.

The Research Experiences for Undergraduates (REU) program is an NSF program that supports undergraduate research opportunities. Through this program, professors can either supplement their current NSF research grants with funds intended to support a few undergraduate students in their laboratory, or may seek funding to establish independent REU sites that support a number of students in a variety of research activities during the summer months. Many past students supported by the program report their REU experience as being pivotal to their decision to pursue graduate education, and faculty involved in the program are equally enthusiastic about it. However, a June 2000 report by SRI International found that REU programs, for the most part, have not developed ways to adequately measure the outcomes or success of the program.

The pressure on faculty at institutions that traditionally focused primarily on teaching to develop productive research programs has intensified enormously. While this new emphasis on research has opened up opportunities for students to engage in hands-on learning about science, the burden on faculty to develop a successful research program—including obtaining research grants and publishing results—on top of extensive teaching demands is sizable. NSF's Faculty Early Career Development (CAREER) program is aimed at addressing the needs of these professors. CAREER awardees are selected based on their ability to effectively integrate research and education within the context of their institution's mission.

Addressing under-represented populations in science, mathematics, and engineering

According to the National Science Foundation, only a third of the minority students who begin pursuing the sciences wind up graduating with a science or engineering degree. Women earn less than 11 percent of the engineering degrees and only 24 percent of the degrees in the physical sciences. And even in the life sciences, where the number of women and men earning advanced degrees is nearly equal, women hold only 19.1 percent of the faculty positions in research universities. Clearly, the shortage of students entering technical fields would largely be reversed were women, minorities, and other populations currently under-represented in mathematics, science, and engineering to achieve parity.

NSF, in the Division of Human Resource Development within the EHR Directorate, has a number of programs aimed at increasing the participation of under-represented students in science including the Louis Stokes Alliances for Minority Participation Program ($26.53 million), the Historically Black Colleges and Universities-Undergraduate Program ($13.97 million), the Tribal Colleges and Universities Program ($9.98 million), the Program for Gender Equity ($10.96 million), and the Program for Persons with Disabilities ($5.38 million), to name a few. Beyond that, the ADVANCE program is a crosscutting program that aims to increase the number of women in all fields of science and engineering. Since 1995, the Division of Environmental Biology has offered the Undergraduate Mentorships in Environmental Biology program, which is aimed at encouraging the participation of under-represented groups within the environmental biology field. This program supports research experiences for undergraduate students who work closely with their faculty mentors across a period of several years including the academic year and intensive summer experiences.

Tapping the Community College student population

More than 1,100 community colleges serve more than 10 million students across the United States, including 25 percent who already hold a bachelors degree or higher. Almost half of all first-year college students begin their work with community colleges. And with a tradition of open door admissions, low tuition, flexible pro-

gramming, customized student services, and quality of learning opportunities, community colleges continue to be the pathway to higher education for minority students. Overall, 46 percent of all African American students, 55 percent of all Hispanic students, and 55 percent of Native American students in higher education attend community colleges. In addition, more than half of community college students are first-generation students.

NSF, through the Advanced Technological Education Program—which was created by Congress in 1992 (P.L. 102–476)—has funded over 200 community-college focused projects including 12 National and 3 Regional Centers of Excellence in areas ranging from information technology to environmental technology and biotechnology. In addition to supporting programs aimed at the production of a highly trained technical workforce, the ATE program also supports articulation partnerships that connect two-year colleges with 4-year institutions, especially in those programs that support the preparation of future teachers. Over 40 percent of all teachers, and potentially an even higher percentage of primary teachers, receive much of their science and mathematics education at community colleges. Given the impact that the ATE program has had on enhancing programs, courses and facilities dedicated to the needs of training technicians at community colleges, it only makes sense that an equal investment in the core academic courses at community colleges will increase the number and quality of students—especially under-represented students—who enter the science, engineering and mathematics education and career pathway.

3. Witnesses

The following witnesses will address the Subcommittee. (For a more detailed description of the issues each witness is expected to address, see Appendix B.)

- *Dr. Steven Lee Johnson,* Provost and Chief Operating Officer, Sinclair College, will address issues related to science and mathematics programs at community colleges and serve as a representative of the League for Innovation in the Community Colleges.
- *Dr. Daniel Wubah,* Professor of Biology, James Madison University, will discuss programs that are particularly successful in identifying and supporting talented students—including non-traditional and under-represented students—in science, mathematics and engineering at comprehensive colleges and universities.
- *Dr. Narl Davidson,* Professor of Mechanical Engineering and Interim Dean of Engineering, Georgia Institute of Technology, will discuss Georgia Tech's efforts to cultivate talent among women and minorities in engineering.
- *Dr. Kathleen Howard,* Assistant Professor of Chemistry, Swarthmore College, will speak to the challenges that new faculty members face in trying to juggle the demands of research and teaching.
- *Dr. Carl Weiman,* Distinguished Professor of Physics and Nobel Laureate, University of Colorado-Boulder, will talk about his work in the area of engaging students—including non-majors—in physics through the development of lecture-based teaching methods that actively engages students.

Appendix A

NSF programs within the Division of Undergraduate Education

- *National Science, Technology, Engineering and Mathematics (STEM) Education Digital Library*—lays the foundation for a national resource to increase the quality, quantity and comprehensiveness of Internet-based STEM education resources while creating virtual learning communities that link students, teachers, and faculty with each other and with a wide array of educational materials and learning tools. ($23.6 million)
- *The NSF Director's Awards for Distinguished Teaching Scholars*—seeks to engage faculty who bring the excitement and richness of discovery within STEM fields to all students. ($1.51 million)
- *Assessment of Student Achievement in Undergraduate Education*—supports assessments of undergraduate student performance and program quality, and provides frameworks and measurable indicators for student academic learning outcomes and the quality of department and institutional environments in support of student learning. ($3.0 million)
- *Course, Curriculum, and Laboratory Improvement*—strengthens NSF's efforts to assure access to a high quality STEM education for all students by focusing on the identification, development, adaptation and implementation of exem-

plary curricular and laboratory educational materials and instructional models. ($45.63 million)

- *Robert Noyce Scholarship Program*—will be initiated this year, in response to H.R. 1858 (Boehlert, NY (R)), to offer scholarships for juniors and seniors who are majoring in mathematics, science or engineering; and stipends for science, mathematics or engineering professionals seeking to become teachers. ($5 million)
- *STEM Talent Expansion*—will be initiated this year to support initial planning and pilot efforts at colleges and universities to achieve an increase in the number of U.S. citizens and permanent residents pursuing and receiving associates or bachelors degrees in established or emerging STEM fields. ($5 million)
- *Federal Cyber Service: Scholarships for Service*—seeks to build a cadre of individuals in the federal sector with the skills needed to ensure protection of the Nation's critical information infrastructure. ($11.18 million)
- *Advanced Technological Education*—supports improvement in technician education by supporting, particularly at two-Year colleges and secondary schools, the design and implementation of new curricula, courses, laboratories, educational materials, opportunities for faculty and student development, and collaboration among educational institutions and partners from business, industry and government. ($38.16 million)
- *STEM Teacher Preparation (STEMTP)*—is the Foundation's principal effort to strengthen the STEM content knowledge and pedagogic skills of prospective K–12 teachers in preparation for the delivery of standards-based instruction. ($6.52 million)
- *Computer Science, Engineering and Mathematics Scholarships Program*—is the activity, under P.L. 106–313, that provides merit-based scholarships for up to two years to students who have demonstrated financial need and who are enrolled in an undergraduate or graduate degree program in one of the listed disciplines. ($55.04 million estimated this program is funded through H1–B Non-immigrant Petitioner Fees).

Appendix B

Witnesses

Dr. Steven Lee Johnson, Provost and Chief Operating Officer, Sinclair College.

Sinclair Community College has been one of the leading NSF-funded 2-year colleges across the past decade and has also been a leader in meeting workforce needs in information technology, manufacturing technology and engineering. In addition to discussing the impact of NSF-funded programs at Sinclair College, he will discuss the work of the League for Innovation in the Community College to advance the community college agenda nationally. Dr. Johnson will address problems community colleges face in securing funding for their core academic and transfer programs, in facilitating faculty development in a non-research intensive environment, and in finding support for the dissemination of good models and practices across the Nation.

Dr. Daniel Wubah, Professor of Biology, James Madison University

Dr. Wubah will discuss programs that axe particularly successful in identifying and supporting talented students—including non-traditional and under-represented students—in science, mathematics and engineering at comprehensive colleges and universities. Dr. Wubah will discuss the unique challenges comprehensive undergraduate institutions face in 1) competing with research and selective liberal arts institutions for funding because of the limited resources on undergraduate campuses; 2) encouraging students to participate in research when facilities are limited and few faculty have established research programs; 3) educating students about their career options and higher education options in science, math and engineering; 4) dealing with the unique needs of non-traditional students, commuter students, working students, and first-generation college students (who represent a wealth of untapped talent). Dr. Wubah will highlight the importance of mentoring in recruiting talent at comprehensive undergraduate institutions and his own successes through the NSF Research Experiences for Undergraduates program and the NSF Undergraduate Mentoring in Environmental Biology program. Dr. Wubah will discuss the need for additional programs or targeted program components—both in NSF's Division of Undergraduate Education and the Division of Graduate Education—that recognize the unique opportunities and challenges of comprehensive undergraduate institutions and the students enrolled at those institutions.

Dr. Narl Davidson, Professor of Mechanical Engineering and Interim Dean of Engineering, Georgia Institute of Technology

Georgia Tech has been a leader in cultivating talent among women and minorities in engineering. Georgia Tech has adopted the philosophy of cultivating talent among those students who express an interest in engineering as opposed to weeding out interested students in hope of finding better talent elsewhere. This witness will speak to the need for programs that support the Romer model of "cultivating the talent you have" rather than discouraging students by a highly selective "culling" model.

Dr. Kathleen Howard, Assistant Professor of Chemistry, Swarthmore College

Dr. Howard will speak to the challenges that new faculty members face in trying to juggle the demands of research and teaching. Dr. Howard, a recipient of an NSF Career award, will discuss her efforts to engage undergraduate students—from freshmen to seniors—in undergraduate research in her classes and her laboratories. Dr. Howard will discuss the impact that HHMI funding has had in stimulating interdisciplinary, institutional transitions toward undergraduate research-based curricula and programs. Swarthmore has been a leader in producing graduate students who go on to win graduate teaching assistant awards at research-intensive universities. Dr. Howard will discuss her thoughts on why Swarthmore students become such strong teachers, themselves, and will also discuss the impact that careful tracking of students beyond graduation has had on the instructional program at Swarthmore.

Dr. Carl Weiman, Distinguished Professor of Physics and Nobel Laureate, University of Colorado-Boulder

Dr. Weiman, winner of the NSF Distinguished Teaching Scholar award, and Nobel Prize winner for physics will talk about his work in the area of engaging students—including non-majors—in physics through the development of lecture-based teaching methods that actively engage students. Dr. Weiman will discuss the difficulties faculty face in implementing novel pedagogical strategies because of student resistance to techniques with which they are unfamiliar and administrator's wishes to keep students happy. Dr. Wieman will discuss the importance of making instruction relevant to the daily lives of students and the need to make courses more attractive to students while maintaining their rigor and content delivery.

Chairman SMITH. The Subcommittee on Research will come to order. Today, this Subcommittee meets to discuss improvements in undergraduate math and science education and how the Federal Government, particularly, in the National Science Foundation, can assist in these efforts.

I think the challenges before us are not exactly clear, except that we want to improve. If we want to maintain our competitive edge in the world, we have to do a better job, it would seem to me, of preparing all students to have a better understanding of the new technology in this new age and new world that we live in and, of course, better preparing our students for careers in science, and mathematics, and engineering, and technology.

Think for just a moment about the war situation we are in today, and it is going to be our research efforts that are not only going to develop the new smart weapons, but it is also going to be these science and math students in our research efforts that are going to develop the tools, and the new computers, and the new technologies that are going to assist us in the research that is going to develop how we can have better national security, number one, and certainly, how we are going to stay on the cutting edge of competitiveness in a world market that is becoming increasingly challenging in terms of other countries trying to move ahead as we move from the industrial age into the information technology age.

I think we must improve our science and math education programs so that we can meet these challenges. It is critical in so many ways. We know that much math and science education problems that we are facing take root in the K through 12 school system that has lacked in exciting individuals into the math and science career. We had a Subcommittee hearing last year, and I asked the witnesses, to the extent that education in K through 12 is more the filling of a container—is less the filling of a container and more the lighting of a fire in terms of interest, in terms of not being fearful of math and science, where does that fire, when is that fire lit, and three out of the five suggested that probably it starts at home, maybe at four years old, but certainly, in kindergarten through 3rd grade and in school. And so to what extent should we be interested in college of doing a better job of developing ways that can excite and light that fire with young people, and then as these youngsters move through the 5th through the 12th grade, how do we maintain the kind of quality teacher with enough experience that they can keep that fire lit until they get to the subject that we are talking today, how do we do a better job once they get to the college arena.

Consistent with this, the House has already passed last year H.R. 1858, a bill authorizing NSF to build partnerships for improved cooperation between high schools and universities so that students are better prepared for college math and science curriculum. This legislation has received funding as a component of the President's significant education reform initiatives.

And I think that means that we are off for a vote, one vote, shortly.

Consistent with those initiatives, we are now beginning to examine how we can improve undergraduate math and science education. To do this, we must first determine exactly where the prob-

lems lie. Today's hearing is intended to do just that, as well as consider potential solutions to these problems so that we can work toward legislation to improve undergraduate math and science education.

We have a very esteemed panel of witnesses before us today with some innovative ideas and opinions on how to best bring about meaningful reforms. They represent an assortment of university systems from large public research universities to private liberal arts colleges, including the 2-year community colleges. I anticipate that each of you will provide a unique viewpoint into the challenges in math and science education, and I hope, I expect, we will discuss a wide variety of issues. I certainly want to thank you for being here and taking time out of what I am sure is your busy schedules. And with that, let me yield to Mrs. Johnson.

[The prepared statement of Chairman Smith follows:]

PREPARED STATEMENT OF CHAIRMAN NICK SMITH

Today the House Science Subcommittee on Research meets to discuss the improvement of undergraduate math and science education and how the Federal Government, in particular the National Science Foundation, can assist in these efforts.

The challenges before us are clear. If we want to maintain our competitive edge in the world, we have to do a better job of preparing our students for careers in science, mathematics, engineering, and technology. Think for just a moment about the war situation we are now in: today's engineering students will be designing tomorrow's military planes and smart bombs; today's biology students will be sequencing biological weapons and generating vaccines for them; and today's computer science students will be securing our computer and networking infrastructure against cyber attacks. We must improve our science and math education programs so that we can meet these challenges. It is critical to our economic security, and it is critical to our national security.

We know that much of the math and science education problems we are facing take root within a K–12 school system that is woefully ineffective at preparing students to pursue math and science majors. The Science Committee, and this Subcommittee in particular, has worked extensively at improving K–12 math and science. Last year, the House passed H.R. 1858, a bill authorizing NSF to build partnerships for improved cooperation between high schools and universities so that students are better prepared for college math and science curriculum. This legislation has received funding as a component of the President's significant education reform initiatives.

Consistent with those initiatives, we are now beginning to examine how we can improve undergraduate math and science education. To do this, we must first determine exactly where the problems lie. Today's hearing is intended to do just that, as well as consider potential solutions to these problems so that we can work toward legislation to improve undergraduate math and science education.

We have a very esteemed panel of witnesses before us today with some innovative ideas and opinions on how to best go bring about meaningful reforms. They represent an assortment of university systems, from large public research universities to private liberal arts colleges to the two-year community colleges. I anticipate that each will provide a unique viewpoint into the challenges in math and science education, and I expect we will discuss a wide variety of issues. I want to thank the panelists for appearing before us today, and I look forward to your testimony.

Ms. JOHNSON. Thank you very much, Mr. Chairman. I am very pleased to see our witnesses and I would like to join you in welcoming them, and I think that this is a very, very important hearing, trying to explore ways to improve undergraduate science, math, engineering, and technology education, or science education, for short.

I see this hearing as addressing two important issues: how we attract and retain more students from all backgrounds in associate and baccalaureate degree programs in these fields, and how do we

ensure that all undergraduate students receive a quality education experience in their science courses regardless of the clear path which they choose. A serious concern about undergraduate science education, which provides a strong motivation for this hearing, is the perception that too few students are moving toward careers in science and technology. The trend for the future is for flat or declining numbers of students in these fields and it is really essential for our economy.

Also, the title of the hearing suggests our interest in the condition of undergraduate science education is tied to the reality that technology infuses more and more aspects of our daily life. So it requires that all students receive a basic grounding in science and math to function in this increasingly complex world and to lead fulfilling lives.

Today, we hope to hear from you who are here about what you have to offer in 2-year colleges, primarily, undergraduate universities, comprehensive universities, research universities, as well. I am interested in the witnesses' assessment of the current state of undergraduate science education experiences regarding efforts to make these improvements. I am also very concerned about how we get the teachers well educated and trained in these areas and keep them in the teaching profession.

So the basic question today is what works, what are the conditions necessary for success? And I hope to hear what barriers and impediments exist in improving undergraduate education. In particular, what kinds of Federal programs have proven to be helpful or not helpful in bringing about reform.

Thank you, Mr. Chairman. I am going to ask that my entire speech be placed in the record.

Chairman SMITH. Without objection.

Ms. JOHNSON. Thank you very much.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF THE HONORABLE EDDIE BERNICE JOHNSON

I am pleased to join the Chairman in welcoming our witnesses to today's hearing on exploring ways to improve undergraduate science, math, engineering and technology education—or science education, for short. I see this hearing as addressing two important issues: how do we attract and retain more students from all backgrounds in associate and baccalaureate degree programs in these fields, and how do we ensure that all undergraduate students receive a quality educational experience in their science courses, regardless of the career path they choose.

A serious concern about undergraduate science education, which provides a strong motivation for this hearing, is the perception that too few students are moving toward careers in science and technology. The trend for the future is for flat or declining numbers of students in fields that are essential to the economy.

Also, as the title of the hearing suggests, our interest in the condition of undergraduate science education is tied to the reality that technology infuses more and more aspects of daily life. This requires that all students receive a basic grounding in science and math to function in an increasingly complex world and to lead fulfilling lives.

Today, we will hear from those who are engaged in undergraduate education in a range of educational settings—two-year colleges, primarily undergraduate universities, comprehensive universities, and research universities. I am interested in the witnesses' assessment of the current state of undergraduate science education and in their experiences regarding efforts to make improvements.

The basic questions today are what works, and what are the conditions necessary. for success? I hope to hear what barriers and impediments exist in improving undergraduate education, and in particular, what kinds of federal programs have proven to be helpful—or not helpful—in bringing about reform. Naturally, the Sub-

committee would be interested in your comments on the value of NSF-sponsored programs, and on any recommendations you may have for ways to improve the recruitment and retention of students in the science degree track.

A major goal of efforts to improve science undergraduate education must be to institute policies and programs that will tap the human resource potential of individuals from groups under-represented in science and technology. Simple demographic trends make clear the importance of increasing participation rates of women and minorities in meeting workforce needs of the future. This is particularly true for attracting individuals to careers in the physical sciences and engineering. I know some of our witnesses have been engaged in programs that address this issue, and I look forward to learning more about them.

Mr. Chairman, I want to thank you for convening this hearing on this important subject. I appreciate the attendance of our witnesses today, and I look forward to our discussion.

[The prepared statement of Mr. Larson follows:]

PREPARED STATEMENT OF REPRESENTATIVE JOHN B. LARSON

Thank you, Mr. Chairman, for convening this hearing today.

It is no secret that America has long recognized that its long-term strength and security, and its ability to recover and sustain high levels of economic growth, depends on maintaining its edge in scientific achievement and technological innovation. Biomedical advances have permitted us to live longer, healthier, and more productively. Advances in agricultural technology have permitted us to be able to feed more and healthier people at a cheaper cost, more efficiently. The information revolution can be seen today in the advanced instruments schools are using to instruct our children and in the vast information resources that are opened up as a result of the linkages created by a networked global society. Our children today can grow up to know, see, and read more, be more diverse, and have more options in their lives for learning and growing. Other emerging technologies—such as nanotechnology—have untold potential to make our lives more exciting, secure, prosperous, and challenging.

Many countries also recognize this and they, therefore, focus their industrial, economic, and security policies on the nurturing and diffusion of technological advancement through all levels of society in a deliberate fashion. Countries that follow this path of nurturing innovation focus a lot of their efforts into recruiting and training the very best engineers and scientists, ensuring that a pipeline which pumps talented and imaginative minds and skills is connected to the needs of the country's socioeconomic and security enterprise.

Yet here in this country, this pipeline is broken, threatening the competitive edge we enjoy in the business of technological innovation. Fewer and fewer Americans are getting degrees in scientific and technical fields—even as the demand grows. For example, the number of bachelors degrees awarded in math, computer science, and electrical engineering has fallen 35 percent and 39 percent respectively from their peaks in 1987, at a time when total BA degrees have increased. The number of graduate degrees in those fields has either fallen noticeably or stayed flat. And only about half of all engineering doctoral degrees granted in the U.S. are earned by Americans.

The Nation has dealt with this crisis in the recent past by expanding the H1–B Visa program to let more foreign residents with science and engineering degrees enter the country. But the H1–B program was never intended to be more than an interim solution. The long-term solution has to be ensuring that more Americans get into these fields.

For these reasons last year along with House Science Committee Chairman Sherwood Boehlert, and Representatives Melissa Hart, Mark Udall, and Mike Honda, I introduced the Tech Talent Act, H.R. 3130, aimed at increasing the number of scientists, engineers, and technologists in the United States. Senators Joseph Lieberman (D–CT), Christopher Bond (R–MO), Barbara Mikulski (D–MD), Bill Frist (R–TN), and Pete Domenici (R–NM) introduced a companion bill in the Senate.

This legislation addresses the tech worker shortage by establishing a competitive grant program at the National Science Foundation that rewards universities and community colleges that pledge to increase the number of U.S. citizens or permanent residents obtaining degrees in science, math, engineering and technology (SMET) fields. The pilot program, which will award three-year grants, is authorized at $25 million in the next fiscal year, with funding expected to increase if the initial results are encouraging.

It always pays to be mindful of the fact—especially in the wake of the September 11 events—that there is a strong and tight linkage between our national security and the level of science and technology proficiency in America. Our strength and leadership in the world is based on the might of our defense, strength of our economy, and the quality of our education system. Without any one of these three components the global preeminence of the Nation suffers.

In the House Science Committee room there is a inscription: Where there is no vision, the people perish. To remain a strong nation, we must ensure that the single most important element that keeps us dynamic, innovative, prosperous, and secure—and therefore mighty—is there for us: our students, teachers, researchers, engineers, scientists, and technologists. In short, we need more people with vision. This bill will keep them coming.

I believe this bill represents an important first step in our efforts to spur anew the interest of our youth in selecting fields that will propel the future growth of this country. I look forward to hearing the witnesses' ideas on how we can build on this bill and ensure that we meet the goal of enhancing our nation's technology workforce.

Thank you.

Chairman SMITH. We will recess. The bell and beepers meant that we have a vote on. It will take us probably eight minutes to go over and vote and return. I understand there is one vote. So with that, the Committee is in recess.

[Recess.]

Chairman SMITH. The Subcommittee on Research will resume, and I will start out by introducing our esteemed panelists. Dr. Carl Wieman is a Ph.D., Distinguished Professor of Physics, recipient of the 2001 Nobel Prize in Physics, from the University of Colorado in Boulder. Dr. Kathleen Howard is an Assistant Professor of Chemistry at—how do I say it—Swathmore. I am sorry, I am just a Midwesterner. Dr. Steven Lee Johnson, Provost and Chief Operating Officer of Sinclair Community College in Dayton, Ohio. I can pronounce that. And Dr. Narl Davidson, Professor of Mechanical Engineering and Interim Dean of Engineering at Georgia Tech. So to all of you, welcome.

And as our panelists may know, the spoken testimony is limited to five minutes and then after that, each member will be given five minutes to ask questions, and we will decide when we finish the first round whether to have a second round of questions. Dr. Wubah, excuse me. Dr. Wubah is Professor of Biology at James Madison University. Dr. Wieman, we will start with you. Your mic might not be on.

STATEMENT OF CARL E. WIEMAN, PH.D., DISTINGUISHED PROFESSOR OF PHYSICS, RECIPIENT OF THE 2001 NOBEL PRIZE IN PHYSICS, UNIVERSITY OF COLORADO, BOULDER

Dr. WIEMAN. Thank you, Chairman Smith and Representative Johnson, for the chance to testify on this important issue. I think that the broad and objective science, math, and engineering education that you are interested in can be done, but you have to understand that it is really a new educational role, particularly, for the departments in large research universities that I am familiar with, and so that makes it to a large extent a cultural problem. It is going against the academic traditions and structures that have developed over more or less 500 years, and that makes change difficult. Not all faculty accept this new goal. And another problem is that it actually works quite well for cloning new faculty, but that obscures the fact that it is a failure for many other students, par-

ticularly, those who come from groups which aren't traditionally have a large presence in these fields.

Now, looking at H.R. 3130, I was asked to comment on, it looks to me like this is an excellent start. It focuses on key issues. I would have added that you should look for widespread support within the departments and the administration and more dissemination to peer institutions. And then, finally, let me turn to some of the big challenges faced with individual faculty in making changes.

You are really fighting tradition here and that is the main thing. And it is tradition represented by other faculty and the students. They are used to something and they dislike change of any kind. And so it takes a lot more time for faculty to do some new and different educational approach, and there is little rewards because department valuations and rankings are primarily research oriented.

And finally, turning to where and how there can be successes, and I have been involved in looking around at physics departments, primarily, all over the country examining this issue, and there are a few notable successes, but frankly, the real reasons behind those successes that I can see are they come from clear threats from above, where administration said, okay, the department is really going to suffer, cut way back, unless it demonstrates some dramatic improvements in making broader, more effective education. And in those cases, that brings in very widespread faculty participation, which is very different from the usual education reform, where you have one lone hero trying to do it on their own. But with that widespread participation, it can lead to very effective results.

[The prepared statement of Dr. Wieman follows:]

PREPARED STATEMENT OF CARL E. WIEMAN

I would like to thank Chairman Smith and Ranking Member Johnson for holding hearings on the important issue of *Meeting the Demands of the Knowledge Based Economy: Strengthening Undergraduate Science, Mathematics, and Engineering Education*, and for inviting me to testify. In many respects, this problem is one of changing cultures and traditions. Although we do not know everything about how students learn and what attracts them or drives them away from SME fields, we know enough to see how substantial improvements could be made. However, to make those changes requires modifying ancient traditions of academia and the basic structure of academic institutions and SME Departments at those institutions. To a large extent an SME education is defined by what is done in the relevant departments at the leading large research Universities such as Harvard, Stanford, University of Michigan, University of California, etc. The priorities of these institutions are on both education and research as it should be; it is difficult to adequately educate students about new knowledge unless you are also involved in creating it. Also the research enterprise is an integral part of graduate SME education, which by most measures is functioning considerably better than undergraduate education. However, research is given considerably more weight in the evaluation and ranking of departments than is undergraduate education. This makes it more difficult to devote resources to make major changes in education, particularly since many faculty see little reason to change. The current system is based on hundreds of years of tradition that has been quite successful at propagating the species of SME faculty. This had led to something of a division in many SME disciplines between the research oriented and teaching oriented faculty. My primary expertise in this field is that I can understand and relate to both sides of this issue and have a broad understanding of the cultural institutions that make change so difficult. I have visited and studied a large number of leading physics departments in various capacities and have observed how they function and how they carry out undergraduate education.

I have read over H.R. 3130 and it looks to me like an excellent start with a focus on nearly all of the critical issues. There are two items to which I would have given additional weight based on my experience. The first is that I would have given more emphasis to successful proposals showing evidence of widespread support by the faculty of the departments to be involved in such a program and the higher administration at the institution. These two items have always played a major part in all of the success stories I am aware of in undergraduate physics education, both for physics majors and majors in other disciplines. The second item that I would emphasize is dissemination of the results to other comparable institutions. It is surprising how poor dissemination of education developments is in SME departments. The same community that has developed the ability to share and duplicate successful research results around the world within days is often ignorant of education innovations in the same city.

Now let me address the questions raised in the invitation beginning with, "What are the major challenges faced by students and faculty at your institution who are engaged in undergraduate SME education?"

As mentioned above, it is clear that the primary challenge is dealing with a very long tradition of how SME education should be carried out. The traditional format of a professor standing in front of a large class of students and pouring forth his knowledge and wisdom into their receptive minds has been in place for hundreds of years. As well as following ancient and well-established tradition, this approach also seems very cost effective for institutions. As a result, the great majority SME undergraduate education takes the form of large introductory courses taught in this format. Furthermore, tradition has led to a similarly traditional and correspondingly ancient and, by my standards, out dated curriculum. However, to teach any other way would requires a faculty member to invest considerably more time and effort because they have to come up with something new and untested, instead of repeating the familiar. Furthermore, the students (and their parents) are as traditional as the faculty. Introducing them to teaching innovations that research has shown to be effective are often distrusted and disliked because they are counter to what they have become familiar with. Finally, the structure of most universities provides a peculiar sort of disincentive to successful innovations in teaching. If one does manage to develop a course that attracts far more students, it may contribute to the overall institution, but it is usually many years, if ever, before those benefits trickle down to the department and the faculty member who was responsible for them. In the mean time, they have a lot more students to teach, with the corresponding increase in workload. So while education research and an examination of practices at many institutions has shown ways that SME education could be improved to better meet the needs of today's society, the structures and traditions of most academic institutions are established to serve a different educational system. As a result there are few incentives for a faculty member to bring about change, and considerable disincentives. This situation is changing, but only slowly and painfully. Until it does change, it is unlikely that widespread improvements will come about. One of the most insidious aspects to this problem is that people are not like widgets coming down the assembly line where it is easy to evaluate whether they are being improved or not. There are always some students who are ornery enough to turn out extremely well in spite of going through what every expert would agree was a terrible educational experience. A high fraction of such students end up becoming faculty in SME disciplines at colleges and universities, and so naturally they see little problem with the system. Unfortunately, it is fairly well established that a far greater number of students, particularly those from groups who have not traditionally had a large presence in such fields, find the present education system gives them little appreciation for such subjects or any incentive to pursue them for a career.

Let me next address the question "What programs have been effective in addressing the challenges identified above, and what were the key elements that led to their successes?" Frankly, the couple of physics departments where I have seen major successful changes in their undergraduate education programs came about almost entirely due to administrative pressure. The departments were threatened with severe cuts unless they demonstrated dramatic gains in numbers of majors, and/or satisfaction and improved education of non-majors. These threats brought about widespread efforts within the departments that went well beyond the typical lone "hero" trying to bring about change largely on his or her own. The results of these "threat-driven" changes have been far more successful and long-lasting. In those cases NSF support for implementing changes played a valuable role, but only after the University administration had turned up the heat.

For me personally the Director's teacher scholar award has provided funds and incentive to undertake a far more extensive education effort than I would have oth-

erwise. The Exxon-Mobil Foundation support of the National Undergraduate Task Force has allowed us to carry out a number of programs that are raising awareness within the physics community about educational issues and the prospects for improvements.

Let me conclude with a brief discussion of how programs within the NSF might further educational goals. I first want to say that while I am very involved with undergraduate physics education; I have not had the opportunity to become expert on the various NSF programs. However, I will briefly give my impressions on the subject. The education program at NSF has largely focused on K–12, with undergraduate science education playing a relatively minor part. I would not want to say that was necessarily wrong, but one must keep in mind that the future K–12 teachers are learning their SME through undergraduate programs. So it is important to have a suitable balance. Much of the support for physics undergraduate education that I am aware of is coming through the MPS research directorate rather than the education directorate. It is admirable that the research directorates take this so seriously, but it does sometimes seem as if the missions are becoming somewhat confused, leading to possible inefficiencies.

Biographical Sketch of Principal Investigator

Carl E. Wieman

Education:

Massachusetts Institute of Technology	Physics	B.S.	1973
Stanford University	Physics	Ph.D.	1977
University of Chicago	Doctorate of Science (Honorary)		1997

Appointments:
Distinguished Professor, University of Colorado, 1997-present
Chairman, Joint Institute for Laboratory Astrophysics, 1993-1995
Professor of Physics, University of Colorado, 1987-present
Fellow, JILA, 1985-present
Associate Professor of Physics, University of Colorado, 1984-87
Assistant Professor of Physics, University of Michigan, 1979-84
Assistant Research Scientist, Department of Physics, University of Michigan, 1977-1979

Honors and Awards:
Nobel Prize in Physics, 2001
Distinguished Teaching Scholar Award (National Science Foundation) 2001
Benjamin Franklin Medal in Physics, 2000, R. W. Wood Prize (Optical Society of America) 1999
Schawlow Prize for Laser Science (American Physical Society) 1999, Cherwell-Simon Lecturer, (Oxford University) 1999, Phi Beta Kappa Visiting Scholar 1999-2000
Lorentz Medal (Royal Netherlands Academy of Arts and Sciences) 1998, American Academy of Arts & Sciences, elected 1998, 1998 Frew Fellowship (Australian Academy of Science), Honorary Doctorate of Science, University of Chicago, 1997, 1997 Award for Science, Bonfils-Stanton Foundation, 1997 King Faisal International Prize for Science
Newcomb Cleveland Prize (AAAS), 1996, Distinguished Research Lectureship, 1996-97 (University of Colorado), Fritz London Award in Low Temperature Physics, 1996 (IUPAP), Distinguished Research Lectureship of the University of Colorado Council, 1996-1997, Richtmyer Memorial Lecture Award (Am. Assoc. of Physics Teachers), 1996
Einstein Medal for Laser Science (Society for Optical and Quantum Electronics), 1995
National Academy of Sciences, elected 1995, Davisson-Germer Prize of the American Physical Society, 1994, E. O. Lawrence Award in Physics (DOE), 1993
Loeb Lectureship (Harvard University), 1990-91, Fellow of the American Physical Society, 1990, Guggenheim Fellowship, 1990-1991, University of Colorado Faculty Fellowship, 1990-1991, Sloan Research Fellowship, 1984, Hertz Foundation Fellow, 1973-1977

Relevant Publications:
(1) C.E. Wieman, "The Richtmyer Memorial Lecture: Bose-Einstein condensation in an ultracold gas," *Am. J. Phys*. **64**, 847-855 (1996).
(2) C.E. Wieman, G. Flowers and S. Gilbert, "Inexpensive laser cooling and trapping experiment for undergraduate laboratories," *Am. J. Phys*. **63**, 317-330 (1995).
(3) K.B. MacAdam, A. Steinbach and C. Wieman, "A narrow band tunable diode laser system with grating feedback, and a saturated absorption spectrometer for Cs and Rb," *Am. J. Phys*. **60**, 1098-1111 (1992).
(4) E.A. Cornell and C.E. Wieman, "The Bose-Einstein condensate," *Sci. Am*. **278** (March), 40-45 (1998).

(5) NRC Physics Decadal Overview Study, "Physics in a New Era," National Academy Press (2001).

Other Significant Publications:

(1) C. Monroe, W. Swann, H. Robinson and C. Wieman "Very cold trapped atoms in a vapor cell," *Phys. Rev. Lett.* **65**, 1571-1574 (1990).
(2) C. S. Wood, S. C. Bennett, D. Cho. B. P. Masterson, J. L. Roberts, C. Tanner and C. E. Wieman, "Measurement of parity nonconservation and an anapole moment in Cesium," *Science* **275**, 1759-1763 (1997).
(3) M. H. Anderson, J. R. Ensher, M. R. Matthews, C. E. Wieman and E. A. Cornell, "Observation of Bose-Einstein condensation in a dilute atomic vapor," *Science* **269**, 198-201 (1995).
(4) S.L. Cornish, N.R. Claussen, J.L. Roberts, E.A. Cornell and C.E. Wieman, "Stable (85)Rb Bose-Einstein condensates with widely tunable interactions," *Phys. Rev. Lett.* **85**, 1795-1798 (2000).
(5) M.R. Matthews, B.P. Anderson, P.C. Haljan, D.S. Hall, C.E. Wieman and E.A. Cornell, "Vortices in a Bose-Einstein condensate," *Phys. Rev. Lett.* **83**, 2498 (1999).

Synergistic Activities:

1. Developed diode laser system, doppler-free laser spectroscopy experiment, and laser trapping and cooling experiment for undergraduate laboratory courses. Wrote these up in great detail in the *American Journal of Physics*, and they are now being widely duplicated.
2. Wrote resource letter for AJP on trapping of neutral atoms and edited book of selected reprints on the subject, published by AAPT.
3. Played an active role in the development of the extensive Physics 2000 website, which provides widely accessible explanations of modern physics using interactive applets.
4. Served in the entire Chair-line of DAMOP, on NRC Board on physics and astronomy, NRC physical sciences overview study committee, member AIP-APS-AAPT national task force on undergraduate education, and many other boards and committees.
5. Served as Phi Beta Kappa visiting scholar for 1999-2000. In this role, gave eight public lectures across the country on atom cooling-BEC, and had countless other lectures, seminars, and meeting with undergraduates discussing physics.

Collaborators:

M.H. Anderson (Meadowlark Optics, Inc.), J.P. Burke (NIST), Donghyun Cho (Korea University), T.E. Chupp (University of Michigan), J.R. Ensher (ILX), S.L. Gilbert (NIST), D.S. Hall (Amherst College), M.R. Matthews (TI), D.E. Pritchard (MIT), M.J. Renn (Michigan Tech), C.E. Tanner (Notre Dame), K.R. Vogel (NIST), D.J. Wineland (NIST)

Grad Advisor: T. Hansch, University of Munich
Post-doc advisor: W. Williams (deceased)
Thesis advisor and postgraduate-scholar sponsor:
Heather Patrick (NRL), S. Bennett (ILX Lightwave Inc.), C. Wood (Photonic Networks Inc.), Kristan Corwin (ENS), Chris Myatt (REO Inc.), Michelle Stephens (REO Inc.), Wolfgang Petrich (Instrumentation Diagnostica), Simon Kuppens (University of Eindhoven), Eric Burt (Naval Observatory), Nate Newbury (Lincoln Labs), Zheng-Tian Lu (Argonne National Laboratory)

Biographical Sketch of Principal Investigator

Totals: 10 postdocs, 21 grad students

PI	Agency	Title	Start Date
Anderson	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Anderson	Ford	Compact Photorefractive Fiber-Optic Vibration Sensor	3/1/1997
Anderson	ONR	Neutral Atom Hoses and Waveguides	1/1/1994
Anderson	NSF	IGERT: Graduate Training in Optical Science and Engineering	8/1/1998
Anderson	ARO: MURI	Ultracold Atom Optics Science and Technology	4/30/2000
Anderson	NSF	Smart Active Antenna Arrays with Optical Processing	10/1/1999
Anderson	Microelectric & Computer Technology	Electro-Opto	2/1/1993
Anderson	ARO	Photonics for RF Signal Processing	8/15/1997
Bohn	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Bohn	ARO: MURI	Ultracold Atom Optics Science and Technology	4/30/2000
Cornell	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Cornell	NSF	Alan T. Waterman Award	7/1/1997
Cornell	ARO: MURI	Ultracold Atom Optics Science and Technology	4/30/2000
Cornell	ONR	Neutral Atom Hoses and Waveguides	1/1/1994
Cornell	ONR	Spontaneious Force Optical Traps	12/1/1996
Cundiff	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Cundiff	ThorLabs	Ultrasfast Instrumentation Development	7/1/1998
Cundiff	NSF	Nonlinear Spectroscopy of Mixed-Valent Materials	5/15/1999
Cundiff	DOE	Electronic Structure and Phase Transition of Complex Electronic Oxides: Angle-Resolved and Pump-Probe Photoemissions Experiments	4/15/2000
Greene	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Greene	CU	Greene's Research	7/1/1998
Greene	DOE	Physics of Correlated Systems	12/1/1993
Greene	NSF	Theoretical Atomic, Molecular, and Optical Physics at JILA	6/15/2000
Gallagher	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Gallagher	DOE/NREL	Characterize and Model the Kinetics of Thin Film Silicon Growth by Hot-Wire Chemical Vapor Deposition	7/1/2000
Gallagher	DOE/NREL	Characterization of Small Particle Formation in the Preparation of Amorphous Silicon Solar Cells and Determination of the Electric Field Profile in Solar Cells Using Scanning Tunneling Microscopy	7/1/1998
Hall	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Hall	NSF	Fundamental Physics Using Frequency-Stabilized Lasers as Optical "Atomic Clocks"	2/1/1998
Hall	NASA	Multi-Color Local Oscillations with 1 x 10-15 Stability	9/1/2000

Hall	U.S. Civilian Research and Development Foundation	Optical Frequency Standards and Principal Testing the New Concept of a Direct fs-comb Bridge Betweem the Optical and Microwave Domains	10/1/2000
Holland	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Holland	DOE	Quantum Theory of Collective Effects in Atom Laser	9/1/1999
Holland	University of Oregon (subcontract of ARO)	Quantum Logic Using Exitonic Quantum Dots in External Optical Microcavities	9/1/1999
Holland	NSF	Theoretical Atomic, Molecular, and Optical Physics at JILA	6/15/2000
Jin	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Jin	ONR	Exploring an Ultracold Gas of Fermionic Atoms	5/1/1999
Jin	DOE	Toward Cooper Pairing of Fermionic Atoms	9/1/1999
Jin	ARO: MURI	Ultracold Atom Optics Science and Technology	4/30/2000
Kapteyn	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Kapteyn	DOE	Coherent Imaging of Laser-Plasma Interactions Using XUV Harmonic Radiation	9/15/1999
Kapteyn	DOE	Nonperturbative Laser-Atom Interactions for Extreme Nonlinear Optics	9/15/1999
Kapteyn	NSF	Ultrafast Laser-Produced Microstructured Plasmas for Soft X-ray Lasers	9/1/1999
Kapteyn	DOE	Electronic Structure and Phase Transition of Complex Electronic Oxides: Angle-Resolved and Pump-Probe Photoemissions Experiments	4/15/2000
Kapteyn	CU	Kapteyn Start Up	7/1/1999
Kapteyn	Colorado State University (a subcontract with DOE)	Amplification of High Order Harmonics in a Discharge-Pumped Soft X-Ray Amplifier	5/1/2000
Leone	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Leone	NSF: Chem	Alignment and Wave Packet Chemical Dynamics	1/1/1998
Leone	DOE	Time-resolved FTIR Emission Studies of Laser Photofragmentation and Radical Reactions	4/1/1994
Leone	ARO	Kinetic-energy-enhanced neutral etching + AASERT	9/1/1997
Leone	AFOSR	Ion and Neutral Dynamics of Ceramic Materials Formation and Atmospheric Processes	11/15/1997
Leone	AFOSR	Ion Dynamics Related to Hypersonics	11/15/1997
Leone	NASA	Laboratory Studies of Low Temperature Rate Coefficients: The Atmospheric Chemistry of the Outer Planets And Titan	1/1/2000
Leone	NSF	Infrared Band-specific Near Field Optical Microscopy Probing of Chemically Amplified Polymer Photoresists	5/1/2000

Leone	NSF: Chem	Phase and Amplitude Dynamics of Rovibrational Wave Packets	11/1/2001
Leone	ARO	Ultrafast Laser Studies of Molecular Rydberg Wave Packets	9/1/2000
Leone	AFOSR	Ultrafast Soft X-Ray Probing of Core Level Molecular Dynamics	11/15/2000
Leone	AFOSR	Ion Dynamics Related to Hypersonics	11/15/2000
Leone	ARO: DURIP	Femtosecond Laser Regenerative Amplifier for Quantum Information Science	4/1/2000
Lineberger	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Lineberger	NSF: Chem	Spectroscopy and Dynamics of Ions	5/1/1997
Lineberger	AFOSR	Photoelectron Spectroscopy Dynamics of Adsorbates on Clusters	4/1/1999
Lineberger	NSF	Physics -2000 Popularizing Modern Physical Sciences through Virtual Interactive Experiments	10/1/1998
Murnane	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Murnane	NSF	Enhanced Ultrafaxt X-ray Generation Using Pulse-Shaping	9/1/1999
Murnane	DOE	Coherent Imaging of Laser-Plasma Interactions Using XUV Harmonic Radiation	9/15/1999
Murnane	DOE	Nonperturbative Laser-Atom Interactions for Extreme Nonlinear Optics	9/15/2000
Murnane	CU	Murnane Start Up	7/1/1999
Murnane	DOE	Electronic Structure and Phase Transition of Complex Electronic Oxides: Angle-Resolved and Pump-Probe Photoemissions Experiments	4/15/2000
Murnane	MIT (a subcontract of DOE)	Ultrafast Coherent Soft X-Rays: A Novel Tool for Spectroscopy of Collective Behavior in Complete Materials	10/15/1999
Nesbitt	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Nesbitt	NSF: Chem	High Resolution IR Laser Studies in Slit Supersonic Jets: Dynamics of Radicals, Molecules, and Clusters	8/15/1998
Nesbitt	AFOSR	State-Resolved Thermal/Hyperthermal Collision Dynamics of Atmospheric Species	2/1/2000
Nesbitt	CU	Chancellor's Support of CU Wizards	3/1/2000
Nesbitt	CU	CU Wizard Gift Fund	11/30/2000
Parson	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1998
Parson	American Chemical Society	Simulation of Photochemical Reactions in Supercritical Fluids	1/1/1998

Parson	NSF: Chem	Reaction Dynamics in Molecular Cluster Ions	1/1/1999
Wieman	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Wieman	CU	Wieman's Research	7/1/1997
Wieman	NSF: INT	US-Korea Cooperative Research: Studies of Trapping and Cooling in a Far Off Resonance Optical Trap Using Circularly Polarized Light	6/15/1999
Wieman	ONR	Spontaneious Force Optical Traps	12/1/1996
Wieman	ARO: MURI	Ultracold Atom Optics Science and Technology	4/30/2000
Wieman	ONR	Neutral Atom Hoses and Waveguides	1/1/1994
Wieman	NSF	IGERT: Graduate Training in Optical Science and Engineering	8/1/1998
Wieman	NSF	Physics -2000 Popularizing Modern Physical Sciences through Virtual Interactive Experiments	10/1/1998
Ye	NSF	A Program of Research in Atomic and Molecular Physics and Related Areas	3/1/1996
Ye	Colorado Photonics and Optoelectronics Program	Development of Highly Stable Solid State Lasers in the 1-2 um Wavelength Region	8/1/2000
Ye	NASA	Fundamental Physics Using Frequency-Stabilized Lasers as Optical "Atomic Clocks"	2/1/1998
Ye	Research Corporation	Ultrastable Optical Frequencies Across the Entire Visible Spectrum and Ultrahigh Resolution Spectroscopy Using a Femtosecond Laser	8/1/2000

1530914	Anderson	NSF	3/1/1996	2/28/2001	12/31/2000	755,443	725,451	35,176	0
1531246	Anderson	ONR	1/1/1994	9/30/2002	11/30/2000	787,000	682,724	1,784	6,575
1531611	Anderson	Coherent	6/22/1999	12/31/1999	11/30/2000	10,000	13,069	(3,093)	0
1532527	Anderson	NSF	10/1/1999	9/30/2001	11/30/2000	118,940	51,905	11,205	5,193
1532614	Anderson	ARO: MURI	4/30/2000	11/29/2001	11/30/2000	979,049	301,932	149,733	50,956
1532915	Anderson	NSF: REU	7/1/2000	9/30/2001	11/30/2000	5,000	0	0	0
1533189	Anderson	ARO:MURI	9/1/2000	12/31/2001	11/30/2000	73,479	18,220	2,215	0
1536710	Anderson	ONR "MURI"	8/15/1997	11/30/2002	12/31/2000	356,714	393,137	14,861	0
1648004	Anderson	Electro-Opto	2/1/1993	6/30/2001	12/31/2000	5,000	1,718	0	0
1648005	Anderson	Ford	4/30/1997	6/30/2001	12/31/2000	16,383	86	0	0
1530908	Bohn	NSF	3/1/1996	2/28/2001	12/31/2000	96,966	74,455	11,094	2,284
1530919	Cornell	NSF	3/1/1996	2/28/2001	12/31/2000	883,576	786,120	74,892	5,864
1531143	Cornell	NSF	7/17/1997	7/31/2001	11/30/2000	500,000	251,110	92,743	0
1530217	Cundiff	ThorLabs	7/1/1998	6/30/2001	12/31/2000	2,962	2,962	0	0
1530913	Cundiff	NSF	3/1/1996	2/28/2001	12/31/2000	407,444	367,176	44,527	6,645
1531109	Cundiff	NSF	5/15/1999	4/30/2001	11/30/2000	73,833	53,407	1,195	0

1530906	Gallagher	NSF	3/1/1996	2/28/2001	12/31/2000	1,059,121	1,040,361	27,875	13,108
1531160	Gallagher	Matsu.	1/1/1997	12/31/1999	11/30/2000	42,900	42,900	0	0
1533310	Gallagher	NREL	9/22/2000	9/21/2003	11/30/2000	75,200	9,446	26,044	17,502
1146303	Greene	CU	7/1/1992	6/30/2001	12/31/2000	3,453	842	3,285	0
1530916	Greene	NSF	3/1/1996	2/28/2001	12/31/2000	663,383	614,712	92,056	5,981
1530951	Greene	NSF	7/1/1998	12/31/1999	12/31/2000	100,000	98,605	(2,226)	0
1531137	Greene	DOE	12/1/1993	6/30/2001	11/30/2000	913,641	815,284	62,336	5,165
1532717	Greene	NSF	6/15/2000	5/31/2001	11/30/2000	150,851	15,057	71,167	8,815
1530907	Hall	NSF	3/1/1996	2/28/2001	12/31/2000	873,840	811,006	8,978	22,739
1531151	Hall	NASA-Marsh	2/1/1998	1/31/2001	11/30/2000	195,000	155,158	28,852	508
1533478	Hall	CRDF	10/1/2000	3/31/2002	11/30/2000	5,790	0	0	0
1124336	Holland	CU	7/1/1998	6/30/2001	12/31/2000	8,633	0	0	0
1530903	Holland	NSF	3/1/1996	2/28/2001	12/31/2000	312,623	287,539	15,871	824
1531695	Holland	DOE	9/1/1999	8/31/2001	11/30/2000	230,000	127,074	38,557	5,474
1531822	Holland	Un. Of OR	9/1/1999	12/31/2000	11/30/2000	61,111	50,318	22,756	22
1530918	Jin	NSF	3/1/1996	2/28/2001	12/31/2000	267,862	175,448	82,483	412
1530921	Jin	ONR	5/1/1999	4/30/2002	12/31/2000	264,198	157,537	13,248	21,235
1531696	Jin	DOE	9/1/1999	8/31/2001	11/30/2000	216,000	120,163	16,953	16,519
1532046	Jin	DOE	1/27/2000	8/31/2001	11/30/2000	44,000	21,963	0	0
1124302	Kapteyn	CU: Physics	7/1/1999	6/30/2001	12/31/2000	35,520	13,449	983	0
1531699	Kapteyn	DOE	9/15/1999	9/14/2001	11/30/2000	589,678	312,302	87,156	4,658
1531901	Kapteyn	NSF	9/1/1999	6/31/2001	11/30/2000	243,700	132,593	53,402	0
1531922	Kapteyn	DOE	9/15/1999	9/14/2001	11/30/2000	174,000	77,605	2,333	0
1775292	Kapteyn	CU	7/1/1999	6/30/2001	12/31/2000	28,000	27,765	1,839	0
1775496	Kapteyn	CU/DOE15 31699	5/12/1999	6/30/2000	12/31/2000	19,972	19,972	0	0
1530920	Kapteyn-Murnane	NSF	3/1/1996	2/28/2001	11/30/2000	588,476	447,168	187,389	688
1531273	Kapteyn-Murnane	NSF	6/1/1999	2/29/2000	11/30/2000	70,000	34,998	35,000	0

Carl Wieman's Current Support

NSF	Group Research in Atomic, Molecular, and Optical Physics at JILA
ONR	Spontaneous Force Optical Traps
ARO: MURI	Ultracold Atom Optics Science and Technology
ONR	Neutral Atom Hoses and Waveguides
NSF	IGERT: Graduate Training in Optical Science and Engineering
NSF	Distinguished Teaching Scholar Award
NIST	No direct funding but much support for JILA

Chairman SMITH. Representative Udall, when the panelists finish their testimony, I would like to ask you to give maybe a more thorough description of the esteemed panelists from your territory. Dr. Howard.

STATEMENT OF KATHLEEN P. HOWARD, PH.D., ASSISTANT PROFESSOR OF CHEMISTRY, SWATHMORE COLLEGE

Ms. HOWARD. Thank you, Mr. Chairman and Members of the Committee, for the opportunity to speak before you today. I don't lecture in my chemistry classes from a script, but in the interest of clarity and brevity, I would like to read a prepared statement.

From my understanding, I was invited to speak to you today as a young faculty member who teaches undergraduates and as a recent recipient of an NSF Career Award, which is currently funding my research in teaching. This is my 5th year teaching at Swathmore College in the Chemistry Department. I have found it a wonderful place to teach and to do first class research. The student body at Swathmore is approximately 1,400 strong and the student to faculty ratio is eight to one. We only have undergraduates; there is no graduate program. Students come to Swathmore because they want a rigorous demanding education. One of the unique hallmarks of the college is that honor degrees are awarded based on oral and written exams given by experts from outside Swathmore. Although this is a challenging program and can be quite stressful for the students, as well as their faculty mentors, it is also invigorating. This external assessment has the added benefit that Swathmore faculty regularly get outside input into the quality of their programs.

At Swathmore, I teach both majors as well as non-majors. We have a lab intensive curriculum. All our standard courses, including the course for non-majors, includes hands-on experimental lab work. Although this is time and resource intensive, it is in the lab that the concepts students hear about in the classroom come alive. Our lab intensive curriculum moves from a rather well defined set of experiments in introductory courses to open-ended inquiry based experiments in the upper level courses. Every faculty member in our department has an active research program in which students are intimately involved as research assistants both during the school year and throughout the summer. Most of our research students not only present their work at local as well as national scientific conferences, but become coauthors on peer review publications as well.

As part of our undergraduate research program, students work side by side with their faculty mentors to solve problems, not simply to provide an extra pair of hands. I think that extensive faculty-student contact is one of the main reasons why about 40 percent of all our chemistry majors continue onto graduate school and earn their Ph.D. Not only do they go onto graduate school, but the feedback we get is that they feel well prepared and thrive in their graduate programs. Just last week, we got an e-mail from the Harvard Chemistry Department, reporting that the three graduate students who will win awards this year for exceptional performance as a teaching assistant are all Swathmore graduates.

Why has Swathmore been so successful at training future chemistry Ph.D.'s? It starts with attracting students to Swathmore who want a rigorous education and attracting enthusiastic faculty who want to be both teachers and research scholars. Furthermore, the college provides a great deal of institutional support to create the infrastructure needed for a laboratory and research based cur-

riculum. Our department has a surprising amount of high quality research grade instrumentation for an undergraduate institution.

How could NSF help us and other undergraduate institutions train the next generation of scientists? As proposed in the Tech Talent Act, I think it is important for NSF to continue to invest in programs that encourage undergraduate research. Conducting research is the best way to learn what it means to be a scientist, both the frustration and the exhilaration. Concrete ways the NSF can bolster undergraduate research include stipend support for the students, as well as summer salary and research leave support for faculty. NSF should also expand its current programs to help undergraduate institutions purchase and upgrade state of the art instrumentation. Strong research and teaching programs rely on access to such equipment. Investing in undergraduate research is one of the best ways the NSF can assure the American workforce remains innovative and productive.

Thank you for allowing me to participate.

[The prepared statement of Ms. Howard follows:]

PREPARED STATEMENT OF KATHLEEN P. HOWARD

I. Background on Swarthmore College and its track record for training scientists:

Swarthmore College is a co-educational undergraduate institution located ~15 miles south of Philadelphia, Pennsylvania. With a student/faculty ratio of approximately 8:1, Swarthmore ensures that its roughly 1400 students have close and regular contact with their professors. Swarthmore College has been a leader in the undergraduate education of future research scientists. In the past ten years, the Swarthmore Chemistry Department has graduated 136 majors of which 61 have gone on to graduate school, 39 to medical school, and 16 to related positions in industry, research or education. Schools that our recent chemistry graduates have attended include Columbia, Cornell, Harvard, MIT, Stanford, UC Berkeley, University of Chicago, and Yale. Although the Swarthmore alumni body is small (about 17,000 living alumni), it is distinguished; three Swarthmore graduates have won the Nobel Prize; 36 have earned membership in the National Academy of Sciences and nine in the National Academy of Engineering.

RECENT QUOTE ABOUT SWARTHMORE:

"The national average (of students in the United States majoring in science) hovers around eight percent of all enrollees. In the selective undergraduate liberal arts colleges, it may be as high as 20 to 25 percent—larger and faster growing than in comparable research universities. The former also go on to earn doctorates at a much higher rate. For the decade 1986 through 1995, the proportional Ph.D. productivity of undergraduate institutions was far higher than that of the research universities; the top five included four liberal arts colleges. The top two, Reed and Swarthmore, nearly doubled the proportional productivity of Harvard and Yale."

Donald Kennedy, in the August 31, 2001 issue of *Science*, the publication of the American Association for the Advancement of Science

II. What I see as Challenges for Science Faculty at Swarthmore College:

1. Finding enough time to teach, do research and actively participate in the college community.
2. Writing competitive extramural grants to support research programs as well as teaching programs.
3. Keeping current so that we not only teach cutting edge-material, but take advantage of new teaching methods and approaches.
4. Balancing "depth" and "breadth" in teaching courses. "Active" learning methods are successful in engaging students, but the amount of material that can be covered in a semester is reduced as compared to straight lecture based classes.

5. Since undergraduates are the primary assistants our research moves at a slower pace than that at graduate institutions where the research assistants are graduate students and postdoctoral fellows working full-time.

III. What I see as Challenges for Science Students at Swarthmore College:

1. Finding time to excel in all their science classes as well as take full advantage of a well-rounded liberal arts education and extra curricular activities. Swarthmore has a lab intensive curriculum that is very time intensive.
2. Committing to major in science early on in their college careers. The chemistry curriculum is hierarchical and requires several math and physics courses as prerequisites. If science courses are not begun in the freshman year, the curriculum is difficult to complete in four years.
3. Deciding what they want to do with their lives. Being a chemistry major requires a great deal of time and effort, and students want a compelling reason (such as the hope of a fulfilling career post college) to make the sacrifices required.

IV. What Makes Swarthmore College Effective at Training Future Scientists:

1. *Enthusiastic Faculty who are Active Teacher/Scholars*. Swarthmore attracts people who want to be active teacher/scholars and realize Swarthmore is an environment where they can flourish. Strong faculty research programs with undergraduates benefit all concerned: faculty members remains professionally active and connected despite extensive teaching responsibilities and the undergraduate students not only learn a great deal but gain inspiration and self confidence from being exposed to "cutting edge" problems in science. As far as teaching, the curriculum in chemistry at Swarthmore benefits from small class sizes, a laboratory intensive curriculum at every level and seminars at the advanced level that are based on current literature. Classes rarely are taught exactly the same way year after year. There is a constant effort to update and improve the content and presentation of material.
2. *Strong Institutional Support*. Swarthmore invests in modern, high quality instrumentation. The college provides generous start-up budgets for new faculty members, and encourages and supports the updating of equipment through various funding sources. Swarthmore College is actively committed to maintaining its leadership role in the sciences. In June 2001, the college broke ground for a $56 million interdisciplinary science center that will include state-of-the-art teaching and research lab space for the Chemistry, Physics, Math, Biology and Computer Science Departments.
3. *Regular Research Leaves for Faculty*. Swarthmore has a research leave program where faculty can take time to focus their energies on research and update their skills after every three full years of teaching. This gives us contact with the outside scientific community which enriches and energizes our research and teaching. A big benefit of the research leave program is that Swarthmore faculty often continue collaborations beyond the leave year. 85% of faculty in the Natural Sciences Division have active research collaborations with colleagues at other institutions. Students thus have access to research underway not only on campus, but also in some of the most exciting work in laboratories across the country and around the world.
4. *Small, "Nimble" Faculty Size*. The size of departments as well as the overall faculty body is small. Through regular college-wide faculty meetings and provost sponsored faculty lunches every week there is constant discussion about how we are meeting the needs of the students. The Chemistry Department also has yearly departmental retreats where we get together to discuss what we are doing well, and what can be improved. What results is a program that can adapt to changes and challenges and take advantage of new opportunities. For example, this year the Chemistry Department decided to change the format of our General Chemistry course for first year students for next year. We thought beginning students could benefit from a small discussion based seminar format class (max 12 students). We will split our General Chemistry class into five groups; four small seminar groups, and one traditional lecture course.
5. *Diverse Set of Talented Students*. The college attracts and recruits a diverse set of students who want a rigorous education. Swarthmore has a longstanding commitment to recruiting and retaining students and faculty from diverse racial, ethnic and economic backgrounds. The graduating class of

2000 included 30 percent minorities (8 percent African American, 10 percent Latino/a American, 12 percent Asian American). One of the my first undergraduate research assistants was an African American woman who successfully completed and defended an independent senior research thesis, presented research at conferences and is an author on two published peer reviewed research papers. Swarthmore has a noteworthy track record in the education of women scientists and engineers. Among the past five graduating classes, 69 percent of Biology majors, 53 percent of Chemistry and Biochemistry majors, 30 percent of Engineering majors, and 29 percent of Physics and Astrophysics majors were women. Approximately half of these women students are continuing their science or engineering education at the graduate level.

6. *Unique Competitive Honors Program.* Honors at Swarthmore are awarded not by Swarthmore faculty, but through a set of exams given to our students each year by external experts as part of the Honors Program. Regular contact with these outside educators serves as a regular diagnostic tool for the curriculum. External assessment is challenging and invigorating for the students, and allows them to interact in a meaningful way with scientists from all over the country.
7. *Emphasis on Interdisciplinary Work.* Interdisciplinary studies significantly expand the sphere of colleagues with whom faculty at a small college can collaborate, and simultaneously create opportunities for students to do research in emerging areas of inquiry. A grant from the Howard Hughes Medical Institute has helped the College in creating an environment in which collaborations can flourish. Swarthmore faculty often share their work with their colleagues and students from other departments. For example, all science and engineering faculty and students engaged in research on campus during the summer come together once a week to present their projects to their peers in other departments.

IV. Funding Sources that have been beneficial to my work at Swarthmore:

I have been awarded three grants since I have been a faculty member at Swarthmore College:

1. NSF CAREER Award for 2001-2006

Spectroscopy of Peptides/Lipids in Magnetically Oriented Membranes ($329,000)
Research grant used to support supplies, equipment and summer research stipends for students. Proposal involves the development of novel spectroscopic methods and the application of these methods to study membrane protein structure and dynamics.

2. Dreyfus Foundation Special Grant in the Chemical Sciences for 1999–2002

Development of X-ray Diffraction Projects ($45,000)
This grant, along with Swarthmore College matching funds, was used for the purchase of a new x-ray diffractometer for use in Physical Chemistry and Instrumental Methods teaching labs.

3. National Institutes of Health AREA Grant for 1998–2001

Peptide/Lipid Studies in Field Oriented Membranes ($105,003)
Research grant used to support supplies, equipment and summer research stipends for students. Proposal involves the development of both EPR and NMR methods for determining the structures and dynamics of both lipid and peptide components of membrane bilayers.

I have also benefited from some institutional grants at Swarthmore College. For the past 12 years the college has had a series of grants from Howard Hughes Medical Institute (HHMI) that average ~$850,000 for a four year period. This money is targeted for biomedical related research activities on campus and pays for 25 student summer research stipends each year, student supply budgets, equipment and outreach to local high school teachers and students. As part of our current grant from HHMI, faculty make weekly research presentations during the school year to an average of 70 first- and second-year students in hope of attracting them to the sciences by giving them insight into the creative process of inquiry, and into the variety of fields represented by the research carried out by members of our faculty.

Other members of my department rely heavily on grants from private foundations such as Camille and Henry Dreyfus Foundation, American Chemical Society-PRF program and Research Corporation. Although many faculty at Swarthmore have done well with NSF, my feeling is that many faculty members at other under-

graduate institutions find the review process at NSF too competitive and discouraging for their research programs and rely on smaller private foundation grants and limited institutional funding to keep their programs going.

IV. NSF Programs That I Feel Are Effective at Catalyzing Change in Undergraduate Education:

I feel that any program that NSF has for supporting high quality research where research assistants are undergraduates is essential for the training of future generation of scientists. At Swarthmore we have found that engaging students in hands-on experiments on research grade instrumentation is a very important part of their educational experience. It allows them to experience the thrill of discovery first hand, and inspires many of them to want to continue their science education in graduate school.

V. Programs that I think NSF should support in the future:

I think that NSF should continue to support high quality grants from faculty members at undergraduate institutions who actively involve students in hands-on science. At Swarthmore, involving students in faculty research programs has been one of our primary educational tools, and one of the main reasons why many of our students go on to graduate school. Although Swarthmore has many faculty with high quality, federally funded research programs, I know that other undergraduate institutions have had a much more difficult time. The problems are related to heavy teaching loads and lack of quality instrumentation.

Programs I think could improve the training of future scientists at undergraduate institutions are:

1. An NSF program that allows salary support for an undergraduate faculty member to work with someone from a graduate institution during a research leave. As far as I am aware, NSF funds currently can not be used for academic year salary. As part of the research leave year program at Swarthmore, the college pays for one semester of the leave, and faculty member raises the other half. Experience has been that the full year is needed to be productive. It would be really helpful if NSF funds could be used to match the institutional investment in this program.
2. Some kind of one-time "ramp-up" grant for undergraduate faculty who are not yet competitive with traditional NSF grants, but would like to acquire the instrumentation and resources to get their research programs to a level where they can compete for federal grants.
3. Continued investment of NSF in funding the purchase and upgrade of instrumentation at undergraduate institutions. We have found that hands-on exposure to high quality instrumentation is essential to our teaching and research programs.

BIOGRAPHY FOR KATHLEEN P. HOWARD

Department of Chemistry, Swarthmore College, 1500 College Avenue, Swarthmore, PA 19081–1397; phone: (610) 328–8519; fax: (610) 328–7355; e-mail: khoward1@swarthmore.edu

PROFESSIONAL EXPERIENCE

Swarthmore College, Swarthmore, PA
Assistant Professor (tenure track), Department of Chemistry (9/97–present)

University of Pennsylvania, Philadelphia PA
Visiting Faculty, Department of Biochemistry and Biophysics, (Fall 2000–Fall 2001)

University of Pennsylvania, Philadelphia, PA
Postdoctoral fellow in the Department of Chemistry (9/95–9/97)

Recipient of Arthritis Foundation Postdoctoral Fellowship

Advisor: Dr. Stanley J. Opella
Project: *Development of Nuclear Magnetic Resonance Techniques for Determining the Structures of Membrane-Bound Molecules.* Reconstituted membrane molecules into phospholipid bilayers that spontaneously oriented in a magnetic field. Implemented oriented sample NMR experiments on home-built solid state NMR spectrometers.

EDUCATION

Yale University, New Haven, CT

Ph.D. in Chemistry (1995)

Advisor: Dr. James H. Prestegard

Dissertation: *NMR Studies of the Structure and Dynamics of Membrane-Bound Diacylglycerol Glycolipids.* Purified the three most abundant glycolipids in nature from ^{13}C labeled algal extracts. Studied the conformations of the three diacylglycerol glycolipids both in solution and bound to a magnetically oriented model membrane system. Used molecular modeling including a membrane bound interaction energy to aid in the analysis of the experimental data.

Fellowships and Awards: National Research Service Award, Samuel K. Bushnell Fellowship, Yale Department of Chemistry Excellence in Teaching Award

Princeton University, Princeton, NJ

B.A. in chemistry, cum laude (1990)

Senior Thesis Advisor: Dr. Jannette Carey

Independent Research Thesis: *Glutaraldehyde Crosslinking Reveals Tetramer Formation by Tryptophan Repressor.* Studied the hypothesized dimer-multimer equilibrium of the *trp* repressor protein in solution was using chemical cross linking and electrophoresis in denaturing gels.

PUBLICATIONS

(† undergraduate co-authors)

Parker, M.†, King, V.† and Howard, K.P. (2001) NMR study of doxorubicin binding to cardiolipin containing magnetically oriented phospholipid bilayers. *Biochimica Biophysica Acta Biomembranes,* 1514 (2), 206–216.

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Howard, K.P. and Opella, S.J. (1996) High Resolution Solid State NMR of Integral Membrane Proteins Reconstituted into Magnetically Oriented Phospholipid Bilayers. *Journal of Magnetic Resonance,* 112, 91–94.

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PRESENTATIONS

(† undergraduate co-authors)

Howard, K. (April 2001) "Development and Application of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," invited seminar given at Villanova University, Department of Chemistry.

Parker, M.†, Lloyd, K.† and Howard K. (February 2001) "Design and Application of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," poster presented at the Biophysical Society Meeting, Boston, MA.

Howard, K. (December 2000) "Development and Application of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," invited seminar given at Drexel University, Department of Chemistry.

Howard, K. (September 2000) "Development and Application of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," invited seminar given at Haverford College, Department of Chemistry.

Parker, M.†, King, V.† Garber, S.†, and Lloyd, K.† and Howard, K. (July 2000) "Design and Application of Magnetically Orienting Bilayers For the Study of Membrane-Bound Molecules," poster presented at the University of Pennsylvania's Department of Biophysics and Biochemistry Annual Department Retreat.

Howard, K. (March 2000) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar given at Georgetown University, Department of Chemistry.

Lloyd, K.† and Howard, K. (February 2000) "Studying Transmembrane Helical Peptides in Magnetically Oriented Phospholipid Bilayers," poster presented at Biophysical Society Meeting, New Orleans, Louisiana.

Parker, M.† and Howard, K. (February 2000) "Doxorubicin Binding to Cardiolipin Containing Magnetically Oriented Phospholipid Bilayers," poster presented at Biophysical Society Meeting, New Orleans, Louisiana.

King, V., Garber, S.†, Parker, M.†, and Howard, K. (July 1999) "Design and Application of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," poster presented at the 14th International Meeting on NMR Spectroscopy, Edinburgh, Scotland.

Garber, S.†, King, V.† and Howard K. (February 1999) "Design and Application of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," poster presented at the Biophysical Society Meeting, Baltimore, Maryland.

Howard, K. (December 1997) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar given at Bryn Mawr College, Department of Chemistry.

Howard, K. (November 1997) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," presentation for the Howard Hughes Medical Institute Interdisciplinary Research Seminar Series at Swarthmore College.

Howard, K. (September 1997) "Design of Magnetically Orienting Bilayers for the Study of Membrane-Bound Molecules," seminar presented at the Tri-College Life Science Symposium, Bryn Mawr College.

Howard, K. and Opella, S.J. (June 1997) "NMR Studies of Membrane Proteins Reconstituted into Magnetically Oriented Phospholipid Bilayers" poster presented at the Gordon Research Conference on Magnetic Resonance, Henniker, NH.

Howard, K. (June 1997) "Preparation of Membrane Protein Containing Bicelles," talk presented at the Biological Solid State NMR Workshop, University of Pennsylvania.

Howard, K. (December 1996) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar presented at the University of Pittsburgh, Department of Chemistry.

Howard, K. (December 1996) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar presented at the University of California-Davis, Department of Chemistry.
Howard, K. (December 1996) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar presented at American University, Washington DC, Department of Chemistry.
Howard, K. (December 1996) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar presented at the Rutgers University-Camden, Department of Chemistry.
Howard, K. (December 1996) "NMR Studies of Membrane-Bound Molecules Using Magnetically Oriented Phospholipid Bilayers," invited seminar presented at the University of Illinois-Urbana, Department of Biochemistry.
Howard, K. and Opella, S.J. (November 1996) "NMR Studies of Membrane Proteins Reconstituted into Magnetically Oriented Phospholipid Bilayers," poster presented at the Eastern Analytical Society Meeting, Somerset, NJ.
Howard, K. and Opella, S.J. (July 1996) "Solid State NMR Structural Studies of Membrane Proteins Reconstituted into Magnetically Oriented Phospholipid Bilayers," poster presented at the FASEB Meeting —Molecular Biophysics of Cellular Membranes, Saxtons River, VT.
Howard, K. and Opella, S.J. (March 1996) "Solid State NMR Studies of Membrane Proteins Reconstituted into Magnetically Oriented Phospholipid Bilayers," poster presented at the Experimental NMR Conference, Monterey, CA.
Howard, K. and Prestegard, J.H. (March 1994) "NMR Studies of Diacylglyerol Glycolipids Bound to Magnetically Oriented Phospholipid Bilayers," poster presented at the Experimental NMR Conference, Monterey, CA.
Howard, K. and Prestegard, J.H. (February 1993) "NMR Studies of Diacylglyerol Glycolipids Bound to Magnetically Oriented Phospholipid Bilayers," poster presented at the Biophysical Society Meeting, Washington DC.

PROFESSIONAL ACTIVITIES

- Reviewer for *Journal of Magnetic Resonance, Journal of Physical Chemistry, Concepts in Magnetic Resonance* and *Journal of Chemical Education.*
- Education Committee, Biophysical Society (2000–2003)
- Member of Biophysical Society, American Chemical Society, American Association for the Advancement of Science, and Sigma Xi.

SWARTHMORE COLLEGE COMMITTEES

Search Committee for Associate Provost of Information Technology, Fall 1999–
Chemistry Department Honors Program Coordinator, 1999–2000
Foreign Studies Committee, 1999–2000
New Science Building Environmental Concerns Committee, Fall 1999–Spring 2000
Search Committee for Academic Computing Coordinator for Natural Sciences, Spring 1999
Search Committee for the Head of Cornell Science Library, Spring 1999
Health Sciences Advisory Committee, 1998–2000
Chemistry Department Library Representative, 1998–2000
Chemistry Departmental Representative to Sigma Xi, Spring 1998

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SWARTHMORE

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March 4, 2002

Dear Chairman Boehlert:

As requested I am reporting sources of Federal Funding which support subject matter on which I will testify this Thursday March 7th as part of the hearing on "Meeting the Demands of the Knowledge Based Economy."

I am currently funded by a NSF grant:

2001-2006 Spectroscopy of Peptides/Lipids in Magnetically Oriented Membranes $329,000

National Science Foundation CAREER Award, CHE-0092940

Research grant used to support supplies, equipment and summer research stipends for students. Proposal involves the development of novel EPR and NMR methods and the application of these methods to study membrane protein structure and dynamics.

Sincerely,

Kathleen P. Howard

Chairman SMITH. Thank you. Dr. Wubah.

STATEMENT OF DANIEL A. WUBAH, PH.D., PROFESSOR OF BIOLOGY, JAMES MADISON UNIVERSITY

Dr. WUBAH. Good morning, Mr. Chairman and Members of the Committee. My name is Daniel Wubah and I am a Professor of Biology and Associate Dean at James Madison University College of Science and Mathematics. I would like to read part of my testimony here, but details I would not be able to provide in five minutes. I consider this to be a privilege to appear before you today to testify on the strengthening of undergraduate science, mathematics, and engineering from the perspective of someone who is in the trenches working with one of our most valuable assets, the students.

At the dawn of the 21st century, the continued global leadership of our country depends on a strong, competitive well-trained workforce and citizens who are equipped to function in a complex technological world. In the preface to his 1990 study, Scholarship Reconsidered, the late Ernest Boyer stated, "The most important obligation now confronting the Nation's colleges and universities is to break out of the tired old teaching versus research debate and define, in more creative ways, what it means to be a scholar." This need to redefine the characteristics of a scholar is the cornerstone of the daily activities in a comprehensive university. Faculty members at this type of institution that normally educate more than 40 percent of undergraduate students in this country—faculty members in this type of institutions educate 40 percent of all undergraduates in the country. However, for a long time, such institutions have not been funded to reflect these efforts. The current concerns about the looming crisis in our ability to be leaders in science education for all citizens calls for changes in the distribution of resources.

My testimony today will address the three broad questions that were given to me to answer. First, I would like to place the two institutions that I have been affiliated with in the right context. Towson University is an urban comprehensive university and the second largest university in Maryland with a student population of approximately 16,500 students. Because of its location in a metropolitan area, a majority of the students are commuters, first generation college students, immigrants, or have families and children. James Madison, on the other hand, is located in the Shenandoah Valley in a rural setting with about 15,000 students, including 900 graduate students. Over 85 percent of students at James Madison are between the ages of 18 and 22 and they live on campus or within a 2-mile radius.

Now, I would like to talk briefly about programs that we have used toward increasing the number of technically trained students for the workforce. At both institutions I was involved in a program that, basically, prepared students through summer programs as well as during the academic year. In these programs, what we normally did was we brought them in over the summer from either the host institution or from other schools across the Nation, and they were merely funded by their research experiences for undergraduate program at the NSF.

Now, these programs, the details have been provided, but I would like to just mention a few items that I think are very, very important in answering the questions that we asked. It is very important to integrate our curriculum with research, as done previous, because this is something that is an immediate challenge in all institutions, especially, in the comprehensives where resources are lacking. The teaching loads of faculty members normally are between 12 and 15 credit contract hours per week. So basically, these faculty members have to teach their full load in addition to mentor students, work with the students. This is very, very challenging. In addition to that, resources are often lacking in comprehensive institutions, particularly, because these institutions are not the flagship institutions in the states.

One other important aspect is to link the research projects that the students do to their everyday life. Without that, it is impossible to get some of these students to understand what they are doing. In addition to that, the lack of role models for under-represented students makes a lot of—it makes it difficult for some students to participate in this program, because these students, in most cases, want to see someone who looks like them in the program.

Now, with regards to effective programs that I have seen so far, what I consider to be the most important aspect is, basically, the mentorship. Mentorship is very, very important. If we can include mentorship in all the programs that would be funded H.R. 3130, it would make a lot of difference. Thank you.

[The prepared statement of Dr. Wubah follows:]

PREPARED STATEMENT OF DANIEL A. WUBAH

At the dawn of the twenty first century, the continued global leadership of our country depends on a strong, competitive well-trained workforce and citizens who are equipped to function in a complex technological world. Hence I applaud the authors of this bill to meet this challenge of facilitating efforts to increase the technically trained workforce.

In the preface to his 1990 study, Scholarship. Reconsidered, Ernest Boyer stated, "the most important obligation now confronting the nation's colleges and universities is to break out of the tired old teaching versus research debate and define, in more creative ways, what it means to be a scholar." This need to redefine the characteristics of a scholar is the cornerstone of the daily activities in comprehensive universities. Faculty members at this type of institution of higher learning educate more than 40 percent of all undergraduate students in this country. However, for a long time, such institutions have not been funded to reflect these efforts. The current concerns about and looming crisis in our ability to be leaders in science education for all citizens calls for changes in the distribution of resources.

My testimony today will address three broad questions posed for examination at this hearing in support of H.R. 3130.

- What are the major challenges facing faculty and students who are engaged in undergraduate science, mathematics, and/or engineering education at comprehensive universities?
- What programs or activities at these institutions have been effective in addressing the challenges and what were the key elements that led to their success?
- What elements of these program(s) require additional attention to enable full achievement of the goals that were set?

Brief descriptions of TU and JMU

I would like to place the two institutions that I will focus on in the right context. Towson University is an urban comprehensive university and the second largest university in Maryland with a student population of approximately 16,500. Of these, 11,500 are full-time undergraduates, 2,300 are part time undergraduates and the remaining 2,600 are graduate students (a majority of them attend on a part time

basis). The institution has 521 full-time faculty members and over 600 part time instructors. Because of its location in a metropolitan area, majority of the students are commuters, first generation college students, or have children.

James Madison University is located in the Shenandoah Valley in a more rural setting with about 15,000 students including approximately 900 graduate students. Over 85 percent of the students at JMU are between the ages of 18 and 22 and they live on campus or within a two mile radius. JMU has 661 full-time faculty and 235 part-time faculty. What the two institutions have in common is their emphasis on providing superlative educational experiences at the undergraduate level to prepare students for the workforce as well as graduate and professional schools.

Overview of undergraduate research programs TU and JMU

The goal of the program is to recruit and provide research experiences to undergraduates who would otherwise never have such an opportunity. The program is designed to enable students to develop skills in effective experimental design and execution, improve their communication skills and enhance their critical thinking abilities. By doing so, outstanding students are provided with the knowledge and skills to enter the workforce or to pursue careers in the sciences.

To accomplish this goal, the student experience resembles that of an independent researcher. Faculty mentors work closely with students as they progressed from a passive research apprenticeship to an active investigative role and eventually to an independent researcher. Working with their faculty mentors, students formulate working hypothesis, design and carry out experiments, collect and analyze data and present their findings in both verbal and written forms. In addition, the program includes seminars by visiting scholars, weekly group research meetings, journal clubs, and workshops in ethics, scientific writing and career development. Students also visit three types of institutions that represent a range of research environments different from the university: a) institutions that combine research with public education b) traditional research institutions and c) industrial research and development divisions. Students are encouraged to live on campus to form a community of learners; they have a variety of opportunities for interactions among themselves and other undergraduates from the host institution, graduate students and faculty. The effectiveness of the program is evaluated on several levels including students' reports, attitudes towards scientific research and career development.

Students participate in a broad range of projects, designed to prepare them to become professionals. Due to the diverse research expertise of the faculty, students are able to find projects that match their interest. The projects include the molecular genetics of spiroplasma, the cellular basis for plant stress responses, the physiology of wood eating fish, urban stream ecology, maternal behavior of salamanders, taxonomy of asilid insects and the role of anaerobic fungi in fiber degradation to reduce greenhouse gases. Exposure to a variety of research projects helps students to understand the interrelationships within and between the various levels of scientific organization

Faculty mentors are chosen on the basis of their experience working with undergraduates in the laboratory and the suitability of research projects for undergraduates. During the first year of the project at Towson University, none of the faculty mentors was paid. That brings me to the challenges that comprehensive institutions face in developing such programs to prepare students for the scientific workforce. These challenges include:

- Integrating the research experience into the curriculum: This aspect requires major financial commitment from the institutional administration coupled with active faculty participation. A few comprehensive institutions have been able to incorporate the axiom "we learn science by doing science" in their curriculum. Some institutions have achieved this goal by infusing a problem-based approach into the curriculum.
- Teaching loads: Faculty members in comprehensive institutions often have to carry their full teaching loads of between 12 and 15 contact hours per week during the academic year while training undergraduate students in their labs. Hence, most faculty members relegate their research to the summer.
- Resources: Comprehensive universities are often not adequately funded at the state level because their mission is teaching. Such institutions are often not the flagship university of the state, yet they educate equal, if not more citizens, for the workforce as the flagship institutions.
- Linking the research projects to everyday life: Using what is local and immediate as a source of curriculum tends to deepen knowledge through the larger understandings of the familiar and accessible. Making science relevant to the

daily life of students increases student understanding and often gives a stronger impetus to apply problem-solving skills.

- Lack of role models for under-represented students: Students are more comfortable if they belong to a community in which they see others like themselves. One of the reasons why the number of undergraduate degrees offered in the sciences, mathematics and engineering has been flat or declining despite the rapid population growth, as stated in H.R. 3130, is the tendency for most minority students to choose the biomedical sciences because there are more funds available in the form of training grants and scholarships in such programs. The need to pay attention to this demographic shift is reaching dire levels.

Elements of effective programs

A major characteristic of effective research training programs at comprehensive institutions is faculty commitment and the support of administration in the form of resources. The intellectual development of undergraduate students is most effectively guided in one-to-one relationships. This type of mentorship has been practiced at the undergraduate level in areas like art and music, where individual performance is watched, corrected, assisted, and encouraged. In the process, an undergraduate student and instructor can develop a supportive relationship not unlike that found between doctoral candidate and advisor. This kind of mentoring is one of the most important characteristic of all effective undergraduate programs.

Another important characteristic of effective programs is that faculty mentors use their research sites as seminar rooms in which their proteges observe and participate in the process of discovery and communication of knowledge. Peer mentoring is an important component of such programs and those with knowledge and skills help to develop the proficiency of others. This approach encourages collaborative learning and it supports the notion that the educational-research process is one of discovery, not transmission, and that communication is an integral part of the shared enterprise.

Integrating students with different backgrounds and diverse experiences into one program that has several audiences and purposes leads to a higher level of professionalism and social interaction. Often such programs require an amalgamation of funds from various sources because federal funds from one source is often focused and limited to a specific initiative. At Towson University, funding for the summer research program was provided by the NSF-Research Experiences for Undergraduate (REU) program, the University System of Maryland initiative to increase minority participation in the sciences and the Maryland Collaborative for Teacher Participation program. At James Madison University, our summer programs are currently funded by four NSF REU grants (Biology, Chemistry, Materials Science and Mathematics), Undergraduate Mentoring in Environmental Biology (UMEB), and private foundations such as the GTE Foundation.

Elements of programs that need additional attention

Although H.R. 3130 addresses the major elements that require attention towards meeting the goals of increasing technically trained workforce, I would like to highlight some of the main elements that need attention.

Emphasis on mentorship: Mentorship should be at the core of the programs funded under H.R. 3130 because it is a proven attribute in all effective programs. It works for all students.

Bridges programs: A large portion of the under-represented students who transfer to baccalaureate institutions attend comprehensive universities due to economic and other social factors. Therefore, previous enrollment of transfer students from under-represented groups in science, mathematics, engineering and technology should be considered as a criterion for making awards.

Summer support for faculty: In most comprehensive institutions, faculty members have to teach during the summer because of 9- or 10-month contracts. Some institutions provide faculty stipends in the summer to ensure their participation in training programs but not all comprehensive institutions can do so. In order to create a far reaching impact, faculty stipends should be provided as an incentive to encourage their participation.

Private and state support: More often than not, graduates from comprehensive universities join the workforce in their local region. H.R. 3130 can enhance active participation of state agencies and the private industry in training of technically adept workforce to benefit the local region by providing supplements to match such efforts.

Teacher preparation: The Research Experiences for Teachers program at the NSF has been run by the Engineering Directorate and selected disciplines. Expanding

this program to other disciplines would benefit all involved. Pairing pre- and in-service teachers in research projects would be a good approach in this effort.

Recommendations

In addition to the recommendations above, specific recommendations that would enhance the participation of comprehensive institutions include:

- Year round programs: Such programs would ensure continuity of student experience and foster integration of scientific knowledge into our daily lives. Faculty in comprehensive universities would be able to mentor and carry out research projects year round.
- Pathway programs: Specific bridging programs between community colleges and baccalaureate institutions should require curricular alignment. This approach would facilitate the transition and also increase the number of under-represented students who enter and stay in the sciences.
- Partnerships between institutions: Programs that involve more than one type of institution often provides students with broader experiences than focused types. For students who have not decided on a scientific discipline to pursue, they will benefit by having an opportunity to participate in programs beyond their campus.
- Involvement of K–12 teachers in research programs: The knowledge that K–12 teachers need to succeed in the classroom is different from what one needs for the workforce. Including pre-service and in-service teachers in research programs always leads to productive outcomes beyond comprehensive institutions. Programs such as integration of teachers in the NSF Collaborative for Teacher Preparation in summer research programs should be encouraged.

BIOGRAPHY FOR DANIEL A. WUBAH

Professor of Biology, Ph.D., University of Georgia, E-mail: wubahda@jmu.edu; Phone: 540–568–3150

Research Interests:

Mycology and Microbial Ecology

Research in our laboratory has two major foci: (a) anaerobic microbiology, specifically the isolation, culturing, and taxonomic characterization of obligately anaerobic zoospore-producing fungi that occur in the gastrointestinal (GI) tract of herbivores and (b) biotransformation of halogenated organic compounds by indigenous microorganisms in contaminated sediments.

Selected recent publications:

Wubah, D.A. 2000. Effect of temperature and pH on fiber degradation by three new species of rumen zoosporic fungi. Submitted to *Microbiol. Res.*

Wubah, D.A. and D.S. Kim. 2000. Isolation and characterization of a free-living species of Neocallimastix. Submitted to *Mycologia.*

Brakke, D.F., D.A. Wubah, G. McDonald, G. Gasparich, D. Downey and D. Schaefer. 2000. Retention of minority students through undergraduate research. *Council of Undergraduate Research Quarterly.* In press.

Wubah, D.A. 1999. Fungal ecology. McGraw-Hill *2000 Yearbook of Science and Technology.* In press.

Wubah, D.A. 1999. Collection and isolation protocols of fungi associated with animals: anaerobic zoosporic fungi. In "Measuring and monitoring biological diversity: standard methods for fungi." Meuller, G. and M.S. Foster (eds.) In press.

Wubah, D.A. and D.F. Brakke. 1999. Summer Undergraduate Research in Biology: Combining programs with different objectives. *Council on Undergraduate Research Quarterly.* 19: 40–44

Chairman SMITH. Thank you, Dr. Wubah.

STATEMENT OF STEVEN LEE JOHNSON, PH.D., PROVOST AND CHIEF OPERATING OFFICER, SINCLAIR COMMUNITY COLLEGE

Dr. JOHNSON. Good morning, Honorable Chairman Smith, Ms. Johnson. Thank you for the opportunity to testify before the Research Subcommittee.

Am I punched in now? How is that? I think we might have a dead mic. I will just speak very loudly, if I can. How is that? We are on.

I strongly believe that Federal investments in core academic math, science, and technology programs must increase and these new investments should be allocated in very large proportions to American community and technical colleges. American community colleges produce and deliver cutting edge technology every day and produce three to five technicians that support each engineer, scientist, and medical doctor across the country, not to mention the fact that many medical doctors, engineers, and scientists themselves begin their education in community colleges. Each year, millions of community college students take core mathematic and science courses to lay the groundwork for further studies. NSF research indicates that as many as 40 percent of the Nation's science and math teachers take courses in community colleges.

Furthermore, literally, thousands of community college students from across the country enter the community college with a baccalaureate degree or an advanced degree already in hand. They have come back to advance their skills, to get retraining, or other critical reeducation throughout their lifetime. Another important point, nationally, 58 percent of the seven million undergraduate students in community colleges are female, 30 percent are from minority groups. Community college student bodies have a higher percentage of minorities and women than other institutions of higher education. Community colleges, therefore, play an extensive role not only in education of our nation's technological workforce, but also, an essential starting point for physicists, chemists, and engineers.

In the written testimony that I have provided, I provide detail of numerous major science and technology reform initiatives at Sinclair College, and these projects would not have been possible without tremendous support from NSF and from the U.S. Department of Education. And those examples are just one institution, one com-

munity college institution, and I urge you to look at what is going across the Nation.

I have some recommendations that I would like to forward to you at this point. First, I think that funding from the National Science Foundation Advanced Technological Education Program has been very important to community colleges. We are very competitive. We have delivered as requested and promised. However, the program focuses on engineering technologies and needs to expand its focus to core mathematics and science courses. And furthermore, we appear to be at a critical threshold in spite of large proposed increases in overall NSF funding. The Division of Undergraduate Education, including Advanced Technological Education, apparently, will lose funding and research funding for universities will probably be increased. This trend is troubling and should be halted.

Second, in general, community colleges are not as competitive at securing Federal funding as 4-year colleges and universities, and one major reason is that many agencies are geared toward a priority of pure research opposed to the practical pragmatic curriculum development that is a forte of community colleges.

Third, the identification and proliferation of already existing successful models is often overlooked in all segments of higher education. We really need to work on programs that allow us to disseminate and proliferate. I strongly recommend that the national role of two outstanding national community college umbrella organizations be supported, strengthened, and expanded through Federal support. That would be the League for Innovation in Community Colleges and the American Association of Community Colleges. The League for Innovation in Community Colleges, in particular, is focused on catalyzing innovations and reformation in undergraduate education and in community college services, and I believe that the League should be embraced by Washington as a partner in organizing national efforts within community colleges across the country.

Finally, I would say that, clearly, innovation and outreach is accelerated by Federal support, State Government support, as well as foundation, private foundation, support. Public community colleges across the country are delivering, and they are delivering on their promise of providing solid and accessible—and I really want to highlight the word "accessible"—higher education. And they need to be embraced by our Federal programs, and for this reason, I wholeheartedly support the passage of legislation similar to H.R. 3130.

Thank you very much for the opportunity to speak before you today.

[The prepared statement of Dr. Johnson follows:]

PREPARED STATEMENT OF STEVEN LEE JOHNSON

Honorable Chairman Smith and Members of the Research Subcommittee, thank you for the opportunity to testify before you today. My name is Steven Lee Johnson, Provost and Chief Operating Officer of Sinclair Community College in Dayton, Ohio. In addition to speaking as one executive from one of the Nation's largest and nationally active comprehensive community colleges, I speak as an active contributor to the national undergraduate education reform movement focused on learning outcomes and placing learning first in all college policies, practices, and procedures.

I will make the following points today:

1. Support for core academic math, science and technology programs must increase for the continued strength and health of the Nation.
2. With federal support, community and technical colleges have proven effective in the delivery of science and technology education to a large proportion of U.S. undergraduates, and have proven strong in the movement toward innovative reformation of education.
3. As flexible, practical, and innovative organizations, community colleges are the seat of many innovations that deserve widespread dissemination and adoption across the Nation.
4. I advocate for the Subcommittee's passage of legislation similar to H.R. 3130 (Technology Talent Act of 2001).

Introduction

Federal investments in core academic math, science and technology programs must increase, and those new investments should be allocated in very high proportion to American community and technical colleges. American community colleges produce and deliver cutting-edge science and high technology every day. We educate the three to five technicians that support each engineer, scientist, and medical doctor across the country. Our nearly 7 million undergraduate students are learning in high tech areas as biotechnology, advanced integrated manufacturing, rapid prototyping, computer networking, robotics, surgical technology, and web-based graphic simulation.

According to the American Association of Community Colleges, nearly half of all U.S. undergraduate college students are enrolled in community colleges. There millions of students take core mathematics and science courses to lay the groundwork for further studies. These core courses are arguably the most important curricular component in a community college because they are required of all associate degree and transfer students—including future teachers. NSF research indicates that as many as 40 percent of the Nation's science and math teachers have taken courses at a community college, with an even higher percentage in some states. Looking ahead to the expected wave of retirements in the teacher ranks, community colleges must be included in the plans to recruit their replacements and provide teachers with a sound educational footing.

America's community and technical colleges total over 1,100 institutions and are found in the largest urban areas of New York and Los Angeles and the most rural areas of Appalachia and the American West. We are the college of the people, with an absolute commitment to serving the current needs of our local communities. As our most egalitarian form of higher education, community colleges continually strive to reduce the cost, policy, location, and curricular barriers that are typical within higher education. Nationally, 58 percent of the nearly 7 million undergraduate community college students are female and 30 percent are from minority groups. Community college student bodies have a higher percentage of minorities and women than do other institutions of higher education. Community colleges therefore play an extensive role not only in the education of our nation's technological workforce, but also as an essential starting point for tomorrow's physicists, chemists, and engineers. This is especially true for minorities currently under-represented in these fields.

Furthermore, literally thousands of community college students across the county enter the community college with a baccalaureate or advanced degree in hand. Throughout their lifetimes, they seek advanced technical skills or critical re-education to augment the theoretical knowledge gained through their previous degree work. Community colleges count among their alumni Craig Venter, mapper of the human genome, and Bruce Merrifield, winner of the Nobel Prize for Chemistry. Federal programs that recognize and facilitate the role community colleges play in the development of future scientists are needed.

A robust national economy requires world-class thinkers and technicians in the workforce. Community college students and faculty who are engaged in undergraduate science, mathematics, engineering, and technology education face many challenges. It is difficult and expensive to bring a fragile, under-prepared student up to the appropriate academic level to enter our cutting-edge technology programs. However, the investment of time, effort, and resources is critical to not only enable disadvantaged students to succeed in a democracy, but to also meet current emerging workforce needs. Obtaining and maintaining the equipment, hardware, and software and providing the professional development for faculty are costly. To be effective, community college more investment from public and private sources to augment our operating budgets (yet I argue that the amount of investment per student would be lower than if invested in other forms of higher education). These economic

and technical challenges directly affect the ability of American community colleges to remain world leaders in technician education.

Today I will highlight major initiatives at Sinclair College that are reforming undergraduate education in the Dayton region. I will share nationally recognized benchmark models that are the direct result of federal funding and support. I will also offer several examples of notable, locally-funded initiatives that illustrate how Sinclair develops and flexes to meet demonstrated needs in science, mathematics, engineering, and technology education. I will conclude with a call for much more support for development and dissemination of innovation in the core academic courses in math, science and technology.

Sinclair College's Federally-funded Programs that Reform Science, Mathematics, Engineering, and Technology Education

1. National Center of Excellence for Advanced Manufacturing Education

Funded by a seven year, $6.8 million grant from the National Science Foundation, the mission of the National Center of Excellence for Advanced Manufacturing Education is to provide national leadership in developing manufacturing engineering technicians with strong fundamental and technical skills. The National Center of Excellence has developed a pedagogy that is competency-based, activity and teamwork-based, contextual, industry-verified, and has assessment embedded at every level. Specific outcomes of this initiative include:

- The creation of a new 62 module associate degree program in Manufacturing Engineering Technology
- More than 4,600 educators introduced to the modules and the methods
- At least 8,600 students educated by the modules and the methods
- More than 3,500 business employees in 1,200 businesses and industries introduced to the modules and the methods.

The National Center of Excellence actively trains both secondary teachers and post-secondary faculty in the development of curricula as well as effective delivery of activity-based learning using the architecture.

2. The Information Technology (IT) Academy Project (IT@Sinclair)

Funded by an $850,000 grant from the National Science Foundation and a $500,000 grant from the Ohio Board of Regents, IT@Sinclair is responding to the growing shortage of highly skilled employees in information technology fields. The project has resulted in:

- *The Learning Center @ Research Park.* The creation of an off-campus learning facility enables Sinclair to expand its IT curriculum offerings to thousands of new students.
- *Competency-based curriculum that is delivered inflexible ways.* The new curriculum is a complete redesign of 18 courses and five degree options to align with state-of-the-art IT jobs and competencies.
- *Increased Skills Among Faculty.* Full-time faculty have undergone extensive retraining needed to develop and teach the new curriculum.
- *Increased enrollment in IT Tech Prep programs.* High school students have increased interest in IT careers as a result of the project's relationship with the Dayton-area Miami Valley Tech Prep Consortium. Enrollments have increased by 38 percent over recent years.

3. Miami Valley Tech Prep Consortium

With an annual allocation averaging $300,000 from the Ohio Department of Education and Carl D. Perkins funding, this Dayton-area consortium strengthens Ohio's workforce competitiveness by preparing students for technology-based careers. The Miami Valley Tech Prep Consortium is a partnership among Sinclair Community College, multiple public school districts and employers in southwest Ohio. It combines the last two years of high school with two years at Sinclair resulting in a four year or "2 + 2" seamless educational pathway leading to the associate degree in a technology-based career. By fall 2002, the Consortium will offer 10 tech prep pathways based at 30 high school sites and Sinclair College. Currently, 2,215 students are enrolled in tech prep pathways within the consortium. In recent years the U.S. Department of Education designated the Dayton area Miami Valley Tech Prep Consortium as "Best in the Nation."

Tech prep prepares and motivates ordinary students to do extra-ordinary things. For example, tech prep students at Sinclair College, many of whom are first genera-

tion college students, demonstrate a higher level of college readiness. Only 20 percent of tech prep students require developmental course work compared to 80 percent from the general full-time college population. Tech prep students perform at significantly higher academic levels than same age comparison groups in first year mathematics, English and biology.

4. Center for Health Communities

The Center for Healthy Communities is a community academic partnership established by the Boards of Trustees of Sinclair Community College and Wright State University. The Center for Healthy Communities works with health professions education programs and over 100 health and human services in the Dayton area to improve community health care service delivery for the underserved and to enhance health professions education. Sinclair offers courses in community health advocacy placing technicians in the poor, urban neighborhoods to assist residents in obtaining improved health care. Each year over 2,500 individuals receive direct health care or educational services from the Center.

5. Chemical Instrumentation Institutes

Over the course of seven recent years with $750,000 of support from the National Science Foundation, Sinclair College led Summer Faculty Institutes in state-of the-art training. Approximately 350 community college faculty nationwide, who teach an estimated 52,000 college students annually majoring in science and pre-health careers, were trained in advanced chemistry instrumentation (Gas Chromatograph/Mass Spectrometer, High Performance Liquid Chromatography, and Fourier Transform Infrared Spectrophotometer, with special topics on Molecular Modeling, Environmental Science, and Software applications in teaching). Key to this successful project was collaboration with four-year universities: The University of Dayton, George Mason University, and Western Washington University.

6. Faculty Development in Engineering Technologies

The National Science Foundation awarded Sinclair College a $100,000 grant to conduct a series of comprehensive professional development programs for two-year college engineering technology faculty. Faculty attended courses and worked with their colleagues from industry and universities while learning the latest technology in the areas of rapid prototyping and workcell simulation. Each workshop incorporated curriculum development concepts by working with Sinclair's National Center of Excellence in Advanced Manufacturing Education.

During the two-year project, the workshops were filled to capacity with 44 engineering and technology faculty from 28 different colleges and universities across 13 states. An estimated 2,000 students benefited from the new material within a year of the workshops.

7. Future of Engineering Technology

In the mid-1990's, the National Science Foundation asked Sinclair College to forecast the changes needed to secure a highly qualified workforce of engineering technicians in commerce and industry. A national "Workshop to Establish a National Agenda for the Future of Engineering Technician Education" convened to identify critical issues and to set forth recommendations for the academic institutions, their oversight bodies, professional societies, the business and industrial community, and governmental funding agencies. The resulting report, which provided a vision for the future of engineering technician education, was disseminated to every two-year college in the Nation.

8. Image and Marketing of Engineering Technology Programs

Sinclair Community College received a $250,000 National Science Foundation grant with its partners, the American Society for Engineering Education/Engineering Technology Council, Middlesex County College, Motorola University (a division of the Motorola Corporation), University of Central Florida, and the University of Dayton Engineering Technology Department. The goal is to create a national marketing campaign and marketing materials to promote a strong, positive image of engineering technology education, to market that image to prospective students, and ultimately encourage more students to enter the profession. The project will be completed this summer with national distribution of the materials at that time.

State and Locally Funded Initiatives at Sinclair College Reforming Science, Mathematics, Engineering, and Technology Education

1. Biotechnology Program

Sinclair has initiated a new associate degree in biotechnology in cooperation with local business and industry. In the fall of 2001, Sinclair began a new regional training center for biotechnology technicians with support from:

- A gift from Eli Lilly in Indianapolis
- A $185,000 Ohio Department of Education grant for equipment, curriculum, and faculty development
- The Miami Valley Tech Prep Consortium which established 2 + 2 programs with area high schools

This new program is projected to enroll 215 high school and 60 undergraduate community college students.

2. Top Gun Academy

The Top Gun Academy provides advanced training to expert workers in the tool and machine industry. The skills and knowledge derived from this training is intended to enable workers and related businesses to compete successfully with industry developments in other countries. Top Gun is an industry specific training program resulting from the partnership of the Advanced Integrated Manufacturing Center of Sinclair Community College, the University of Dayton, the Dayton Tooling and Machining Association, and TOOLVALLEY Network, a consortium of local industry and government partners. The program was launched in 2001 and is currently serving 25 students. Plans are underway to disseminate information concerning the Top Gun Academy as a national model for other communities.

3. Fire Science Technology Apprenticeship

In a city with a 42 percent African-American population, the City of Dayton Fire Department has only 5 percent African-Americans in the uniformed ranks. In addition, only 6 percent of Dayton Firefighters are female. In response to this situation, Sinclair College has cooperated with the City of Dayton to develop a Fire Science Technology Apprentice Program designed to educate and train a more diverse group of students. The program combines on-the-job experience in the Dayton Fire Department with academic training through Sinclair. The program enhances the technical and educational skills needed to be competitive on the firefighter recruiting test. The program, which started in the spring of 2001, has 26 participants. The first cohort group will complete their program in December 2002. Of the 26 participants, 53 percent are minorities and 19 percent are women.

4. Women in Engineering Technology

The challenge of attracting and retaining women in engineering technology disciplines is approached by Sinclair College's Women in Engineering Technologies Program.

Approximately 700 7th–8th grade girls participate in hands-on workshops through a bi-annual Career Day introducing them to engineering technologies, science, and mathematics careers. A two-week Summer Institute Program introduces 10th–12th grade young women to the engineering and industrial technology career opportunities while they earn college credit.

5. Human Patient Simulator Technology

Sinclair College has been a national leader in the use of human simulators in healthcare education. Health care is experiencing unprecedented change and allied health educators are challenged to prepare students to work in a dynamic health care culture. Critical thinking skills, good communication, and teamwork skills must be taught in conjunction with specific course content. The Division of Allied Health uses a Human Patient Simulator, which is a life-size computer controlled manikin that breathes, has a heartbeat, and includes sophisticated modeling of physiology and pharmacology, enabling it to mimic accurately many human responses. The system comes with a number of pre-programmed scenarios in which the underlying physiological model is tailored to duplicate a particular kind of individual. The manikin, therefore, can be male or female, young or old, fit or unwell, and can even simulate some aspects of the pregnant patient. The Human Patient Simulator is used:

- To prepare students in a controlled, pre-clinical learning environment. Students have the opportunity to work on "a patient," make mistakes, and receive appropriate feedback from faculty before ever touching a live patient.
- Each quarter approximately 300 Emergency Medical Services, Nursing, and Respiratory Care students work in teams as they will in the workplace to care for the patient while developing clinical decision-making skills.

6. Radiologic Technology On-line Learning Project

This unique partnership between Sinclair Community College and the American Society of Radiologic Technologists offers on-line learning experiences for approximately 250,000 radiologic technologists nationally. During January 2002, the website recorded approximately 30,000 hits from six continents. Web-based instruction is critical because:

- There is a severe workforce shortage of technologists and other allied health disciplines, making it difficult to release staff from work to seek professional development experiences.
- Content developed for nurses and radiology professionals is applicable no matter where the professionals are geographically located.
- Training is easy to access anywhere, any time. For example, Sinclair College is currently meeting with the Air Force to explore a contractual arrangement for use by military services personnel deployed around the world.

7. Teacher Recruitment and Preparation in Mathematics and Science

Large percentages of newly certified teachers take much or all of their science, mathematics, and technology coursework in two-year colleges. The National Science Foundation estimates that this percentage is as high as 70 percent of elementary school teachers in the state of California (National Science Foundation, A Report of the Division of Undergraduate Education, NSF O1–44). To assist in the preparation of future teachers, Sinclair is participating in the SUSTAIN project to develop core curriculum for mathematics and science courses for the preparation of elementary and middle school teachers using National Science Education Standards. SUSTAIN receives federal funding through the state, with Ohio State University as the lead institution.

Concluding Recommendations

Community colleges constitute a large proportion of our undergraduate students, and with Congressional support can increase their proven role as a cost-effective leader in the delivery of reformed science, mathematics, engineering, and technology education. The work at Sinclair College that I have highlighted is just one example of the grassroots work being done across America; there are thousands of additional examples of both national and local impact across community and technical college sector.

Funding from the National Science Foundation Advanced Technological Education program has been invaluable to community colleges. We are very competitive and we have delivered as requested and as promised. However, the program focuses on engineering technologies and does not truly address the core mathematics and science courses. Furthermore, we are at a critical threshold. In spite of large proposed increases in overall NSF funding, the Division of Undergraduate Education (including the Advanced Technological Education program) apparently will lose funding, and research funding for universities will probably be increased. This trend is troubling and should be halted.

In general community colleges are not as competitive at securing federal funding as four-year colleges and universities. Each year the Council for Resource Development creates the *Federal Funding to Two-Year Colleges Report* based upon interviews with program officers. The report details the number of submissions and awards by agency and program comparing community colleges and universities. The data indicates that there are only a handful of programs where community colleges are competitive. One major reason is that the priorities of many agencies are toward pure research as opposed to the practical and applied types of curriculum development and workforce development initiatives—the forte of American community colleges. For example, funding for health programs is often focused on the graduate level in spite of the volume of allied health professionals educated at community colleges.

As in other forms of education, community colleges themselves face depletion in their faculty ranks. The NSF could do more to encourage graduate students contemplating a career in higher education to consider the option of teaching at a community college. A program similar to the K–12 program, where future faculty members have the opportunity to experience teaching at a community college, might be one way to achieve this result.

The identification and proliferation of successful models is often overlooked in all segments of higher education. We place many of our needed resources into research and development, with relatively little resources remaining for regional or national dissemination. I would estimate that of the $6 million that Sinclair College receives in annual grant funding, only five to ten percent is devoted to dissemination; the

bulk is for research, development, testing, and operations. Many educational, agency, and political bodies need to work together to shift that traditional thought and practice structure to include more emphasis on the dissemination and proliferation of innovations.

I strongly recommend that the national role of two outstanding umbrella organizations with the community and technical college sector be supported, strengthened, and expanded through federal support. The League for Innovation in the Community College and the American Association of Community Colleges both have assumed national roles in disseminating best practices and educational innovations. Both organizations offer conferences, teleconferences, seminars, publications, and web sites devoted to disseminating benchmark-quality models of science, mathematics, engineering, and technology education.

The League for Innovation in the Community College is particularly focused on catalyzing innovations and reformation of undergraduate education and other community college services. Since 1968 The League is the only major international organization specifically committed to improving community colleges through innovation, experimentation, and institutional transformation. *Change* magazine calls the League the "most dynamic organization in the community college world."

Over its history, the League has worked with nearly every major national educational organization and received grants from dozens of major foundations, corporations, and government agencies. More than 100 League corporate partners play key roles in sponsoring conferences, publications, projects, and other ongoing activities. Members of the League board of directors are among the first, and sometimes the only, representatives of community colleges to sit on the boards and serve as officers for numerous national higher education organizations and corporate advisory councils, including:

- The American Council on Education
- American Association of Community Colleges
- American Association for Higher Education
- Business-Higher Education Forum
- The College Board
- Carnegie Foundation for the Advancement of Teaching
- American College Testing, Educational Testing Service
- Education Commission of the States

Clearly, innovation and outreach is accelerated with the support of federal and state government and private foundation grants. Public community colleges across the country are delivering on their promise of providing solid and accessible higher education, but they simply do not have the resources in their general funds for national outreach. For this reason, I advocate for the Subcommittee's passage legislation similar to H.R. 3130 (Technology Talent Act of 2001) as well as expanded financial support for such federal programs as:

- National Science Foundation, Advanced Technological Education
- Carl D. Perkins Vocational and Technical Education Act
- The Fund for the Improvement of Post-secondary Education
- Part A of Title III of the Higher Education Act of 1965, as amended.

Thank you for allowing me to appear today.

BIOGRAPHY FOR STEVEN LEE JOHNSON

Provost and Chief Operating Officer, Sinclair Community College, 444 West Third Street, Dayton, Ohio 45402; e-mail: steven.lee.johnson@sinclair.edu; phone: 937–512–5300, 937–512–2128

Dr. Steven Lee Johnson's commitment to excellence and innovation has been a driving force throughout his career in higher education. As Provost and Chief Operating Officer of Sinclair Community College he is central to the shaping of Sinclair's transition to the future. Sinclair is a nationally acclaimed college: One of the 19 board member colleges of the League for Innovation, one of 12 national Vanguard Learning Colleges, and consistently the highest rated higher education institution in Ohio for maintaining outstanding financial health. Johnson also has some acclaim, including being named one of Converge magazine's "Shapers of the Future in Technology and Education," periodically serving on the faculty of professional training institutes and summits, and serving as an expert witness on educational technology to the U.S. Congress.

As a Vanguard Learning College Sinclair strives to continually improve the services and learning experiences for the 22,000 students it enrolls. Johnson is responsible for leading the team of Sinclair's five vice presidents who collectively manage the internal operations of the college. Sinclair's operations include a $90 million dollar annual budget, 1,500 full and part-time employees, a campus approaching 2 million square feet of buildings, 300 classrooms and labs, over 2,000 different college courses, and several satellite locations within metropolitan Dayton.

Johnson's first experience in the lead role of a campus was at the Clearwater Campus of the St. Petersburg College District, where he served as the Provost and Campus CEO. While there, he designed and developed the Hard Drive Cafe and led the expansion of the one-stop academic support system that has since been recognized as an outstanding example of community college innovation.

Johnson earned his Ph.D. from The University of Texas in Educational Administration with a focus on community college leadership. Throughout his career, he has maintained a commitment to the classroom by serving as a college instructor of various courses, including management, technology, developmental writing, and communications. In addition, he has presented at a wide variety of national conferences, frequently gives keynote addresses to large audiences, and has published several articles on such topics as managing technology in higher education and innovations in community college leadership.

In addition to his Texas doctorate, Johnson has earned degrees from Iowa State University of Science and Technology and from the University of Wisconsin-Superior.

March 4, 2002

The Honorable Sherwood L. Boehlert
U.S. Representative, New York, 23rd District
2246 Rayburn House Office Building
Washington, DC 20515-3223

Dear Representative Boehlert:

In accordance with the Truth in Testimony Rules, the following describes Sinclair's sources of operating funding for the past two fiscal years and a list of federal grants received related to the testimony.

SOURCE	FY 2002	FY2001
State Appropriations	$43.2 million	$42.6 million
County Tax Levy	$20.8 million	$20.7 million
Student Credit Fees	$19.1 million	17.6 million
Other (investment income, parking, non-credit enrollments, etc.)	$5.6 million	$5.6 million

FEDERAL GRANTS	FY2002 (TO DATE)	FY2001
U.S. Department of Labor, Employment and Training Administration Earmark Grant	$850,000	$0
U.S. Department of Labor, Workforce Investment Act (pass through state of Ohio and local county agencies)	$1,800,000 (est)	$637,465
U.S. Department of Education, Carl D. Perkins (pass through the Ohio Department of Education)	$464,516	$504,446
Workforce Investment Act, Title II, Adult and Family Literacy Act, P.L. 105-220	$311,716	$357,950
U.S. Department of Education, TRIO Programs	$499,401	$453,767
U.S. Department of Justice	$0	$2,800
National Science Foundation	$768,925	$1,550,696
NASA	$162,500	$162,500

Sincerely yours,

Steven Lee Johnson

Chairman SMITH. Thank you. Dr. Davidson.

STATEMENT OF JAMES NARL DAVIDSON, PH.D., PROFESSOR OF MECHANICAL ENGINEERING AND INTERIM DEAN OF ENGINEERING, GEORGIA INSTITUTE OF TECHNOLOGY

Dr. DAVIDSON. Mr. Chairman, I am honored to appear before this Committee and thank you for the opportunity. I would like to give you a brief summary of my written statement. I will concentrate on engineering education and, in particular, the recruitment and retention of under-represented groups at Georgia Tech.

The programs we have used to enhance the diversity of our community fall into three broad categories. First, we try to encourage middle school and high school students to pursue education in science and technology. There are several groups on campus that run summer programs for middle and high school students. They are part recruitment, but the primary purpose is to expose the attendees to science and engineering as career choices.

We administer an exceptionally effective program called GIFT, the Georgia Industrial Fellowships for Teachers. The year round program is designed for high school and middle school science and mathematics teachers. It begins with a six to eight week summer experience, in which teachers work with a mentor in business, research, or other science based organization. Teachers experience scientific inquiry and see the application of new technologies in the workplace. The teachers are linked to interdisciplinary professional networks and returned to their classrooms renewed and empowered to teach technical subjects.

Georgia Tech has taken advantage of the NSF program, Graduate Teaching Fellows in K Through 12 Education, to place several pairs of science and engineering Ph.D. students in high school classrooms in the metro Atlanta area. These students, the group there is about half female and half minority, not only enhance the instruction in the technical areas, but serve as excellent role models for pre-college students.

I am particularly proud of a program the College of Engineering has initiated in public high school in Rockdale County, Georgia. Three years ago, we entered an agreement with the Rockdale County School Board to help to establish the Rockdale County Magnet Program with a focus on information and communication technologies. Georgia Tech has provided instructional help, advice on curriculum, some equipment, and enthusiastic support. The students are taught how to design, carry out, and report research projects. In its three years of existence, students in the Rockdale Magnet Program have almost taken over the regional and state science fairs and have come to understand that the skills they learn and the research experience help them to excel in all their classes.

Second, we recruit undergraduates, graduate students, and faculty members from under-represented groups. We have a very strong partnership with the four undergraduate institutions at the Atlanta University Center, the Morehouse College, Spellman College, Morris Brown College, and Clark Atlanta University. Students at any of these schools who meet the admissions criteria may transfer to Georgia Tech at the end of their third year, take two

years of engineering subjects in a particular discipline, and graduate with both a degree from their AUC school and an engineering degree from Tech. About 80 students choose this path each year. Tech has initiated a discussion with the Miami-Dade County Community College in Florida to develop a similar transfer program for Hispanic students.

In January 1991, we started a small program designed to encourage African-American students from around the Nation to consider graduate school in engineering and built it around Atlanta's celebration of Martin Luther King, Jr. birthday. We called it FOCUS and it was a resounding success. This past January, we invited over 350 excellent students to the 3-day FOCUS program. We hope to have encouraged most of these students to go to graduate school. We know it has made a difference at Georgia Tech. Last year, Tech graduated 11 percent of the Ph.D.'s in engineering earned by African-Americans in this country.

Finally, we work to retain the students already on campus. Nothing creates enthusiasm for learning like participating in meaningful research projects. One of the most effective programs has been the Research Experience for Undergraduate supplements to National Science Foundation grants. We encourage all of our faculty members who have such grants to request REU funding and involve their good undergraduates in the work in their labs. The correlation between a student's involvement in research and satisfaction with their undergraduate experience is very strong.

Effective retention invariably requires cultural change, and change in academics is slow. One change agent has been the good work of Georgia Tech's two NSF engineering research centers; one in electronic packaging and one in tissue engineering. Because of the NSF emphasis on the transfer of the research results to the curriculum, the centers have materially impacted the classroom experience of many students in science and engineering. Exposure to the results of a large, relevant research program has obviously been beneficial for the enthusiasm and, hence, retention of a large number of students.

There are no silver bullets in the recruitment and retention of good, technically talented students. We need to encourage new ideas and to try lots of experiments. We also must attack the problem from all sides by encouraging pre-college initiatives for students and their teachers, enhancements of the university and college experience for undergraduate and graduate students, and increase in the diversity of the academic faculties in science and engineering. To this end, I recommend the following: Provide a mechanism for fast response to grant requests for small experimental programs. Facilitate the sharing of ideas among different constituencies by helping to sponsor conferences on recruiting. Provide increased opportunities to middle and high school science and math teachers to have meaningful industrial or research experiences. Allow some non-traditional groups to help with the problem. Continue the strong support of science and engineering research in the colleges and universities. And enact the Tech Talent Act, House Bill 3130. This bill is very flexible. It would allow the NSF to implement most of the recommendations listed above. The engineering education community strongly supports this bill.

Many of the things I have told you are examples of tech, but I want to make it clear that the engineering education community is very committed to the development of strong science and technology programs and diversity in both our students and faculty. The most important element of our success in attracting good students, faculty, and developing a diverse population is the clear intention to do so. We try to communicate a clear and consistent message. We want the best students we can attract. The best students will be a diverse group, and we will do what it takes to accomplish this goal. In that environment, we are not afraid to try new ideas, and failure at some efforts is just a learning experience, but then we are scientists and engineers.

Thank you for the opportunity to speak today.

[The prepared statement of Dr. Davidson follows:]

PREPARED STATEMENT OF JAMES NARL DAVIDSON

Sustained economic growth in the twenty-first century will depend in large measure on the productivity increases resulting from scientific and technological innovation. To participate in this growth, the United States must insure an adequate supply of technically and scientifically trained talent to create and develop new ideas. Georgia Tech is dedicated to producing such talent. I would like to discuss some of the challenges we face in recruiting and retaining good students, some programs we have found to be effective in meeting those challenges, and some recommendations for future programs which can enhance that effectiveness. I will concentrate on engineering education, and in particular, the recruitment and retention of under-represented groups in our population.

Georgia Tech is a large research university with a good reputation for engineering education. We have produced more engineering degrees over the last decade than any other engineering school in the country. Our reputation and relatively low tuition allow us to attract a very good pool of well-qualified applicants. However, there are some significant challenges. As stated in the vision statement of the College of Engineering, we are committed to be a national leader not only in technology development, but also in educating a workforce that is diverse and globally aware. Our major efforts in the recruitment and retention of undergraduate students have been directed at developing the diverse educational community that will allow us to meet this goal. Because faculty and students at all levels are inseparably involved in the research and education at Georgia Tech, there are recruitment and retention efforts directed at all members of our community.

The programs we have used to enhance student diversity fall into three general categories: (1) encouragement of middle school and high school students to pursue education in science and technology; (2) recruitment of undergraduates, graduate students and faculty members from under-represented groups, and (3) retention of students already on campus.

Middle and High School Programs

There are several groups on campus that run summer programs which are part recruitment but are primarily directed at providing middle and high school students with an exciting scientific and technological experience. These programs vary among weekend events, day-camp experiences, and week long residential camps using campus housing. The clear purpose is to expose the attendees to science and engineering as career choices.

The Office of Minority and Special Programs, a unit of the College of Engineering, offers, five pre-college programs directed at students from the fifth through the twelfth grade. Some of these programs, such as the successful Minority Introduction to Engineering, are directed to minority students, but most are open to all. The Center for the Enhancement of Instruction in Science, Mathematics, and Engineering (CEISMC) is operated by the College of Sciences and provides similar programs for pre-college women students. The programs are funded by grants from private foundations and corporations, fees collected from participants, and some discretionary funds available to the College of Engineering.

SECME, Inc., originally the Southeastern Consortium for Minorities in Engineering, is an independent educational alliance organized in 1975 by Georgia Tech. Still housed on campus, it partners with schools, departments of edu-

cation, and corporations to strengthen the capacity of K–12 teachers in science and engineering. SECME does hold some programs for students but always works through the local teachers. It solicits its funding primarily from corporations and foundations, but also receives significant federal support from NASA.

The College's Women in Engineering program also operates a week-long, summer program for high-school girls that introduces them to the various disciplines of engineering. Because many of the engineering faculty participants are women, the participants are exposed to women engineers, often for the first time.

CEISMC administers an exceptionally effective program called the Georgia Industrial Fellowships for Teachers, or GIFT. The year-round program is designed for high school and middle school science and mathematics teachers. It begins with a six to eight week summer experience working with a mentor in business, research or informal science organization. Teachers experience scientific inquiry or applications and uses of new technologies in the workplace. Through GIFT, teachers linked through interdisciplinary professional networks return to their classrooms renewed and empowered. GIFT was initiated in 1990 by the Georgia Institute of Technology with the assistance of the Triangle Coalition for Science and Technology Education in Washington, D.C., and the California-based Industry Initiatives for Science, Mathematics, and Engineering (IISME). The GIFT Advisory Council is chaired by Dan McGlaughlin, President and CEO, Equifax, Inc., and statewide leadership has been provided by Georgia Power Company.

Georgia Tech has taken advantage of the NSF program, Graduate Teaching Fellows in K–12 Education, to place several pairs of science and engineering Ph.D. students in high school classrooms in the metropolitan Atlanta area. The feedback from the schools has been very gratifying. It is clear that these students, a group that is about half female and half minority, are not only enhancing the instruction in technical areas but are serving as excellent role models for young men and women who might not otherwise have considered careers in technical fields.

I am particularly proud of a program that the College of Engineering has initiated in a public high school in Rockdale County, Georgia. Three years ago, at the suggestion of a successful Tech alumnus living there, we entered an agreement with the Rockdale County School Board to help establish the Rockdale County Magnet School within Rockdale High School. The focus of the magnet school is on information and communication technologies, fields that mesh with important local industries. Georgia Tech has provided instructional help, advice on curriculum, some equipment, and enthusiastic support. Gifts from local corporations and interested individuals have provided financial support. The magnet school students and teachers are routinely brought to the Tech campus for lab demonstrations, tours of facilities, and celebrations of success. The curriculum includes a very important class in research in each of the four years of the program. The students in these classes, which are not discipline specific, learn the techniques necessary to design, carry out, and report research projects. In its three years of existence, the Rockdale Magnet program has almost taken over the regional science fair, has garnered many of the top prizes at the state level, and sent students to the national competition. More importantly the students have come to understand that the skills they learn in the research experience have helped them to excel in all of their classes. It is most gratifying to see the confidence these students have, to know they have a real appreciation for the values of science, and to experience their enthusiasm for pursuing scientific and technical careers.

Recruiting Students to Georgia Tech

As mentioned above, most of Georgia Tech's student-recruiting efforts are directed at under-represented groups. Besides the programs for high school students described previously, we have several programs designed to allow minority students at liberal arts schools to transfer to Georgia Tech to receive their engineering degrees.

We have a very strong partnership with the four undergraduate institutions of the Atlanta University Center: Morehouse College, Spellman College, Morris Brown College, and Clark Atlanta University. Students at any of these schools who meet the admissions criteria may transfer to Georgia Tech at the end of their third year, take two years of engineering subjects in a particular discipline, and graduate with a BS or BA degree from their AUC school and an engineering degree from Tech. The AUC schools can use the availability of this dual-degree program to attract good students, and Tech graduates some exceptional engineers—about eighty per year—who have chosen this path.

Tech has initiated a discussion with Miami-Dade County Community College in Florida to develop a similar transfer program for Hispanic students.

The strength of our undergraduate programs is dependent on the quality of our faculty and is intimately tied to our strong graduate programs. Georgia Tech is consequently quite active in the recruitment of graduate students, and we have special interest and programs in attracting, minority students and women. Since attracting excellent graduate students is a core function, it is funded almost exclusively by internal sources. However, the support of graduate education would be impossible without the strong support of federal funding for research in science and technology from a variety of agencies or without the availability of the many fellowships for graduate education.

In January, 1991, we started a small program in the College of Engineering designed to encourage African-American students from around the nation to consider graduate -school, and built it around Atlanta's celebration of the birthday of Martin Luther King, Jr. We called it FOCUS, and it was a resounding success. The program has grown and has become an Institute-wide effort involving all of the colleges at Tech. This past January we invited over 350 superb students to the three-day, eleventh running of the FOCUS program. We certainly benefit in that about a third of the invitees will end up attending graduate school at Georgia Tech. However, we believe twice that number are encouraged to pursue a graduate education they may not have considered, and that is its real benefit. It is an expensive program, funded by internal resources and corporation grants, but it is clearly successful. Last year, Georgia Tech granted eleven Ph.D. degrees in engineering to African-Americans; the total number for all programs in the United States was 96.

The Facilitating Academic Careers in Engineering and Science (FACES) is a National Science Foundation sponsored collaboration among the College of Engineering, the College of Sciences, Morehouse College, and Spellman College. It is designed to increase the number of African-American students receiving doctoral degrees in science and engineering with the specific goal of increase the number of these individuals entering the professoriate. The ultimate goal is to alter the face of the science and engineering faculty. The program identifies upperclassmen in the three participating institutions, involves them in research as undergraduates, and encourages them to pursue graduate education. If they choose to continue the students become eligible for a supplementary fellowship support from the FACES program.

Retention

Georgia Tech has many programs designed to enhance the success and ultimately the graduation rate of its undergraduate students. Some are specifically designed to help students over the hurdles of the first couple of years of a demanding curriculum: tutoring programs, discipline specific living arrangements for first year students, etc. Some of these are quite successful, but I believe the real objective is to enhance the educational experience. Good graduation statistics will follow. Here are some programs that have been particularly effective.

Nothing creates enthusiasm for learning like participating in meaningful research projects. One of the most effective programs has been the Research Experience for Undergraduate supplements to National Science Foundation grants. We encourage all of our faculty members who have such grants to request REU funding and involve their good undergraduates in the work in their labs. The correlation between a student's involvement in research and satisfaction with their undergraduate experience is very strong.

Georgia Tech was a participant in the SUCCEED coalition, one of the National Science Foundation's Engineering Education Coalitions. Many SUCCEED initiatives contributed to the enhancement of engineering education at Tech. The institution of design courses in the first couple of years, a uniform assessment of the climate for engineering education across several schools, the design of better teaching evaluation instruments for students, and the initiation of a process for peer evaluation of teaching were all positive actions resulting from our participation in SUCCEED.

Following a particular instance of gender insensitivity in a widely attended seminar, the College of Engineering and the College of Sciences designed and ran a gender equity workshop for faculty. Based on much of the work of David and Myra Sadker, and drawing on similar workshops at Purdue University and Cornell University, the voluntary workshop was presented to a majority of the

faculty at Georgia Tech. The feedback from the participants was almost uniformly positive. Many commented that the workshop raised issues of which they were previously unaware and that it had significantly changed their style of teaching.

The most important tasks in enhancing the educational environment for all students involve a change in the culture and are consequently difficult and exceedingly slow. When we institute a new retention program, its focus is usually short term, and unfortunately so are its effects, no matter how meritorious they maybe. Below are some programs that have produced real cultural change.

Georgia Tech has two NSF Engineering Research Centers, one in electronic packaging and one in tissue engineering. Because of the NSF emphasis on the transfer of the research results to the curriculum, the centers have materially impacted the classroom experience of many students in science and engineering. Exposure to the results of a large, very relevant research program has obviously been beneficial to the enthusiasm and hence retention of a large number of students. Several have taken advantage of the opportunity to work in the centers' labs. In general, the presence of large active research programs has a very positive effect on undergraduate education that goes far beyond the obvious. Students know of the programs and take pride in them. The size of the programs encourages showcases collaboration among many disciplines.

In the 1998–99 school year, the College of Engineering undertook an extensive program to look at the climate for women undergraduates, women graduate students, and women faculty. The survey exposed several problems that were quickly fixed, and let to some longer term initiatives that will certainly enhance the climate for women. But the most important effect was raising the of awareness of women's issues in the whole community. The fact that an assessment was important to the administration of the College changed the culture in many ways. A similar effort for minority faculty is in process this year.

High profile efforts to recognize women and minority faculty have proven very beneficial in changing the climate. We are currently participating in the National Science Foundation's ADVANCE program to promote the success of women faculty, and a recent grant from the Roberto Goizueta Foundation has provided the means to recognize and offer supplementary support to our excellent Hispanic faculty.

Needs & Recommendations

There are no silver bullets in the recruitment and retention of good, technically talented students. We need to encourage new ideas and to try lots of experiments. We also need to attack the problem from all sides by encouraging pre-college initiatives for students and their teachers, enhancements of the university and college experience for undergraduate and graduate students, and an increase in the diversity of the academic faculties in science in engineering. To this end, I recommend the following.

Provide a mechanism for fast response to small experimental programs.

Facilitate the sharing of ideas amongst different constituencies by helping to sponsor conferences. The NSF engineering education coalitions provide a good model.

Provide increased opportunities for middle and high school science and math teachers to have meaningful industrial or research experiences. Most high school science teachers I know are competent in their discipline, but have never put their knowledge to use in practical applications. Some "real-world" experiences could give them a world of confidence in their abilities.

Allow some non-traditional groups to help with the problem. For example, it is difficult for a place such as Georgia Tech to compete for grants directed at high school curricular issues because we do not have a College of Education. But our experience with the magnet program in Rockdale County shows we do have something to offer.

Continue the strong support of science and engineering research in the colleges and universities. Such research is really the base on which all education rests.

Enact the "Tech Talent Act," H.R. 3130. This bill is very flexible and would allow the National Science Foundation to implement most of the recommendations listed above.

Conclusion

I believe the most important element of Georgia Tech's success in attracting good students, good faculty, and developing a diverse population is the clear intention to do so. From the President on down there is a clear and consistent message: we want the best students we can attract; the best students will be a diverse group; and we will do what it takes to accomplish our goal. In that environment, we are not afraid to try new ideas, and failure at some is just a learning experience. But then. . .we are scientists and engineers.

BIOGRAPHY FOR JAMES NARL DAVIDSON

Office of the Dean of Engineering, Georgia Institute of Technology, Atlanta, GA 30332–0360; (404) 894–3350

PRESENT POSITION:

Interim Dean, College of Engineering

EDUCATION:

Bachelor of Engineering Physics, Cornell University, 1963
M.S. in Nuclear Engineering, University of Michigan, 1964
Ph.D. in Nuclear Engineering, University of Michigan, 1969

EMPLOYMENT:

Georgia Institute of Technology:

1990–Present—Associate Dean, College of Engineering
1983–1990—Associate Professor and Associate Director, Mechanical Engineering
1973–1983—Associate Professor, Nuclear Engineering
1977–1985—Consultant, Tennessee Valley Authority, Power Operations Training Center
1977–1980—Consultant, Oakridge National Laboratory, Fusion Division
1975—Visiting Scientist, Argonne National Laboratory, Fusion Division
1971—Visiting Scientist, Gulf Energy & Environmental Systems, Fusion Group
1970–1973—Assistant Professor, Texas A&M University, Nuclear Engineering
1969–1970—AEC Postdoctoral Fellow, University of Michigan

PROFESSIONAL:

Member, American Society of Mechanical Engineers
Member, Society of Sigma Xi
Member, American Society for Engineering Education; Past Chairman, Nuclear Engineering Division

HONORS AND AWARDS:

American Nuclear Society's Mark Mills Award—1969
Student Engineering Council's Outstanding Teacher Award, Texas A&M University—1973
Outstanding Teacher Award, Georgia Tech—1977
Engineer of the Year in Education Award, Atlanta Section, ASME—1988

REPORTS AND PUBLICATIONS:

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Georgia Institute of Technology
College of Engineering
Office of the Dean

March 4, 2002

The Honorable Nick Smith
Chairman, Subcommittee on Research
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Smith:

Thank you for the invitation to testify before the U.S. House of Representatives Committee on Science, Subcommittee on Research, on March 7, 2002 for the hearing entitled *Meeting the Demands of the Knowledge Based Economy: Strengthening Undergraduate Science, Mathematics, and Engineering Education.* In accordance with the Rules Governing Testimony, this letter serves as formal notice that I personally have no Federal funding at the present time.

Sincerely,

J. Narl Davidson
Interim Dean

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A Unit of the University System of Georgia   An Equal Education and Employment Opportunity Institution

DISCUSSION

Chairman SMITH. Dr. Davidson and all, thank you very much. Without objection, the written testimony of Elaine Oakland, on behalf of the Counsel of Undergraduate Research, will become part of the official record, as well as Jeannie Narm, the Director of BCAL, is also going to submit testimony.

With that, I will start my five minutes. Let me start by getting your impression of the problems of taking away potential researchers that might otherwise go into the graduate work, the Master's and Doctoral programs, but the lure of business and industry to hire these individuals out with a Bachelor's degree, is that pretty serious? Especially, in engineering, my understanding is they are reaching in there with $40,000 to $60,000 salaries with a B.S. Is that a problem? And then the other part of the question, how about the hiring away of the real seed corn, and that is the professors? Give me your comments, starting with you, Dr. Wieman, and going across.

Dr. WIEMAN. I mean, I think these are issues, but frankly, I am not sure they are ones that anything like the National Science Foundation can solve. I mean, our country is based on free market system. Right? And so if they get hired away, then people have a freedom of choice. What the important issue is, to try and make students aware that there really are attractive alternatives with very interesting fulfilling things you can do. And I think that is where we fail. So we could get enormously more students who—or we could——

Chairman SMITH. Well, that is the market, but if we doubled the stipend or whatever for additional, then that loan obligation would look more feasible to stay in school maybe?

Dr. WIEMAN. Yes, that is true. I mean, if there was more support. But I think it is really showing there are attractive alternatives in the subject, which would help more, frankly. I mean, there are so many who just don't realize that there are reasonable careers in these fields.

Chairman SMITH. Dr. Howard, any comment?

Ms. HOWARD. No.

Chairman SMITH. Dr. Wubah?

Dr. WUBAH. What I would like to add to it is I think most students who end up going into the job market just after their baccalaureate degree do so for various reasons. We keep talking about the pipeline effect. I think we should be thinking about the pathway effect, because there are people who would go out of—that is after baccalaureate degree—go out to work for a couple of years, but would go back to graduate school. We should provide them with opportunities to be able to do that. That is something that we tend to forget. So that is something that this H.R. 3130 should provide so that those who go out and would like to come back to continue academics can do so.

With regards to losing the professorate to industry, I fully believe that teaching as a profession is a calling. And those who go into teaching, who for whatever reason leave the professorate, try to keep their hands in teaching by being part-time teachers some way. So I think we have to make it physically and something that

we can at least support these people. But those who are committed to teaching stay in teaching one way or the other.

Dr. JOHNSON. I would agree that losing well-trained science and math faculty and scientists is a major issue, and so I agree with that—big problem. Another problem is the fact that there are all those potential young folks out there that 10 years from now or 20 years from now, will never be scientists, or faculty, or teachers, because we don't have the programs in place right now to give them incentives to go into that.

Chairman SMITH. And so, Dr. Davidson, maybe include in your answer also taking talent, teaching talent, out of the classroom in terms of demands of a lot of universities to require research and writing from the professors so some of the greatest professors are spending a lot of time outside the classroom.

Dr. DAVIDSON. I think it is actually the other way around for us. We are very successful in attracting people out of industry to come into the university. So some of our most effective faculty members are people who we have taken from research labs at IBM, or Xerox, or wherever. So it works both ways and that doesn't seem to be a problem for us.

Chairman SMITH. How many of your institutions have some kind of a tracking program, what happens to these students? Part of our concern after—part of my concern after September 11 is where do we go on foreign students that have been a significant contribution to our graduate program and our research program. Do your institutions track what happens to your students that are graduating, either undergraduate or postdoctoral? I will start with you, Dr. Davidson.

Dr. DAVIDSON. That is a very difficult job. We try the best we can because we want some feedback for assessment purposes, and it is incredibly difficult to track them beyond a few years and except through alumni organizations.

Chairman SMITH. And so even in terms of does the universities know or should we have a better knowledge, and we should. How many of these graduate students go back home to their home countries that are coming in from foreign countries? Fifty years ago, most of them stayed in the Unites States because that is where the greatest rewards were. Now we see more going home, but we don't have exact——

Dr. DAVIDSON. We know what they do initially, and you are right, we do see more of them returning to their home countries where the economies can absorb them now where they couldn't before.

Chairman SMITH. But tracking, also, not just to the foreign students, Dr. Johnson?

Dr. JOHNSON. In the community college systems across the Nation, there is variance in the states and how they track. Some do better than others. Basically, we do have a good idea of how many transfer to senior institutions to continue their studies. Lots and lots of our students go right into industry, into jobs in the workforce, and continually come back to us. So we have a pretty good handle on that, also.

Chairman SMITH. Dr. Wubah, any comments?

Dr. WUBAH. Okay. Quickly, with regards to tracking, I think the alumni offices, they normally are charged with tracking students and what they do after they leave, so they are good at that. With regards to students going back, or foreign students getting their graduate degrees in the U.S. and going back, and I think two weeks ago, there was an article in Science that talked about the fact that European countries are making a concerted effort to recruit all the nationals who come here to get their Ph.D. back to those countries. So that is something that I think we should be mindful of, that we have to start encouraging people and growing our own scientists instead of relying on those who come from outside.

Chairman SMITH. Dr. Howard?

Ms. HOWARD. At Swathmore, we have the advantage that we are relatively small. We, actually, have a very good idea where out students go. Every five years we get certified by the American Chemical Society, our curriculum, and that includes a report where we have to say where all of our graduates have gone, and so we have this for the last 20 years. Every five years we have—we know what school they went to, what they did and everything, so it is easy for us to keep records.

Chairman SMITH. And so Diane, we are going to try to get a copy. I don't know how typical Swathmore is, but the tendency is to just briefly stay on toward additional education or industry or——

Ms. HOWARD. About 40 percent of our graduates go to—of our majors go to graduate school; about 20 to 30 percent go to med school, 10 to 15 percent do related careers, and about 10 percent decide science isn't for them.

Chairman SMITH. Dr. Wieman.

Dr. WIEMAN. Yes. So in physics, the community, actually, through the American Institute of Physics, tracks fairly carefully a lot of these statistics. Within our own institution, we do a reasonable job of tracking things. I mean, within physics, over half the graduate students now are foreign, and I think it is clear that the great majority of those stay in the U.S. after they graduate. So in some sense, that is a big group of—we are pulling in talent from all over the world. Other countries are getting more sensitive to this and, in fact, are setting up programs to try and lure these back, but so far it is a relatively small impact, but it could become larger in the future, because there clearly is an international battle shaping up to try and attract these people.

Chairman SMITH. Well, I need some follow-up, but Mr. Etheridge.

Mr. ETHERIDGE. Thank you, Mr. Chairman. Let me thank you for holding this hearing, because I think it is a very important one on the issues as we think about where we are headed in the 21st century, and let me thank these experts for their knowledge and expertise this morning on this very important topic. The engineering and technology fields are so critical to us.

I know that our hearing here this morning is on undergraduate education, but my experience, having been a state superintendent of schools before coming here, I can say with a certain level of confidence that a lack of preparation of science and mathematics of

many of our high school and middle school students at that level, clearly, plays a role in how many students we have available to us at the university level. And we haven't talked about this, this morning, but I am going to give you an opportunity in just a minute. Further, many of these students only take one or two courses. They are just not available to them so that they can move to the advanced levels of math and science. It has been my experience that, you know, if you don't take algebra, you don't get any other courses, and that tends to be the filter that keeps all of them out, or many out. In terms of courses offered and taken in high school, recent data shows that 1/3 of high school students did not offer any advanced courses in science and another 28 percent offered advance science only in one science subject, typically, biology. Graduate requirements tend to include far fewer advanced and core course offerings than most colleges and universities require as a minimum to get into college.

Now, granted, we need the undergraduates, the graduate level, and the Ph.D.'s, you know, but I think the true seed corn are all those students who are missing, that aren't showing up at the door, the minorities, the women, etcetera, because about half of our population falls in that category. Less than half of the U.S. schools require three years of math and just one-quarter of high schools require three years of science. Minorities tend to have less access to advance science and math courses. I think we have got to do a much better job. If we don't, then the number of undergraduate students available at the university level and the community college level are going to continue to be woefully inadequate for our 21st century economy that is going to require the very thing we are talking about today, we want them to be involved and have knowledge of math and science, in the jobs that are available. The Chairman mentioned the military. Well, that is just one little area. What about all of our economy that is tied to technology and all this research shows that well prepared students in science and mathematics and academically competent students are more likely than other students to persist in their choices of college science majors. So if you have had a higher level of courses, you are more likely to choose that opportunity when you get to college.

Having said that, in terms of the policy and practice of instruction, curriculum, and student support, what type of reforms or modifications do your undergraduate programs undergo that would be able to connect science, mathematics, engineering, and technology with the students at the high school, and more importantly, the middle school level, because if you don't get them in middle school, you are not likely to get them in high school either because, you know, that would help them, in my opinion, make those informed decisions to pursue a career in science or a science related field. And Dr. Davidson, let us start on the reverse side this time with you at Georgia Tech.

Dr. DAVIDSON. Well, I agree with you, Mr. Etheridge, as to that. Getting to students in, particularly, middle school is critical. And we do have some programs. As I mentioned, we have some programs that work directly in high schools with students. We also have some programs that work with teachers. As I said, the GIFT program that we have in Georgia, I think is a model. We have real-

ly effected the enthusiasm and confidence to teach technical subjects of a lot of teachers in Georgia. I think it is a broader issue, however, than just technical talent. We live in a world in which technology is pervasive, and it is more than just providing talented technicians. It is really teaching everybody some basic science, and technology, and mathematics.

Dr. JOHNSON. I think, looking at Sinclair, and before I even say anything about Sinclair and what we are doing, I would say Central Piedmont in Charlotte has got many, many good models to look at as far as the seamless web reaching out into all segments of education.

We have a program at Sinclair called the Young Scholars Program that starts in the 8th grade. It starts with the 8th graders and it is a 5-year program. It is an academic enrichment program, largely minority students, serving hundreds of students. The success of that program is unbelievable. It is locally funded and it is funded with private contributions. If a program like Young Scholars, which is a proven successful program to increase this seamless web, could be proliferated, to be increased and proliferated, there you go. I mean, there is an example of, instead of hundreds, we would have hundreds of thousands perhaps.

Dr. WUBAH. The newer of these programs that at JMU we take advantage of, the first one is the research experiences for teachers, which is a program that supplements the research experiences for undergraduates. We have teachers from the high school come to James Madison in the summer in our chemistry program and they do actual research. And we have extended it to where we require them to come with their students, so they come as a group and they work with undergraduate students. That is one method that we use. In addition to that, there are some private foundations that support working with high schools from the university level so the GTE Foundation, for example, we have funding from them to work with high school students during the summer. So our program is like that. We have students all the way from high school through the graduate level, so we approved it for that full gamut.

Ms. HOWARD. We have one program at Swathmore that involves outreach to high schools. Every summer we get money from HHMI to support summer stipends for our college students, but as a stipulation of getting the money, we must have an outreach program to local high schools as well. So every summer we have several high school students and several high school science teachers coming in to work with Swathmore faculty.

Dr. WIEMAN. So I mean, I would completely agree with you that the K–12 education issue is enormously critical, but I would point out that one of the major problems in this is the science and mathematics background of those teachers, and that is one that I think needs a lot of attention. Large education departments have largely become completely separated from the mathematical and science disciplines, and so these teachers who are going to go out to teach math and science can learn virtually nothing about it, and when they do take science courses, they are very poorly taught. They have—you know, at the undergraduate level. So I think that one needs to look at both sides of this issue. You have got to prepare those teachers better to deal with the issues better.

Let me just make one other point on this, and that is that this economic issue, I see that happening much more at the K–12 level. Students who are good in math and science can earn so much more by going off to work in a company that you lose a lot of potential K–12 teachers that route, just because of economics.

Mr. ETHERIDGE. Sure. Thank you. Thank you, Mr. Chairman.

Chairman SMITH. Mr. Baca.

Mr. BACA. Thank you very much, Mr. Chairman. First of all, I want to commend you for having this hearing, as others have indicated. I think it is a very important topic in an area as we look at where we are going to be in the future and, also, the ability to recruit students in the science, math, and engineering, and technology. But at the same time, I am also very disappointed in one sense, Mr. Chairman, that when I look at the panelists, that I don't see a Hispanic panelist or a doctor in that panelist. If we look at the diversity of our country and where we are at, and the idea is to recruit individuals, and when you look at individuals, they also become the role models for a lot of us. So from that perspective, hopefully, in the future, that we can think of possibly bringing in Hispanics as well to participate as part of our panelists.

From that perspective, I do agree that part of the problem that lies ahead of us as we look at recruitment, also, we need to have qualified teachers. And that is very important, because if you don't have the qualified teachers at each and everyone of our institutions, it becomes very difficult. It doesn't matter whether it is in physics, chemistry, algebra, math, whatever the case may be, unless we have the qualified teachers.

Second of all, I believe that we have also got to have funded programs, because what is the cost of a program in comparison to nontraditional costs as well, that we have got to assess. Does it cost us more then to provide assistance to someone in chemistry, in math, in engineering versus some other curriculum in our K through 12? I think we need to assess that, because sometimes I think the administrators end up taking programs and, yet, these are the programs that we have to look at in terms of our future, but we are not investing there. And what is it that we are doing in terms of recruiting the diversity of the different students? And I say diversity, that means inclusive of everybody, in getting students to get into science, math, engineering, and technology.

I don't know what kind of outreach or programs that we have. I have heard some of those that you have had right here. I have read the testimony. I even heard about the MESA program that I think is an effective program in a lot of our areas. Nobody has mentioned that, too, as well. We are not all from back east, you now. Some of us are from the west side and we have effective programs in recruiting minorities and others, and looking at some of those programs that are very effective.

But I also believe that we have got to offer the kind of curriculum, and when you look at reform, the reform needs to start at our K through 12, and unless there is a program that are structured, because most of our students who are going there, which becomes very difficult when you are going to a public school, is that we don't offer the curriculum. Then how, in fact, then can they transfer to a state college or university and meet those kind of re-

quirements when we are not even offering them at schools. So it becomes difficult. So what do you do with those students who want to get into science, math, and engineering, but it is not offered at that public school? So we need a change to make sure that there is the requirement for students who are going to our public schools that they have an opportunity to take the kind of curriculum that would allow them to transfer to a state college or university.

My daughter is in an honor program and thank God that they have to offer it, but I had to go to I don't know how many schools to make sure that she could take the right kind of curriculum so she can transfer to a 4-year institution. And that is why the success of an individual being successful or failure is low, because we don't offer that kind of curriculum that will allow those students to be successful when they go to a state college or university and are taking the courses. So we need to make sure that we do offer those at our K through 12, and I think that is the kind of reform that I think I heard some of you talk about at the very beginning because we normally go on the tradition, and people don't want change, and I think we have got to change. We have got to change the traditions and offer the kind of curriculum.

So what is it that you feel that we need to do if we are really looking at a structure and really get students into science, math, technology—what it is it that we really need to do and what changes really need to be said, not a generic. What is it that we really need to do, and I am going to ask all of you, I mean, just a simple question, what is it that we really need to do? What changes do we need to make in the way our public schools are run right now? What is it in terms of how do we change the kind of reform that needs to be done to allow students to make sure that he or she takes the kind of curriculum that will allow us to meet our demands for the future? Because do you know what, we just can't wait for that one special gifted student. We have got to motivate students. We have got to give them the self esteem. And what is it that we as teachers, as parents, and the community are doing to enhance this endeavor? I will throw it to anyone of you or all of you.

Chairman SMITH. I think we have to start with Dr. Wieman.

Dr. WIEMAN. Put me on the spot. To try and give you very specific things, I mean, you know, these are gigantic broad issues, and I think you have to tackle them at a very broad level. You can't change K–12 unless you change the undergraduate preparation of the teachers that are going to K through 12 at the same time.

Mr. BACA. But if we need to change the K through 12 in terms of the curriculum that they develop, then that is the step that we have to, because remember, we have made it softer for success, and then we have the accountability, we have the standards. I mean, we put other divisions in that teachers now or the administrators change the whole curriculum because the whole idea is to have students succeed. So this way they get their funding and, also, teachers are retained. And that is the problem that we have is that you have good teachers, yet, a lot of these teachers are afraid at one point or another to have a failure system because we have the accountability, the standards that are there. So if we have to go back

and change it, we need to, but we shouldn't punish the institutions as well for trying.

Dr. WIEMAN. Yes. I certainly don't disagree with that.

Chairman SMITH. We both supported the Math-Science Partnership Program that we passed out of the House that tries to get pretty much exactly at least part of that problem. Dr. Howard, did you have any——

Ms. HOWARD. I think—well, the key to attracting people is to have well-trained scientists teaching high school and having people that are enthusiastic. And like, I mean, it seems it is obvious, but it is true. I mean, I think why I became a scientist was that I was well-trained in high school. I just went to a typical public school in a suburb and had teachers who were excited and taught well and it turned me onto science.

Mr. BACA. Did you have a curriculum to take at that time to gear you toward it?

Ms. HOWARD. Yes.

Mr. BACA. See, that is what the difference is. Other schools may not have that. You were lucky at where you were at, and so we have to measure our population in everyone of our schools. Now, if every school has the same opportunity, someone in the barrio, someone in the ghetto, someone somewhere else has the same curriculum that is offered there. This isn't about the schools in Hollywood or Beverly Hills. I am talking about in San Bernardino, you know. Do they have the same kind of curriculum, the same opportunities, and that makes a big difference, and that is what you had.

Chairman SMITH. And just let me comment. I think I agree with you that it is tremendously crucial to any success. We sort of geared this hearing to say, specifically, try to look at the community college/college level. Is there something we can do in that arena, but there is no question, I think we all agree, if you don't have that stock going into that community, that—Dr. Wubah, do you have a comment?

Dr. WUBAH. Yeah. I think once again I will go back on the pathway effect. It is not a pipeline. The pipeline is where someone gets out of it and comes back into it. If we look at the pathway, what we have here is an institution in which—in the comprehensive universities, those that tend to be in the urban areas or even remote, the colleges of education are not separate from the disciplines. For example, at JMU we just created a new college of education. We didn't have one. And we have a content and pedagogy academy, so you have the proof from the discipline working with the people who deliver the course. The teacher preparation is an integral part of what we do. In almost every state, one can identify the universities that produce the most teachers for K through 12. Those are the schools that at the moment I think we should start paying attention to. If those schools would produce the best teachers, then we would get students coming to college who are prepared, and that is something that I think is very, very important in this day and age.

In addition to that, organizations such as BCAL have programs that CARE have programs that we basically call the best practices. And some of these best practices are models that can be used in almost every institution. In those organizations, we have schools

from the suburbs, we have schools from downtown, and those schools have models that can be used, so we can work with those organizations for them to provide us with models that can be spread throughout the Nation.

Chairman SMITH. Dr. Johnson.

Dr. JOHNSON. I have two words, fun and fragments. First of all, fun. I really believe that we have the capability of making science and mathematics education fun for our students and engaging, but we don't do it except in special programs that students really love and they really get engaged in, but it needs to be fun and engaging. And I think that is a key word, I really do. I think it is a key word. The second one, fragments. Our system, our K through 12 system, is fragmented from our large community college system in many respects, which is fragmented from the senior institutions. I mean, there are so many disconnects. I don't have an answer, but I certainly can define the problem as a problem of fun and disconnects.

Dr. DAVIDSON. If we knew the answer, we would have done it. Right? So I think that one of the things we need to do is try lots of ideas. We need to be real flexible. I would also say, and I am speaking out of my expertise, so I will talk louder, I guess. That one of the things in high schools that we need to do is we all recognize good teaching counts, and I think we have to reward good teaching, and I fear that that does not really happen in K through 12.

Chairman SMITH. Let me—back to the student that comes in from the high school that is interested in math and science that starts out, how many of those people are we losing that first or second year? Dr. Wieman.

Dr. WIEMAN. So there have actually been studies on this, one fairly major study, and we lose an enormous fraction.

Chairman SMITH. So make part of the answer what do we do about it.

Dr. WIEMAN. Anyway, I will just we lose far more than other disciplines do, and I think it is clearly the issue of the way our undergraduate science and math courses are taught, and they aren't taught to keep all those students. They are taught, in large part, to develop to winnow out a few special ones. And so we have to have clear incentives to our institution to think about restructuring those by-and-large large introductory courses to really provide clear incentives to keeping and building, bringing in more students, not dropping them off along the way.

Chairman SMITH. So the fun is probably less, but should we still make it fun that first year in college?

Dr. WIEMAN. Absolutely.

Chairman SMITH. This is the expand to Dr. Howard and everybody else responding to this one. This is reading month, so I go around to the elementary schools and read Dr. Seuss and say, look, reading is important. That is the equalizer is education, etcetera. The new program that a lot of schools are doing is sort of a one-on-one where they see a weakness, an at risk child in kindergarten or 1st grade, then they try to do a one-on-one to bring that individual up so that they aren't progressively worse off. Do we do anything like that in colleges? Do we look at some of those people that

might be overwhelmed, depending on what high school they came to and what college they came to, to reach out and try to say, look, let us try to bring you along and help you catch up? Because the tendency, of course, is boy, if you don't want to study, go someplace else. Dr. Howard.

Ms. HOWARD. Yes. We try to do that at Swathmore, so we start, our first course in the chemistry curriculum has about 120 students in it and we end up with about 15 to 20 majors at the end. That sounds worse than it is because a lot of people take first year chemistry because they want to be a bio major or an engineer and it is a requirement for many things. But we feel that we are losing majors that perhaps are overwhelmed in that first course. So what we have decided to do is instead of making our—typically, the big classes are the beginning ones. You start with a big lecture and then you get smaller as you go upward. So we decided to switch that and we are going to change our first year general chemistry class to be seminar style with no more than 12 students. And the idea is when you have a small class, it is hard for students to fall through the cracks. It is much more obvious who is struggling and to get more attention. So it is a problem in our curriculum because we are taking faculty out of the upper level courses, but we have decided that it is worth the risk to try to encourage those few people that seem to be sliding out.

Chairman SMITH. Dr. Johnson. Especially in math and science, you get a little bit behind and it is so easy to get overwhelmed is my experience.

Dr. JOHNSON. Chairman Smith, what you just described, the support systems, the intervention systems, you have just described American Community College and you have also described the private liberal arts colleges that are focused on teaching and learning. That is a description of those. What you are not describing, probably, are the large research institutions.

Dr. WUBAH. But in addition to that, the comprehensive institutions also face immediate challenge because we have a faculty-student ratio that goes all the way from 15 to 1, to 20 to 1, so you have a department with about 500 class majors and maybe 20 faculty members. It becomes an immediate problem when it comes to advising these students. These support structures, normally, on the comprehensive campus can't be easily provided because we don't have the manpower to do it. One way that, currently, some schools are trying to do, and at James Madison we have tried this, is, basically, to have group advising, group mentoring, where we have peer mentoring in addition to faculty mentoring the students. This is very, very important because the faculty to student ratio which one needs to be able to carry out what Dr. Howard just said is virtually impossible on the comprehensive campus. And on these campuses, you have more students who may be the B/C students who normally just need a slight push to become an A student. They tend to fall through the cracks. Students at places like Swathmore are already motivated, they are A students. But we are losing a large number of students who are at the cusp of B/C and those are the ones that we really need to focus on if we want to get more people in science and mathematics.

Chairman SMITH. Dr. Davidson, did you have a comment? Give me a guess what percentage drop out in the first two years that start math and science and then—do you think $\frac{1}{3}$ of them?

Dr. WIEMAN. Eighty percent.

Chairman SMITH. Eighty percent decide to switch their majors to political science or some other endeavor that looks easier?

Dr. WIEMAN. That is from physical science.

Dr. DAVIDSON. That is not true at Tech. We do lose—I think everybody has pretty much the same experience as far as retention. You lose about half, again, every year as you had in the first year, as far as leaving a university.

Chairman SMITH. But math and science as opposed to other disciplines.

Dr. DAVIDSON. Well, our experience, of course, is that people who come to Georgia Tech come because they are interested in technical education, so we lose a lot less than——

Chairman SMITH. Thank you. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. I apologize for missing a lot of the testimony, but I sense that there was a lot of conversation on how to recruit and retain students in the math and science through the programs you are suggesting. And I guess the question I have is the instructional team that you are suggesting—you mentioned you reversed the class size, which I think is a good idea. Is there a lot of attention paid to the professors and teaching them how to teach, because I think the assumption is that because they are professors, that they know how to teach. That is number one.

Number two, if you are looking at students that are coming in first and second year, the barriers that they face are varied. Some are well prepared, others aren't. And in retention, it is about holding their interest, by about achieving well maybe the first year. I graduated with a biological science major. The first four semesters I was on academic probation. And what I found out, just upon reflection, was the sense of being important, the sense of being there, and that, you know, my presence was important to the professor and to the system, because a lot of times the institution is larger than anyone has ever experienced. So adjusting the orientation is probably very keen, and because of one professor, Dr. Charles Smith, who taught biology, he mentioned my name on campus in daylight, and all of a sudden, I felt part of that campus again. And it is about understanding what our role is as professors with those students. And then the role of the students, understanding what their strengths and witnesses are and being able to grow in that, to become competent and successful in the area of science, and get in touch with this so they can go back to the K–12 and teach as they are going to. Are there ways that you can sort of incorporate people's own experiences, improving the teaching staff, and then looking at creative ways of moving class sizes, which I think is great? Is there any response to that?

Dr. JOHNSON. At Sinclair Community College, we have a new initiative to address the question can professors teach or do they know about teaching just by virtue of the fact that they have an advanced degree in a field or discipline. The answer is, of course no. They don't come with, necessarily, an innate ability. So we are moving to implement a project we call LENS that deals with how

to teach, how to manage a classroom, how to assess learning at two or three different levels. And so it is something that we are consciously working on and consciously doing.

Dr. WUBAH. With regards to preparing faculty to teach, there are programs out that—Preparing Future Faculty, for example, which is, basically, designed to train those who are going to the academy. But in addition to that, there are programs that are designed on certain campuses to prepare teaching assistants before the output in the classroom. For example, at James Madison, we have a small Master's program in biology. And when we have a first year graduate student, we don't let them go to the class to teach unless they take two classes in how to teach. So in their first two semesters they have to take a class in teaching. Then in the second year we leave them in the classroom to be the teachers. And that is something that the graduate schools might consider. We put it into our program because we were concerned about the ability of someone who had just graduated with a baccalaureate teaching another student. So I think that definitely will help if there are programs that will help these students, those who are in the graduate school, learn how to teach before they become teachers.

Dr. DAVIDSON. We certainly have intervention programs, and I think most people do to deal with people who are struggling teaching. But I would say that my experience is that the people who come to teach in colleges and universities are all there because they enjoy interaction with young people and that they really care about being teachers. They care about being good teachers. The last three out of the last four semesters, I have sat in informal discussions looking at teaching techs, how to teach engineering, what are methods to use, discussing different methods, that were informally arranged by people who teach, in one case, thermodynamics, which I teach, and so I think there is a real commitment on the part of the faculty to make themselves better teachers.

Mr. HONDA. Mr. Chair, if I may? I understand that folks who are in the institution of instruction like people, but that doesn't mean that you are skillful in teaching concepts or teaching content, and each one requires different kinds of approaches besides just monitoring. It is an acquired skill. I am not talking about their characteristics of why they are there. It is about skills building in the instructional staff.

Dr. DAVIDSON. I agree with you, but I think that—my point is that my experience is that faculty realize that they need more skills, they need to develop their skills in teaching, and they actually work at that.

Mr. HONDA. Okay. It is just the difference between a planned approach versus serendipity. Thank you.

Chairman SMITH. Mr. Akin.

Mr. AKIN. I survived thermodynamics, though.

Chairman SMITH. Well, certainly, part of it has got to be somebody that is a little motivational and my impression is that once you get to the college, or university, or community college level, that quite often you have an expert that might be a qualified scientist, or biologist, or chemist, but they are not a teacher. Because traditionally, we have thought, you know, we teach in K through

12, and after that, here is the information. If you want to learn it, fine. Dr. Wieman.

Dr. WIEMAN. Yes. I mean, I would actually disagree with that. I think that throughout the large research universities teaching, especially, in mathematics and science disciplines, has taken on a much larger role, much larger importance. There is still a very unclear issue as to what you are learning to teach and what the function of that is. And so that is where there is a considerable problem, frankly. And I would also sort of add that on this level, both of you have mentioned this kind of personal individual faculty-student contact. It is clear that that is enormously important, and I have done a lot of work in physics, seeing how profoundly that influences students. But you have got to turn around and look at the fact that, you know, at a place like University of Michigan or University of Colorado, if you are going to provide the opportunities for that, that you have at a school like Swathmore, you are going to have to spend two or three times as much money on those institutions. It just—I think you have got to find new ways and maybe that is one thing the NSF cold look at, new ways to have that kind of impact in a sort of cost efficient way, because you can't afford to just triple the number of faculty, which is the easy way.

Chairman SMITH. You wanted to comment on that, Dr. Johnson?

Dr. JOHNSON. I sure do. Thank you. At least in undergraduate education, I disagree just a little bit with Dr. Wieman. Obviously, in graduate and upper division, that is true. But community colleges have proven that for less than half the cost of, what the cost of a public university, they can provide teaching and learning and learner oriented education. So the cost does not have to double and triple. We have proven that you can reduce the cost by half, at least at the freshman and sophomore level, and also in the development level.

Chairman SMITH. Let me ask you a question. How about your individual disciplines, the science and math, interacting with the schools of education where you have them in terms of ideas and suggestions of turning out better teachers that are going back into the K through 12 system with some of the feelings, or attitudes, or enthusiasm for the more technical science—do you interact with the departments of education? Is there interaction?

Dr. WUBAH. Yes. As I mentioned earlier, at James Madison we just created the college of education, and as part of the structure of that college, we are going to have faculty from the content based areas, from the science and mathematics, liberal arts, being part of this structure of the college of education. So in this case, we are going to work with them not only in the pedagogy, that is teaching them the skills and how to teach by the content that needs to be taught. So students would have to be able to meet that, but there are some impediments in doing so. For example, in chemistry, currently, students who want to be chemistry teachers, that is K through 12, would have to be a scholar major in chemistry and education. So this keeps, you know—there are students who would like to do that, but they would prevent—you know, they will avoid doing that. So those are issues, they are systemic issues, that need to be addressed, and this involves talking between the different disciplines and seeing the teachers as part of who prepared the raw

materials that does affect the discipline that we will be using, that we will be working with. And that I don't think currently exists on most campuses. But we are fortunate to have it because we are—in our administration, we are basically breaking boundaries. So we don't have infrastructures where departments exist. We have a fluid system and that is one thing that is needed in the emerging number of colleges and universities.

Chairman SMITH. Mr. Honda, did you have any additional questions?

Mr. HONDA. No. I think that is a very critical arena, where the very pedagogy and instruction needs to look at themselves and say, as a vice principal of a middle school, you know, they have a lot of problems. And one of these we found was that it was so compartmentalized that the total learning experience was lost just because the instructional areas that they were concerned about. And to yourself, Dr. Wieman, yes, I think there is a distinction between graduate and postgraduate work versus community college in the first couple years of general education, where the integration of career decisions and instruction become a critical part of our—what we do.

I stuck with biology because political science had small letters, and the books were too thick, and there were no visuals in there, and biology had more visuals, and I found out I was a multi-faceted learner, but that is after it is all done. So Mr. Chair, thank you very much.

Chairman SMITH. Well, we will let you go. Again, thank you all very much. But what I would like to do is maybe each, in about one minute, anything else that you suggest—we used to have the Young Scholar Program at NSF where we brought in people from high schools into the research area. Is there any other things that you think Congress should be thinking of, looking at, in terms of improving our efforts in science and math education? And let us start from the middle, Dr. Wubah.

Dr. WUBAH. Okay. In sum, what I would say is the NSF should put emphasis on programs that require or involve mentorship, and this mentorship should not be only between the faculty and the student body, with peer mentorship, and this, in most cases, should be linked to K through 12. So such programs are very important, and we shouldn't be thinking of pipeline, but pathway. That is something that currently—the current system is built for pipeline. Once you get out of it, it is very difficult to come back into it. And if NSF can think that way, the pathway, and provide opportunities for people to come back once they leave the system, that will help.

Chairman SMITH. Dr. Johnson. We have got about $4 billion here and another $16 billion over in education so——

Dr. JOHNSON. We will take it. Thank you. Sir, if you want to go to where the undergraduates are, especially, in their first couple of years of college where it is very, very critical, America's community colleges need and deserve better equipment. They need and deserve your attention. They need and deserve a voice and your consideration. If you want to go where women are beginning college, where minorities are beginning college, then you would look to America's community colleges. I really appreciate the time. Thank you.

Chairman SMITH. Dr. Howard.

Ms. HOWARD. Well, undergraduate institutions have been pretty successful at generating Ph.D.'s, and I think anything that NSF can do to support our ability to do good undergraduate research by providing instrumentation, and faculty support, and student support would be very fruitful.

Chairman SMITH. By instrumentation, do you mean equipment, facilities?

Ms. HOWARD. Yes, because in order to have a lab intensive and research intensive curriculum, we need equipment that is not just, you know, a demonstration, but something that we can do real work on it and create high quality results.

Chairman SMITH. Dr. Davidson.

Dr. DAVIDSON. My experience with NSF is that they are pretty sensitive to getting these issues in their research budgets. The REU, for example, in support with their research experience for undergraduates and normal grants. Like I said, the centers push taking that information and putting into the classroom, and I think they are sensitive. I would just encourage that those programs be grown. The REU program is a wonderful program and I would encourage that that receive more money.

The other thing is just basic research, doing basic research. We rely on the NSF, and that basic research involves a whole community, undergraduates as well. It is very effective in drawing people into science and technology.

Chairman SMITH. We are looking at expanding as best we can not only the stipends and the grant level but, also, where we can, expanding it to three years. Dr. Wieman.

Dr. WIEMAN. I would say, you know, looking for opportunities where one can really provide clear incentives for—again, I am speaking for large research universities—at the department level, where departments really define the educational programs. Looking for incentives that can be provided to one, dramatically improving the education and with particular emphasis on making it much broader, much more inclusive. I think that is what I would say have the most direct impact.

Chairman SMITH. Again, thank you all very much. The record will remain open for the next five working days in case staff would like to ask you a particular question, if you would be so considerate to respond in writing. And with that, this Committee is adjourned.

[Whereupon, at 12:20 p.m., the Subcommittee was adjourned.]

Appendix 1:

Additional Material for the Record

Undergraduate science education reforms at public comprehensive universities: a model

Daniel A. Wubah

James Madison University

Types of higher ed institutions

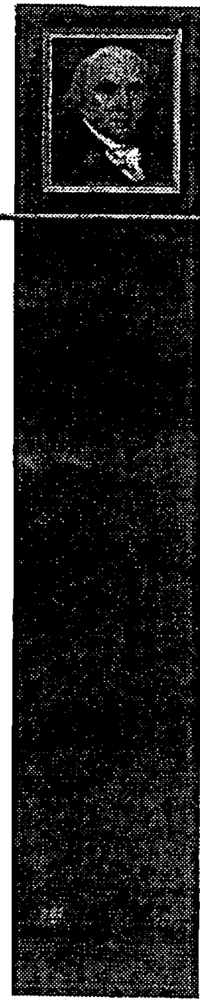
- Research intensive universities
- Doctoral universities
- Public comprehensive universities
- Baccalaureate institutions and private liberal arts colleges
- Community colleges

Types of comprehensive universities

- Large urban universities
- Small urban universities
- Non-urban universities

Groups of students at urban universities/colleges

- First generation students
- Non-traditional students
- Disadvantaged students
- Immigrants



Quick facts about Towson University

- Largest comprehensive university in the Baltimore area
- **Total enrollment:** 16,647
- **Undergraduate enrollment:**
  - full-time 11,536
  - part-time 2,445
- **Graduate enrollment:** 2,666
- **Faculty:**
  - full-time 521
  - part-time 619

Quick facts about Towson University

- **DEGREE PROGRAMS:**

  57 undergraduate majors

  29 graduate programs

  2 doctorate programs

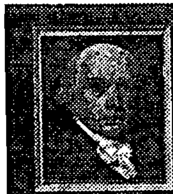
- **FINANCIAL AID RECIPIENTS:**

  8,796 undergraduate

  788 graduate

Research initiative at Towson

- NSF Research Experiences for Undergraduates
- USM Minority Program
- Undergraduate Mentoring in Environmental Biology
- Instruction and Laboratory Improvement Grant



Summer undergraduate research activities

- <u>Group Meetings</u> : To foster cooperative learning and to encourage group problem solving and communication
- <u>Research Seminars</u> : By invited speakers to broaden the participants exposure to the biomedical sciences.
- <u>Field Trips</u> : To local research institutions to expose participants to a range of research venues.
- <u>Workshops</u> : In ethics, scientific writing and the graduate school application process.

Scientific writing

- Locating, acquiring, evaluating, selecting, and documenting information from existing databases and personal interviews on the research topic of their choice.
- Reading and writing abstracts and titles with appropriate descriptors.
- Designing valid and reliable experiments, conducting pilots and controlling variables

Workshop in ethics

- Students are taught how to analyze an ethical dilemma and construct a well-reasoned argument.

<u>Topics covered include:</u>

- Data fabrication and falsification
- Authorship, attribution, and plagiarism
- Uses of human and animal subjects
- Reporting suspicions of misconduct

Applying to graduate and professional schools

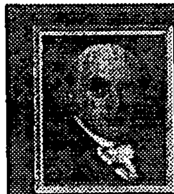
- A detailed discussion of the Graduate Record Exam, the funding mechanisms for graduate study, and the application process
- Completing graduate/professional school applications and the interview process

Program outcomes

- End of program oral and poster presentations
- Regional meetings e.g. UMBC Undergraduate Research Symposium
- National Conference for Undergraduate Research
- Professional meetings e.g. FASEB, ASM
- Posters on the Hill

Where do you see yourself in 5 years?

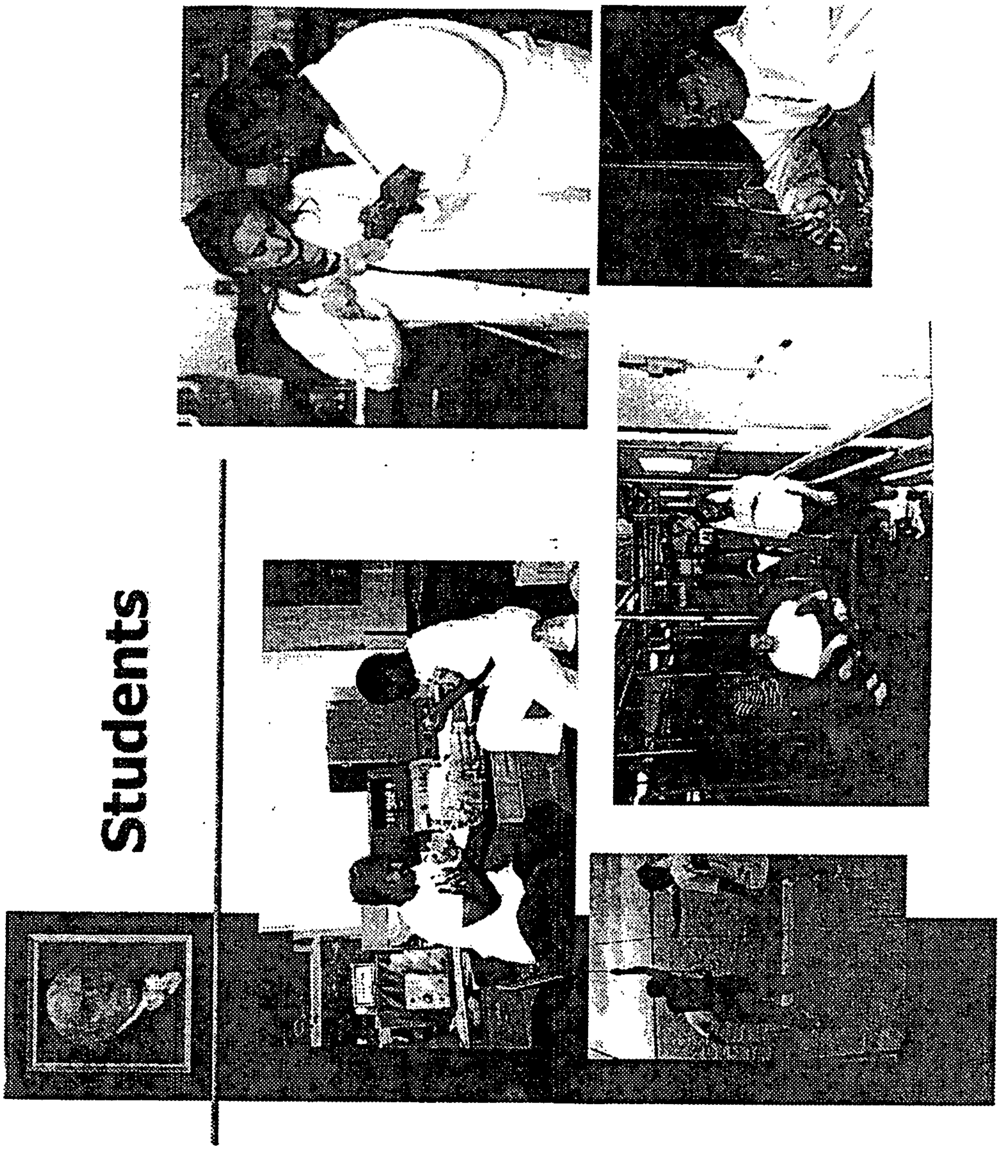
Item	Before	After
Ph.D. program	20%	55%
Medical/Vet school	33%	33%
Teacher	20%	12%
Don't know	27%	0%



Projects

- Development of DNA extraction methods in fungi
- Characterization and classification of the first Spiroplasma isolated from a biting midge (*Forcipomyia glauca*) using serological and molecular techniques.
- Angiotensin II (ANG II) induced constriction of rat outer medullary descending vasa recta (OMDVR) is partially Thromboxane (TXA2) receptor dependent.
- The development of a molecular technique to determine the sex of tree swallows (*Tachycineta bicolor*) a monomorphic species.
- Effects of antibiotics on fiber degradation by rumen fungi.

Students

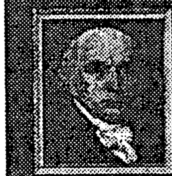


JMU demographics

Undergraduate	15,150
– Graduate	850
– Male	42%
– Female	58%
– In-State	71%
– Out-of-State	29%
– Minority	11%
– International	4%

JMU demographics

- Instructional Faculty
  - Full-time 661
  - Part-time 235
- Number of Programs
  - Bachelor 47
  - Master's 26
  - Ed.S. 2
  - Doctorate 2
- Total Operating Budget 2000-01
  - $211.1 million



Characteristics of JMU

- A Learning Culture of Academic Excellence
- A Residential, Comprehensive and Student-Centered Environment
- A Connected and Diverse Campus Community
- Outstanding, Involved Students Who Are Preparing for the Future
- Faculty, Staff, and Administrators Who Are Leaders and Mentors

"Research for all"

- Research Experience for Undergraduates in Biology, Chemistry, Materials Science and Mathematics
- Undergraduate Mentoring in Environmental Biology
- NIH Bridges to the baccalaureate
- Private foundations e.g. GTE program
- Over 200 students and faculty participate in summer research activities

Program impacts

- Wider array of programs
- Emphasis on mentoring
- Easy accessibility to K12 students and teachers

Steps we are currently taking

- Commonly understood and accepted initiatives with responsibilities shared across departments
- Highly targeted programs
- Engineering a cultural change in learning
- Redefining our funding base
- Establishing formal relationships with business, government, and other academic institutions

Emerging philosophies

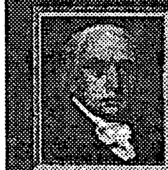
- Overlapping Jurisdictions
- Cross Disciplinary
- Focusing on Areas of Strength
- Teaming with Private Sector
- Accountability - Assessment in Curriculum Development

Ongoing concerns

- Quality of entering students
- Use of technology in instruction
- Undergraduate research
- Faculty rewards
- Enhancing diversity
- New facilities/renovation – focus on learning
- Providing a challenging yet supportive and nurturing learning environment

The New American University

- Focus on function and not structure
- Collaboration and communication
- Facilitation
- Accountability and assessment
- Permeable boundaries
- Programs, not departments
- Performance and evaluation



Funding reforms

- Targeted programs to comprehensive institutions
- More emphasis on mentoring students
- Longer terms
- Assessment efforts
- The "pathway" effect

Reform premises

- Takes a long time
- About people, not process or policies
- Intra- and inter-institutional collaborations
- Teachers are central
- Must focus on learning needs
- Positive conditions must be established

PREPARED STATEMENT OF DR. K. ELAINE HOAGLAND

Federal Support of Undergraduate Education in Science and Technology: Using the Undergraduate Research Model

BY DR. K. ELAINE HOAGLAND, NATIONAL EXECUTIVE OFFICER

On behalf of The Council on Undergraduate Research, 734 15th St., NW, Suite 550, Washington, DC 20005; www.cur.org

The Council on Undergraduate Research (CUR) and its affiliated colleges, universities, corporate members, and individuals in nearly every state in the union share a focus on providing undergraduate research opportunities for faculty and students, especially those at predominantly undergraduate institutions. The mission of the Council on Undergraduate Research is to support and promote high-quality undergraduate student-faculty collaborative research and scholarship. CUR believes that faculty members enhance their teaching and contribution to society by remaining active in research and by involving undergraduates in research. CUR's leadership works with agencies and foundations to enhance research opportunities for faculty and students. Our publications and outreach activities are designed to share successful models and strategies for establishing and institutionalizing undergraduate research and related programs. We assist administrators and faculty members in improving and assessing the research environment at their institutions. CUR also provides information on the importance of undergraduate research to policy-makers including college trustees and public officials.

The Council on Undergraduate Research appreciates the opportunity provided by the Subcommittee to participation in the national dialogue concerning undergraduate education in science, technology, engineering, and mathematics.

The U.S. science, engineering, and technology enterprise enjoys a premier place in the world because of the close relationship between education, research, and entrepreneurship. The keys to our system's strength include DIVERSITY in the kinds of institutions (public and private) that deliver education; DIVERSITY in the approaches to science education in our 50 states; DEDICATION of many fine scientists and educators; and INTEGRATION of research and education at the college level. Federal support for research and science education is a major element in our success. In recent years, federal programs have been initiated that seek to reinvigorate K–12 education, including the President's Math-Science Partnerships and National Science Foundation programs that use the talents and enthusiasm of university scientists and graduate students in the classroom and in teacher training. NSF hopes to increase the size of graduate fellowships in its 2003 budget, and efforts are underway to improve the teaching skills of the next generation of college professors through Preparing Future Faculty, funded by a combination of federal and private dollars.

Now that programs are underway for K–12 and graduate students, **the Congressional agenda for 2002–2003 rightly focuses on the undergraduate level of science and technology education.** This is often the choke point in the science pipeline. Many students drop out of science courses because education at the undergraduate level too often treats science only as something to be memorized rather than something alive, personal, and full of creative potential. Too many students never see science education as relevant to them, and they leave school without the tools to understand much of the modern world.

S. 1549/H.R. 3130, the "Technology Talent Act," seeks to increase the number of U.S. students studying science, technology, engineering, and mathematics. The legislation authorizes the National Science Foundation to establish a demonstration program that supports grants to undergraduate programs. Support is promised to projects that emphasize mentored undergraduate research and experiential learning of all kinds, including industrial and governmental internships. Thus the legislation encourages science and technology partnerships between government, colleges and universities, and local industries to provide opportunities for young people to enter science and technology fields. Such incentives will help industries and scientific/technological corporations to work with the educational system that will produce their workforce for this new century. CUR supports this legislation. We would like to suggest two additional elements:

—**Mentored undergraduate research programs at the national laboratories and experiment stations, such as NASA's Undergraduate Student Research Program (USRP) at the NASA Centers.** The NASA program can be a model for federally funded programs at the other national laboratories. Alternatively, NSF

could be tasked with developing and administering a program in partnership with the various national labs and centers including DOE, USDA/ARS, EPA, and others. There should be an opportunity for faculty and their students to come together to work at the National Labs, and then take research ideas back to their campuses for further work, as well as opportunities for students to go to the laboratories to work with federal scientists as mentors. An undergraduate research program for the national labs will increase public awareness of the scientific missions of the agencies and improve the use of national labs as research and educational resources, as well as achieving the goal of entraining U.S. students in the STEM fields.

—Development of a **program at NSF that recognizes excellent science and technology educational opportunities at our COMPREHENSIVE UNIVERSITIES, especially those that successfully integrate scientific research and education.** These are the schools, often within our state university systems, that train the majority of our K–12 science teachers and most of our students from under-represented groups. The size, high student to faculty ratio, high faculty teaching loads, limited budgets, and diversity of students require creative means to reach students with investigative science learning tools including undergraduate research. Attached is a detailed proposal to develop a program at NSF in support of STEM education at the comprehensive universities. NSF has already held competitions that recognize the importance of integrating research and education at research universities and baccalaureate colleges and reward model programs, but has thus far not focused similar attention on the comprehensive universities.

We would be pleased to work with Congress to flesh out the details of such programs.

An NSF Recognition Awards Program for the Integration of Research and Education at Comprehensive Universities

A Proposal from the Council on Undergraduate Research

K. ELAINE HOAGLAND, NATIONAL EXECUTIVE OFFICER

Background

The central mission of the Council on Undergraduate Research (CUR) is to promote research by undergraduate students in all settings of science, mathematics, and engineering education (SMET) and to strengthen the research programs of faculty in predominantly undergraduate institutions. We believe that education is best served by faculty-student collaborative research combined with investigative teaching strategies. We work with federal agencies, including NSF, to develop and maintain research-based educational opportunities.

In the past several years, NSF has held two competitions that speak to the heart of the CUR mission: Recognition Awards for the Integration of Research and Education (RAIRE) and Awards for the Integration of Research and Education at Baccalaureate Institutions (AIRE). Most of the AIRE award winners are CUR institutions, and we have helped them to disseminate their successes to the broader educational and research community. CUR congratulates NSF for making this opportunity available to (a) help good programs move to a higher level of achievement, and (b) provide avenues and funding for widespread dissemination and adaptation of successful programs.

It was wise for NSF to divide the program by institutional type. Having run successful programs specifically for the research universities and the baccalaureate colleges, it is now time for NSF to make this program available to the third major type of American academic institution: the Comprehensive University.

What is the Comprehensive University?

Comprehensive universities are academic institutions that offer a full range of baccalaureate programs and that are committed to graduate education through the Master's Degree. Many of these institutions continue a tradition of educating substantial numbers of the Nation's K–12 teachers. However, today they have evolved into universities with a variety of constituents and programs.

The majority of the Nation's students who are members of populations under-represented in SMET—African Americans, Hispanics, recent immigrants, and non-traditional students—attend comprehensive universities (see appendix). Most of our first generation college students attend comprehensive universities, as do women returning to school after having started families, and persons returning to education after military service. Many comprehensive universities have a significant commuter population.

Comprehensive universities are generally much larger than baccalaureate colleges, with student populations of about 4,000 to more than 30,000 students. They range in complexity from private universities (e.g., Trinity University) to geographically isolated public institutions (Angelo State University in Texas) to urban campuses (California State University–Los Angeles; University of Michigan–Dearborn) and historically black universities (Morgan State). Many are members of large state systems (e.g., the La Crosse and Eau Claire campuses of the University of Wisconsin).

These institutions have in common a need to educate students for local employment, because many of their students are bound to the geographic area for financial and personal reasons. Many comprehensive universities have relatively low tuition and less selective admission requirements, thus providing opportunity for students who could not otherwise attend an institution of higher education. They tend to have large class size, especially in introductory classes, compared with baccalaureate colleges. In many states, their faculty are under pressure from administrators and state legislators to maximize hours in the classroom, and to adopt distance learning, neither of which may be suitable for optimum student learning in SMET fields.

Comprehensive universities have important strengths. They use their human diversity to advantage in the educational process. Many of their faculty members are dedicated to both teaching and research. They are involved in research projects supported by a full range of funding sources, including NSF, NIH, NASA, and many private agencies such as the W.M. Keck Foundation and the Howard Hughes Med-

ical Institute. Undergraduate research is alive and well at comprehensive universities, many of which have student undergraduate research poster or presentation events. The quality of work exhibited at these events is fully competitive with that at other types of academic institutions. Many comprehensive universities have received highly competitive grants that focus on the quality and productivity of undergraduate research including NSF-Research at Undergraduate Institutions and Beckman Scholars awards. In fact, a true combination of research and teaching is more likely to be the mission at comprehensive universities than at either research or baccalaureate institutions.

The contribution comprehensive universities make to the U.S. scientific workforce is substantial. More undergraduates are educated at comprehensive universities (3.187 million) than any other category of academic institution except two-year colleges. In the year 1995, comprehensive universities awarded over 31 percent of U.S. bachelor's degrees in the sciences (NSB, Science and Engineering Indicators, 1998 edition). The NSF/SRS Survey of Earned Doctorates revealed that 12,589 individuals who received doctoral degrees between 1991 and 1995 in SMET disciplines received their baccalaureate degrees from comprehensive universities. This represented more than 16 percent of the total science and engineering doctoral degrees awarded and was comparable to the productivity of baccalaureate institutions (15 percent) and surpassed that of doctoral institutions (11 percent). In some disciplines, the contribution of comprehensive universities was greater; 23 percent of doctoral recipients in chemistry and 19 percent of those in the physical sciences, in general, earned their Bachelor's degree from a comprehensive university.

Comprehensive universities are accustomed to being asked to "do it all" with limited resources. Faculty members often have research relationships within the local community—local corporations, other academic institutions, or community services organizations. Some students come to a comprehensive university with greater maturity, and with a focused professional goal. Educational experimentation is an important part of the teaching experience at a comprehensive university. In sum, the comprehensive university is a fundamental part of the American academic scene.

The Purposes and Goals of an AIRE for Comprehensive Universities

The AIRE guidelines for Baccalaureate Institutes state: "It is critical that baccalaureate institutions provide an undergraduate experience that is rooted in inquiry and discovery." CUR would say that this is a critical need for ALL academic institutions. For research universities, where the research element is strongly in place and well funded externally, this goal is met by beefing up the teaching component. In the premiere baccalaureate institutions, where small class size and individual attention are already hallmarks of undergraduate education, the goal is met by improving undergraduate access to research. It is no less important at comprehensive universities to address this goal, and many schools already have done so with success by improving both elements together. Therefore the first purpose of an AIRE competition for comprehensive universities is one of FAIRNESS. There is no rationale that CUR can see for leaving these institutions out.

A second goal for a comprehensive university AIRE competition would be to reach out to under-represented groups. An AIRE for comprehensive universities would not merely give lip service to broadening the scientific pipeline, but would showcase institutions that are using undergraduate research and other investigative teaching strategies to entrain minorities and other under-represented groups in the sciences and engineering professions.

A third goal for a comprehensive university AIRE program would be to facilitate SMET education for future K–12 teachers. Most K–12 teachers are educated at comprehensive universities; for example, the California State University system alone prepares 60 percent of California's teachers and 10 percent of teachers credentialed nationwide. AIRE guidelines could be drafted to focus on pre- and in-service teacher training using investigative teaching methods and exposure to research.

A fourth goal would be to educate students in science and technology who will remain in their home communities and will not go on to advanced training. Many of those students will find technical and scientific jobs within the local workforce in the biotechnology, pharmaceutical, aerospace, computer science, health care, and other key fields. An AIRE for comprehensive universities should emphasize connections with local industry to provide internships, research experiences, and jobs for graduating students. A major goal would be to help universities connect with their communities and to augment a much needed sector of the scientific workforce.

Comprehensive universities are a resource for research on teaching and learning. AIRE awards to comprehensives might provide an opportunity for a focus in this area. A key goal of an AIRE for comprehensive universities would be to demonstrate how research and education could be integrated when classes may be large (al-

though not as large as those typically found in research universities) and where many disadvantaged students find it difficult to succeed in demanding introductory classes, particularly chemistry, calculus, and physics. These constraints must be met with special pedagogical skill. Since faculty members from comprehensive universities often have heavy teaching loads and little funding for travel to meetings, visible role models are particularly important. Conversely, it is important that those who are successful get proper recognition for their work and have the opportunity to disseminate their successes.

AIRE for Baccalaureate and Comprehensive Schools: What Is the Same?

Much of the program guideline text for AIRE/baccalaureate institutions could be applied to the comprehensive schools—for example, the NSF vision statement for the future and the characteristics that mark academic institutions that are committed to the integration of research and education. It would be a mistake to set the bar lower for comprehensive universities, or to think that research, to be good, must be done somewhere else. We need to build research and educational infrastructure right within the comprehensive universities and their communities, not in some distant [and elite] environment. We need to reward the best programs of their kind now, just as was done for the other types of schools. We should celebrate the progress that is being made, regardless of the type of academic institution and its constraints.

Conclusion

The challenges of combining research and education at comprehensive universities are different from those at either baccalaureate or research institutions. This is the reason for establishing separate competitions and not ignoring these schools that educate a majority of American undergraduates. Indeed, the lower national recognition level for success at comprehensive universities is all the more reason why NSF should focus on these institutions now, to encourage further success. We urge that Congress help NSF institute an AIRE-like program for comprehensive universities. CUR is willing to provide background information on the types of successes that we see in these schools, as well as their special needs.

Appendix

Ethnic Distribution of Students: What is the Contribution of Comprehensive Universities to training Students from Under-represented Groups in STEM?

Data were extracted by Don Coan of Cal State Long Beach (2000, personal communication) from 1997 IPEDS Survey data, and reworked by E. Hoagland to calculate the percentages shown below.

The following data were calculated based upon a table of the number of students attending research universities, comprehensive universities, and liberal arts colleges (using the 2000 Carnegie classification scheme). Students were subdivided by sex and by ethnic group (Black Non-Hispanic, Native American, Asian, Hispanic, White, and Unknown). For the purposes of these calculations, the unknown category was ignored.

Comprehensive Universities contain the following percentages of the total number of ethnically-identified students:

	Men	Women	Both Sexes
Black Non-Hispanic	52%	56%	55%
Hispanic	53%	56%	55%
Native American	48%	52%	50%
White	41%	47%	45%
Asian	34%	36%	35%
Total student body	43%	49%	46%

Percentage of today's undergraduate students who are female: 56%

Percentage of today's undergraduate students who attend:

Research Universities	38%
Comprehensive Universities	46%
Baccalaureate Colleges	16%

These numbers demonstrate that opportunities denied to comprehensive universities are being denied to slightly less than half of today's undergraduates. The loss of opportunity disproportionately affects women, blacks, and Hispanics, all of whom are over-represented at comprehensive universities. While 46 percent of the overall undergraduate student body attends comprehensive schools, 49 percent of women, 55 percent of blacks and Hispanics, and 50 percent of Native Americans do so.

Asians, on the other hand, are under-represented at comprehensive universities (35 percent) and over-represented at research universities. 57 percent of Asian students, 26 percent of blacks, 36 percent of Native Americans, 36 percent of Hispanics, and 39 percent of whites attend research universities.

These numbers do not include two-year colleges, trade schools, and colleges in Carnegie categories other than those described above.

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