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ABSTRACT

The hearing, opened by Rep. Ray Thorton of Arkansas, addressed the perceived imbalance between teaching and research among university professors and the concern that the quality of undergraduate science education within the United States has deteriorated. Witnesses were called to examine factors that contribute to establishing an appropriate balance between research and teaching responsibilities for professors and factors that improve the quality of undergraduate science education. Witnesses included Dr. Charles M. Vest, President, Massachusetts Institute of Technology, Cambridge, Massachusetts; Dr. Karl S. Pister, Interim Chancellor, University of California at Santa Cruz, Santa Cruz, California; Dr. E. Fred Carlisle, Senior Vice President and Provost, Virginia Polytechnic Institute and State University, Blacksburg, Virginia; Dr. Pamela A. Ferguson, President Grinnell College, Grinnell, Iowa; Dr. Homer A. Neal, Chairman, Department of Physics, University of Michigan, Ann Arbor, Michigan; Dr. Samuel Ward, Professor and Department Head, Department of Molecular and Cellular Biology, and Professor of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona; Dr. Jack R. Lohmann, Associate Dean, College of Engineering, and Professor of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia; and Dr. Denice Denton, Associate Professor, Department of Electrical and Computer Engineering, University of Wisconsin, Madison, Wisconsin. Topics discussed by the witnesses included faculty evaluation and promotion; the interaction of teaching and research; the Virginia Tech plan for undergraduate education and faculty rewards; the need for continued research funding; and faculty incentive systems. A copy of "America's Academic Future: A Report of the Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the year 2010 and Beyond" is included. (MDH)

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THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE

OF THE

COMMITTEE ON

SCIENCE, SPACE, AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

SECOND SESSION

MARCH 31, 1992

[No. 105]

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*Ranking Republican Member.

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WITNESSES

THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION

TUESDAY, MARCH 31, 1992

U.S. House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Science,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1:47 p.m. in room 2318, Rayburn House Office Building, Hon. Ray Thornton [acting chairman of the subcommittee] presiding.

Mr. Thornton. The hearing will come to order.

I'd like to ask our first panel, Dr. Vest, Dr. Pister, Dr. Carlisle, and Dr. Ferguson to please come up to the witness table, if you will.

I want to first thank each of you for making the effort to come down and talk about this most important topic. The quality of undergraduate science education is a matter of great concern, and how to improve that science education, not only at the undergraduate level, but with the consequences of that education and its impact upon education throughout the seamless web, from the beginning of the educational process through the highest degree.

Following World War II, the United States did create the finest research infrastructure in the world by choosing wisely to contract its investment in basic research with institutions of higher education.

By integrating both pedagogy and research, we were able to capitalize on the strengths and complementary roles of each, producing a student academic environment that was unparalleled in excellence and in opportunity.

Today, however, a nationwide perception exists that the balance between teaching and research has become skewed in favor of research and that the quality of undergraduate science education within this country has seriously deteriorated.

Students and parents are alike in voicing their dissatisfaction with an academic system that sometimes seems to have lost sight of the educational needs of the students.

The faculty reward systems of universities give the appearance that faculty are awarded promotion and tenure primarily on the basis of research endeavors.

In addition, the current imbalance between the amount of federal funds available for research and the increasing number of research opportunities, has placed the university research enterprise under stress, and has significantly reduced faculty success rates for obtaining research support.

As a result of these pressures, faculty tend to allocate more and more time to research and proposal writing, while teaching responsibilities are transferred to graduate students or teaching assistants.

Our goal today in these hearings is to examine factors that contribute to establishing an appropriate balance between teaching and research responsibilities of the professorate, and to enhancing the quality of undergraduate science education.

It is not our intent to denigrate or to take away in any respect from the important role of scientific research within the academic institution, or to criticize those faculty whose demonstrated excellence in research-related endeavors are so often rewarded.

As a Nation, we have collectively reaped significant benefits from their dedication and valuable contributions to science.

Now, one could take the simplistic view that undergraduate science education represents just one of many segments along the continuous spectrum of formal education that begins with preschool and ends with post-doctoral study.

A more pragmatic view, and one that is instrumental to this hearing, is that undergraduate science education serves as a pivotal element within the formal education structure. It serves as the core from which scientific knowledge emanates to future scientists and researchers, to future teachers, and to future leaders in every sector of our society.

In short, undergraduate science education provides the foundation upon which this Nation's scientific literacy is ultimately based.

Ralph Waldo Emerson once remarked, and I quote, "The secret of education lies in respecting the pupil."

Despite the laudable successes and significant achievements of our research infrastructure, we must look to our academic institutions to ensure that the needs of those students are addressed, and that all students receive the quality undergraduate science education they fully expect and deserve.

All of us here today share a common goal—to reaffirm the importance, value, and honor associated with educating our Nation's youth. This hearing, I hope, will afford us the opportunity to identify viable options and means to achieve that common goal.

Our first panel of witnesses is composed of leaders from several academic institutions, and your guidance, direction, and stewardship of your faculty have a great effect, not only on academic priorities, but upon the rewards that teaching faculty receive.

Our second panel will be composed of senior and junior faculty whose decisions regarding their own research and teaching responsibilities are influenced by the faculty reward systems of their respective institutions.

We look forward to the candid views and recommendations of all of our witnesses.

I'm reminded of the story once told about a Greek philosopher, a couple of thousand years ago, saying, "Isn't it terrible what happened to Socrates? They've killed him."

The response was, "Well, he may have been a good teacher, but he never published." Plato did the publication, I believe.

Mr. Packard has a prepared statement which, without objection, I would like to enter into the record at this point in these proceedings.

I recognize my colleague from Maryland, Mr. Gilchrest, if he has an opening statement.

[The prepared statements of Mr. Thornton, Mr. Packard, and Mr. Boucher follow:]

OPENING STATEMENT
OF THE
HONORABLE RAY THORNTON (D-AR)
SUBCOMMITTEE ON SCIENCE
ON THE
QUALITY OF UNDERGRADUATE SCIENCE EDUCATION

March 31, 1992

Following World War II, the United States created the finest research infrastructure in the world by choosing to contract its investment in basic research with institutions of higher education. By integrating both pedagogy and research, we were able to capitalize on the strengths and complementary roles of each, producing a student academic environment that was unparalleled in excellence and opportunity.

Today, however, a nationwide perception exists that the balance between teaching and research has become skewed in favor of research and that the quality of undergraduate science education within this country has seriously deteriorated.

Students and parents alike are voicing their dissatisfaction with an academic system that appears to have lost sight of the educational needs of its students.

The faculty reward systems of universities give the appearance that faculty are awarded promotion and tenure primarily on the basis of their research endeavors. In addition, the current imbalance between the amount of federal funds available for research, and the increasing number of research opportunities, has placed the university research enterprise under stress and has significantly reduced faculty success rates for obtaining research support. As a result, faculty tend to allocate more time to research and proposal writing, while teaching responsibilities are transferred to graduate students or teaching assistants.

Our goal today is to examine factors that contribute to establishing an appropriate balance between the teaching and research responsibilities of the professoriate, and to enhancing the quality of undergraduate science education. It is not our intent to denigrate the role of scientific research within the academic institution, or to impugn those faculty whose demonstrated excellence in research related endeavors are so rewarded. As a nation, we have collectively reaped significant benefits from their dedication and valuable contributions to science.

One could take the simplistic view that undergraduate science education represents just one of many segments along the continuous spectrum of formal education - a spectrum that begins with pre-school and ends with post-doctoral study. A more pragmatic view, and one which is instrumental to this hearing, is that undergraduate science education serves as a pivotal element within the formal education structure. It serves as the very core from which scientific knowledge emanates to future scientists and researchers, to future teachers, and to future leaders in every sector of our society. In short, undergraduate science education provides the foundation upon which this nation's scientific literacy is ultimately based.

Ralph Waldo Emerson once remarked, "The secret of education lies in respecting the pupil." Despite the laudable successes and significant achievements of our research infrastructure, we must look to our academic institutions to ensure that the needs of the students are addressed and that all students receive the quality undergraduate science education they fully expect and deserve.

All of us here today share a common goal - to reaffirm the importance, value, and honor associated with educating our nation's youth. This hearing will afford us the opportunity to identify viable options and means to achieve that common goal.

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STATEMENT OF
THE HONORABLE RON PACKARD
SCIENCE SUBCOMMITTEE
HEARING ON THE QUALITY OF UNDERGRADUATE EDUCATION
1:30 PM, 2318 RHOB
MARCH 31, 1992

* I welcome the gentleman from Arkansas, Mr. Thornton, who will be chairing the hearing today for Chairman Boucher. I am sure Chairman Thornton will provide some valuable insights given his former role as the President of the University of Arkansas.

* I welcome all the witnesses and extend a special welcome to Dr. Karl Pister from the University of California at Santa Cruz. Dr. Pister has had a very distinguished career within the University of California -- a career that includes being selected as a Fulbright Scholar in both Ireland and Germany. Dr. Pister is the Chairman of the newly created Board on Engineering Education of the National Research Council and he currently serves as Interim Chancellor at the University of California, Santa Cruz.

* I will be interested to hear more about the recommendations that were generated by the task force of the UC system that looked at faculty rewards. It is my hope that these excellent recommendations are now in the process of being implemented.

* With that, Mr. Chairman, I will conclude my opening remarks so that we can move on to the testimony.

OPENING STATEMENT
OF THE
HONORABLE RICK BOUCHER (D-VA)
CHAIRMAN, SUBCOMMITTEE ON SCIENCE
ON THE
QUALITY OF UNDERGRADUATE SCIENCE EDUCATION

March 31, 1992

The people of the United States have justifiably taken great pride in the scientific excellence demonstrated by this nation as a whole, particularly in this competitive global environment. Our research infrastructure, established as a cooperative joint venture between the federal government and the academic community, has become the envy of the world. But we can ill afford to rest on our laurels. Current indicators reflect a potentially disturbing erosion of the scientific literacy in this country - a trend that may ultimately and irreversibly damage the economic strength and competitiveness of this country.

The purpose of the hearing today is to examine one of the most crucial and pivotal elements in the determination of our nation's scientific literacy - the quality of undergraduate science education. This area of examination is not limited solely to the education of those individuals who seek professional careers in the sciences. On the contrary, the quality of undergraduate science education received by non-science majors has equal, if not greater, impact on society as a whole.

Those undergraduate students who choose careers in other fields will require a solid foundation in science in order to apply their respective skills in a technologically explosive international environment. Even more significantly, those undergraduate students who choose careers in teaching will eventually impart their knowledge and understanding of science to the children of today - the leaders of tomorrow. Thus, limitations or deficiencies in undergraduate science education ultimately impact every sector of our society.

Has the quality of undergraduate science education been deteriorating? Public perception seems to indicate "yes". However, we seek today not to "pass judgement" on the academic community, but rather to address a root cause of this perception and to solicit constructive mechanisms to effect institutional change.

At the very heart of this issue is the current faculty reward system, which appears to favor the research endeavors of the professoriate at the expense of the teaching endeavors. If faculty are primarily recognized and rewarded on the basis of their research efforts, where is the incentive (other than personal devotion and motivation) to dedicate one's time to teaching the undergraduate students? Clearly, the element of instruction must be recognized for its value and importance to this nation, and rewarded accordingly.

I welcome the witnesses who have come here today to share their views, observations, and recommendations on this important issue with our Subcommittee. Working together we can learn from past experiences, identify areas for potential change, and explore new and innovative programs designed to improve the quality of undergraduate science education.

We are all in agreement on the importance of science education to this nation. Let us take the opportunity of this hearing to collectively address substantive, proactive measures to enhance the quality of that education, for we are all the ultimate beneficiaries.

Mr. GILCHREST. Thank you, Mr. Chairman.

I have no formal opening statement. I do look forward to the testimony from the panel this afternoon.

I know that it is significantly important for us to understand how science and math can be a part of the instructional fabric of universities and colleges, so that they make a significant impact on those teachers and people that will absorb that information.

This is probably the most important infrastructure that our country has, and that's the manner in which we instruct people to further disseminate that information. It is vital that we get some sense of how we can improve upon that—what our strengths are, what our abilities to be creative are, and so forth.

I would also like to emphasize the importance of this as a history teacher, over the past so many years, up until last year, in that after they get out of undergraduate school, I think it is vital not to let the line go, but teachers continually need to be updated on specific information, and motivated, because the term "burn-out" is fairly prevalent in our public schools.

Undergraduate schools can do a great deal to perpetuate their sense of importance in the community. After they leave these undergraduate schools, some continued association with them in some manner, I think, is vitally important.

I'll just throw a plug for a book that was written about 25 years ago. As a history teacher, I read the book, and use it as part of my instruction periodically, but I think it's a great blending of the disciplines. It was a book written by Jacob Bronowski, called "The Ascent of Man."

It blended, so perfectly, philosophy, economics, history, science, of course, religion, in a way that people understood the context of science and math in the importance of people's lives.

So, ladies and gentlemen, I look forward to your testimony.

Thank you, Mr. Chairman.

Mr. THORNTON. Thank you very much.

I also enjoyed the wonderful Bronowski book. It is an excellent piece.

I want to express, for the Chairman of the Science Committee, the Honorable Rick Boucher, his regret that he could not be here today. He was really looking forward to this hearing.

When it appeared that his schedule would not allow him to be here, he asked me, I think, because I left the presidency of the University of Arkansas to seek to return to Congress to chair the hearing.

He said, "Ray, why did you give up being president of the University of Arkansas to come back to Congress?" I admitted that I got tired of all the politics.

[Laughter.]

Mr. THORNTON. Henry Kissinger once said that, "The reason that university politics is so fierce is that the stakes are so small."

[Laughter.]

Mr. THORNTON. But the administration of universities is the most significant task that faces our country, because the foundation of education is higher education.

Education means to educe or to pull up or pull out of or pull through. It is at the level of higher education that you put the pulley, and that you lift, as we did with the land grant college system, the entire fabric of a Nation's educational structure.

Dr. Vest, I'd like to ask you to begin the testimony today. Your excellent prepared testimony will be made a part of the record, without objection, in full. I would like to ask that you summarize it so that we may hear from each of the witnesses today.

STATEMENT OF DR. CHARLES M. VEST, PRESIDENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS

DMr. VEST. I would like to begin by warning my colleagues that if we are facing a chairman who is a former university president, and a Congressman who reads Bronowski, we'd better speak the truth today.

Mr. Chairman, it's a great honor to be here to address the committee on a topic of utmost importance, the quality of undergraduate education, the relationship and balance between teaching and research.

This Nation is in a slump, economically, politically, and socially. As my favorite philosopher, Pogo Possum, once said, "We are surrounded by insurmountable opportunities."

You have heard the litany of things that many believe are necessary to pull ourselves out of this trend. The essential prerequisite for progress, the sine qua non for a vibrant American future, is the development of our human capital— our people and their ideas.

Our system of public and private higher education is one of the most successful undertakings in human history. It is unparalleled in scale, scope, and quality.

It has repaid the Nation's investment in many ways, and at rates that defy ordinary economic analysis. It is the best in the world—period.

But greatness can be fleeting, if we rest upon our laurels, if we do not move with the times, or if we fail to anticipate the future.

American undergraduate education must be continuously improved, and therefore it must be valued and invested in by the Nation.

Because of research at institutions such as MIT, undergraduates are taught by faculty members who teach the future, not just the past, of their fields.

Where there are problems with science education, I believe that it is more often because of an artificial separation of teaching and research than because of an overemphasis on research.

Faculty in the universities that I am aware of work very, very hard. Indeed, they work obsessively. We keep asking more and more of them, and they keep asking more and more of themselves. Nonetheless, the promotion and reward system clearly influences what they work on and how.

Promotion, tenure, and salary setting must be designed to promote excellence in learning through education and research.

I do not recommend that we deviate from that goal. The times call for more flexibility than I sometimes observe.

I'm aware of schools that have carefully quantified the minimum number of publications they require for tenure, for example. This is nonsense and a cop-out. It is an evasion of judgment of merit and excellence.

Teaching and instructional innovation must be recognized and rewarded, but they must be held to the same standards of excellence that we attempt to hold scholarship and research to.

The system must allow for a broader range of activities along the teaching/research spectrum, but quality and effectiveness must remain the bottom line.

The most important considerations are those that deal with young faculty. These considerations are indeed influenced by federal policy and funding.

Many of our younger faculty are fixated on what they see as the mechanics of attaining tenure. They feel pressed to rapidly establish research programs, laboratories, funding, and lengthy publication records, and to do so in a world where the competition is fierce for research grants that continue to shrink in size and duration.

In my view the surest way to dampen further efforts of junior faculty in teaching would be to cut research budgets, or to continue the erosion of merit and peer review, as the criteria for awarding research funding, thereby increasing still further the difficulty of meeting this area of faculty responsibility.

There are many areas that we could discuss today, and certainly many more than I could possibly cover in the allotted time.

For example, universities must educate for a changing world—a world in which virtually every activity is carried out in an international context, and in which women and members of under-represented minority groups must fully participate.

But let me offer a few recommendations that I believe should be implemented by universities, by the Federal Government, or jointly by academia and government.

First, fix the K-12 system. The Nation simply must come to grips with the enhancement of primary and secondary education, and the establishment of popular respect for learning and accomplishment. Issues of undergraduate science and engineering education will be much easier to deal with once that is done.

Senior faculty and administrators must bring about a shift in the academic culture that more strongly recognizes the importance of teaching and educational innovation. However, I again emphasize that excellence and rigor must be demanded.

Particular emphasis should be placed on improving the quality of introductory science and mathematics courses. It is in these courses that fundamental understanding and knowledge are imparted. Inspiration and motivation are most important at this level, and course content must be related to the contemporary world.

We must use graduate student teaching assistants only in contexts that are reasonable. We have a responsibility to see that they are appropriately prepared for their duties.

Particularly in engineering education, we must give greater emphasis to design, to integrative activities, and to teamwork.

Major institutional and national awards and fellowships recognizing faculty who have made extraordinary contributions to education of undergraduate students should be established. The new

Margaret MacVicker Faculty Teaching Fellows Program at MIT is intended to establish this precedent.

We must foster a greater diversity of kinds of educational institutions. Not every institution should aspire to be a PHD-granting research university. The country can't afford it, and more importantly, we need to more clearly recognize the value of different kinds of education and training for different people.

Programs should be developed and extended that involve undergraduates in research together with faculty and graduate students. Examples include MIT's Undergraduate Research Opportunity Program or UROP.

NSF has developed add-on funding to research grants to support undergraduate involvement. All the evidence that I am aware of shows tremendous payoffs for such efforts.

A more concentrated effort is needed to increase the productivity of universities, both individually and collectively, through the use of modern information technology such as computing, simulation, and interactive video.

We should more fully exploit the developing computing infrastructure and networks of the country. Imaginative educational applications seem to me to be lagging behind even the available technology.

Research funding for faculty should become more plentiful, not less, and it should be awarded on the basis of merit, not politics. Proposal writing and administrative loads on faculty, especially the younger faculty, must be reduced.

As part of this, we must get away from the devastating, developing view in some corridors of the Federal Government of universities as simply research contractors.

Instead, we must promote the interaction of research and teaching within institutions, and recognize the importance of these institutions to the Nation.

We must recognize that universities are financially very fragile at the moment. Private universities have only three sources of income—tuition, private giving, and sponsored research.

Whenever federal support for research or fellowships do not cover the actual costs incurred, then cost sharing from the other two sources is forced, and funds available for direct teaching and educational purposes decrease.

Programs that support equipment and facilities for undergraduate teaching laboratories should be expanded and, in general, encouraged.

Government agencies should fund educational pilot projects and the development of innovative curricular and teaching materials.

However, in my view, universities should not walk out on the limb of long-term dependence on external sponsorship for faculty salaries and operating costs directly associated with the teaching function.

Reform and tuning of the academic culture is needed and, in my view, is beginning to occur. Despite the fact that some significant changes are necessary to further enhance the quality of undergraduate science and engineering education, it remains my view that it is the synergy of research and teaching that has made our system of higher education the best in the world.

Thank you very much.

[The prepared statement of Dr. Vest follows:]

Written Statement of Charles M. Vest
President, Massachusetts Institute of Technology

before the

Subcommittee on Science Hearing on
Quality of Undergraduate Education
House Committee on Science, Space, and Technology

Tuesday, March 31, 1992

INTRODUCTION

Mr. Chairman, I am Charles Vest, President of the Massachusetts Institute of Technology. I am honored to have the opportunity to address this committee on a topic of utmost importance -- the quality of undergraduate education and the balance between teaching and research.

I was born and raised in West Virginia, where I attended public schools and graduated as a mechanical engineer from West Virginia University in 1963. Thereafter, I moved to The University of Michigan where I earned a masters degree and, in 1968, my PhD in mechanical engineering. I served on the faculty of Michigan's College of Engineering from 1968 to 1990.

During most of these years I was active in both teaching and research. I taught both undergraduate and graduate courses every term. At Michigan, I served as dean of the College of Engineering and then as Provost and Vice President for Academic Affairs. In October 1990, I had the honor to become president of MIT. I view this appointment as a call to national service, and it is in that spirit that I come before this committee today.

This nation is in a slump -- economically, politically and socially. As my favorite philosopher, Pogo Possum, once said, "We are surrounded by insurmountable opportunities." You have heard the litany of things that most believe are necessary to pull ourselves away from this trend, especially economically: increase savings rates...focus on the long term...learn to live in the world of interconnected economies, production systems and communications...and train tomorrow's workforce so that it is committed to excellence and is representative of the rapidly changing demography of our nation. But the essential prerequisite for progress, the *sine qua non* for a vibrant American future, is the development of our human capital -- that is, our people and their ideas.

Our system of public and private higher education is one of the most successful undertakings in human history. It is unparalleled in scale, scope and quality. It has repaid the nation's investment in it in many ways and at rates that defy ordinary economic analysis. It is the best in the world - period.

But, I can imagine that just a decade or two ago, the president of some major U.S. manufacturing firm might have spoken to you with equal conviction about the unparalleled strength of his firm or industrial sector. It is unlikely that today that same individual would be able to claim to represent the best in the world. Greatness can be fleeting if we rest upon our laurels, if we do not move with the times, or if we fail to anticipate the future. American undergraduate education must be continuously improved, and therefore it must be valued, and invested in, by the nation.

There are two issues in undergraduate science and engineering education -- the education of scientists and engineers; and the scientific and technological literacy of students majoring in the arts, humanities, business, and other fields. I will concentrate on the education of science and engineering majors today, but would like to register my view that the scientific literacy of non-majors is a growing national problem. Indeed, when Harvard students recently interviewed just prior to their graduation, were asked "What is your one biggest academic regret", 39% of the humanities majors answered "I wish that I had taken more science."

THE INTERACTION OF TEACHING AND RESEARCH

In many universities, significant change is required to improve the quality of undergraduate science and engineering education. However, posing the issue starkly as a balance between teaching and research evades the complexity of this important topic.

For example, it is important to understand that in science and engineering, undergraduate course topics and materials generally evolve from research developments, then move into graduate courses and only then, as they are refined and honed and their essentials understood, move into undergraduate classrooms and textbooks. In recent testimony before the National Research Council Board on Engineering Education, several educators who described innovative new approaches to undergraduate education noted that this mode of evolution continues today. Furthermore, in engineering education, the coupling of industrial research interactions with undergraduate course development is clearly increasing in importance.

Because of research at institutions such as MIT, undergraduates are taught by faculty members who teach the future, not just the past of their subjects. In addition to their classroom work, students learn from tutors and fellow students in study groups, and -- increasingly -- by working directly with faculty, graduate students, and staff on research projects.

Where there are problems with science education, I believe that it is more often because of a separation of teaching and research, rather than an overemphasis on research. As Professor Hal Abelson of our computer science faculty, a widely respected teacher of undergraduates, has put it:

> A lot of science education is fossilized, largely because people have forgotten that learning about science must involve doing science. One symptom of this is the way that discussions about faculty roles in education get polarized around the "research vs. teaching" issue MIT's Undergraduate Research Opportunities Program is a wonderful example of how to get around this, and it's puzzling and troubling that the program has been so hard to transplant to other universities.

I believe that in the long run, it requires the discipline, joy and continual renewal of original research, scholarship or other creative intellectual activity to keep us lively and successful as teachers. One may start out as an effective and even brilliant teacher, but without the kind of continuous renewal that research and scholarship provide, one will not grow in wisdom and breadth, and over time may lose rather than gain in effectiveness as a teacher.

FACULTY PROMOTION, TENURE AND REWARDS

Faculty in the universities that I am aware of work very, very hard. Indeed they work obsessively. We keep asking more and more of them, and they keep asking more and more of themselves. Nonetheless, the promotion and reward system clearly influences what they work on, and how.

Promotion, tenure and salary setting must be designed to promote excellence in learning through education and research. I do not recommend that we deviate from that goal, but I do believe that the times call for more flexibility than I sometimes observe. I am aware of schools that have carefully quantified their requirements for tenure, for example requiring a certain minimum number of publications. This is nonsense and a cop-out. It is an evasion of judgement of merit and excellence.

Teaching and instructional innovation must be recognized and rewarded, but they must be held to the same standards of excellence to which we attempt to hold scholarship and research. The system must allow for a broader range of activities along the teaching/research spectrum, but quality and effectiveness must be the bottom line.

The most important considerations are those that deal with young faculty. And these considerations are influenced by federal policy and funding.

It is true that many of our younger faculty are fixated on what they view as the mechanics of attaining tenure. They feel pressed to rapidly establish research programs, laboratories, funding, and lengthy publication records, and to do so in a world where the competition is fierce for grants that continue to shrink in size and duration. (Today, both the NIH and the NSF fund fewer than one-third of their grant applications.) These younger colleagues believe that research sponsors and university administrators require them to spend most of their time generating entropy rather than useful work. And they wonder if they will ever have time to spend with their families.

Many assistant professors building their careers and moving toward tenure do express concern about a lack of time to commit, and rewards to be reaped, for innovation in undergraduate teaching. In my view, however, the problem is not doing research; it is the increasingly oppressive environment for developing sponsorship for their research. Too much time must be devoted to proposal writing and research administration, and not enough time to research itself. The surest way to dampen further the efforts of junior faculty in teaching would be to cut research budgets, or to continue the erosion of merit and peer review as the criteria for awarding research funding, thereby increasing still further the difficulty of meeting this area of faculty responsibility.

RECOMMENDATIONS

There are many more areas to be discussed than I can possibly cover in the alloted time. For example, universities must educate for a changing world -- a world in which virtually every activity is carried out in an international context, and in which women and members of underrepresented minority groups must participate fully. But let me offer a few recommendations that I believe should be implemented by universities, by the federal government, or jointly by academia and government.

- Fix the K-12 system. The nation simply must come to grips with the enhancement of primary and secondary education and the establishment of popular respect for learning and accomplishment. Issues of undergraduate science and engineering education will be much easier to deal with once that is done.

- Senior faculty and administrators must bring about a shift in academic culture that more strongly recognizes the importance of teaching and educational innovation. An atmosphere of respect for first-rate teaching, and enjoyment by students and faculty of learning together must be fostered. However, excellence and rigor must be demanded.

- Particular emphasis should be placed on improving the quality of introductory science and mathematics courses. It is in these courses that fundamental understanding and knowledge are imparted. Inspiration and motivation are most important at this level, and course content must be related to the contemporary world.

- We in the universities must use graduate student teaching assistants only in contexts that are reasonable, and we have a responsibility to see that they are appropriately prepared for their duties.

- Particularly in engineering education we must give greater emphasis to design, integrative activities and teamwork.

- Major institutional and national awards and fellowships recognizing faculty who have made extraordinary contributions to the education of undergraduate students should be established. The new Margaret MacVicker Faculty Teaching Fellows Program at MIT is intended to establish this precedent.

- We must foster a greater diversity in kinds of educational institutions. Not every institution should aspire to be a PhD-granting research university. The country can't afford it, and, more importantly, we need to more clearly recognize the value of different kinds of education and training.

- Programs should be developed and extended that involve undergraduates in research together with faculty and graduate students. Examples include MIT's Undergraduate Research Opportunity Program (UROP). NSF has developed add-on funding to research grants to support undergraduate involvement. All the evidence that I am aware of shows tremendous payoffs for such efforts.

- A more concerted effort is needed to increase the productivity of universities both individually and collectively through the use of modern information technology such as computing, simulation, and interactive video. We should more fully exploit the developing computing infrastructure and networks across the country. Imaginative educational applications seem to be lagging behind the technology.

- Research funding for faculty should become more plentiful, and it should be awarded on the basis of merit, not politics. Proposal writing and administrative loads on faculty, especially the younger faculty, must be reduced.

- We must get away from the devastating developing federal view of universities as simply research contractors. Instead, we must promote the interaction of research and teaching within institutions whose importance to the nation is recognized and valued.

- You must recognize that universities are financially very fragile at the moment. Private universities have only three sources of income -- tuition, private giving and sponsored research. Whenever federal support for research or fellowships does not cover the actual costs incurred, then cost sharing from the other two sources is forced, and funds available for educational purposes decrease.

- Programs that support equipment and facilities for teaching laboratories should in general be encouraged.

- Government agencies should fund educational pilot projects and the development of innovative curricular and teaching material. However, universities should not walk out on the limb of long-term dependence on external sponsorship for faculty salaries and operating costs of teaching.

CLOSING

Universities should be dedicated to learning. Learning takes place in a variety of ways -- through formal course work, through research, and through involvement in the general academic discourse. Reform and tuning of the academic culture is needed, and in my view is beginning to occur. Despite the fact that some significant changes are necessary to further enhance the quality of undergraduate science and engineering education, it remains my view that it is the synergy of research and teaching that has made our system of higher education the best in the world.

Before coming down here today, I asked several of MIT's most accomplished undergraduate teachers what they would like to say to you. Let me close by quoting the response of Dan Kemp, a member of our Chemistry faculty and a MacVicker Fellow:

> We are living at a unique moment in human history, in which we are finally answering many of the deep remaining questions concerning the nature of the physical universe, of the human organism, and of life itself. A nation that can seize the creative potential of these exciting times can ensure that it is governed by a political process that is grounded in rationality, and it can foster a level of technological creativity that guarantees prosperity and decent quality of life, both for itself and for its future generations.

Mr. THORNTON. Thank you very much, Dr. Vest for an eloquent statement.

A former president of the University of Arkansas, who also left the university to come to Congress, named J. William Fulbright, once made the statement in talking about the politician as an educator, that it was essential that we educate our leaders before they become our leaders, that the old system of the politician educating the constituency had fallen into a lot of problems with the 30 second sound bites, and that it was very important for us to have—not only in the sciences, but throughout the philosophy of education—to have educational institutions that presented well rounded people to become our leaders.

I thank you very much for your testimony. Dr. Pister.

And, let me identify our witnesses more completely for the record. President Vest is head of the Massachusetts Institute of Technology, one of our truly great national treasures, and we are so honored that you are here.

Dr. Pister is Chancellor of the University of California at Santa Cruz. Dr. Pister we are honored that you are here.

STATEMENT OF DR. KARL S. PISTER, INTERIM CHANCELLOR, UNIVERSITY OF CALIFORNIA AT SANTA CRUZ, SANTA CRUZ, CALIFORNIA

Dr. PISTER. Thank you, Mr. Chairman and members of the committee.

For the record, I should also say that I spent most of my faculty career at the University of California at Berkeley, the last ten years of which were service as Dean of the College of Engineering.

Also, I am currently Chair of the National Research Council Board on Engineering Education, which has a great deal of interest in the subject under discussion today.

In 1991, I was Chairman of the University of California Systemwide Task Force studying the faculty reward system at the University of California. That experience is largely the basis for my testimony today.

It's not surprising—

Mr. THORNTON. Mr. Pister, without objection, your full, prepared testimony will be made a part of the record, verbatim, at this point in the record.

Dr. PISTER. Thank you, sir.

Since Dr. Vest and I were both educated as engineers and served similar experiences in our academic careers, it will be no surprise that much of my testimony follows his, with perhaps just a few minor nuances.

First of all, the research university system in the United States, which is largely a post-World War II phenomenon is, indeed, a great institution. Nothing that I have to say should be construed as a need for substantial change in the research institutions of the United States.

Nevertheless, there are important characteristics that have been acquired over the last 50 years or so that I believe are important and must be considered and changes made if the research university system of this country is to serve the Nation as it must in the coming century.

First of all, our research universities have a tripartite mission of teaching research and public service. This, in itself, has a major impact—the balance among those three categories on how these institutions serve the Nation.

Secondly, these institutions supply the faculty to most all other higher educational institutions in the United States. They are the Ph.D.-producing institutions that supply faculty.

Therefore, the value system that is set by research universities is inherited and passed on in some sort of educational genetic code that influences almost all of higher education.

In addition, the research university model sets the value system for faculty performance, by and large, in most of our institutions.

The research university has, likewise, tended to homogenize institutional mission. Dr. Vest referred to this already. It's too many institutions in the United States, in my view, aspire to become a research university in the present scene.

This was captured in a recent paper by Clark Kerr entitled, "The Race to be Harvard, Berkeley, or Stanford," clearly written before recent events at Stanford.

[Laughter.]

As a Berkeley person, off the record, I couldn't avoid saying that, of course.

Research universities have also created the pressure of productive scholarship.

Mr. THORNTON. Dr. Pister, let me just interrupt at that point, though, to say, that when one evaluates the contributions that that great university has made to our Nation—its knowledge, its ability to develop high technology skills, employment opportunities for our people— the fact that a mistake is made does not necessarily condemn the system or the process by which the Federal Government has provided support for those institutions.

Dr. PISTER. The record must show that that was a remark made in jest. Only people that either have gone to Stanford or Berkeley fully appreciate the friendly rivalry between the institutions, which I entrusted two of my daughters, to I should say.

Mr. THORNTON. Thank you very much.

Dr. PISTER. Research universities have created the pressure of productive scholarship, often called the "publish or perish syndrome."

Indeed, this manifests itself in such pressures as the need for academic year salary offsets for university faculty in research universities. In other words, the substitution of research for teaching, which is a pressure that is dictated all too often by institutional economics more than mission of the institution.

They have created institutional and individual metrics for prestige and awards. The national rankings, however determined, whether by the news media or by surveys, typically look at the research component of the institution in establishing a hierarchy.

They have tended to erode the loyalty and allegiance of faculty to the home institution in favor of allegiance to the discipline.

This horizontal peer group, so to speak, is a peer group that has, in many cases, displaced the institutional loyalty, because of the need for peer group evaluation in the publication process, and in the evaluation of research proposals.

There is thereby created a loss of a sense of community at a typical research university and, in turn, this strongly impacts curricular development, and undergraduate teaching.

There have been several surveys, one notably by Ernest Boyer, who called attention to the age-related concerns that lie in this area that are in the printed text. This is a problem that is particularly acutely felt by those under 40 years old in the academy.

Lastly, research universities have been relatively unresponsive to diversity issues—issues which, in my view, are poised to overwhelm our post-secondary institutions in the coming decade.

As an example, in 1995, the public high school graduating classes of California and Texas will be more than 52 percent minority. The disciplinary focus, as opposed to a more community focus, of our research universities make it difficult to deal with the human resource questions that are typically associated with large under-represented minority populations in our institutions.

So what recommendations for change can I give?

First, a set for our institutions—first, encourage and reinforce diversity in institutional mission. Let's not all try to be Harvard, or MIT, or Stanford. Let's encourage flexibility in rewarding faculty performance over the full range of institutional mission, teaching research and service, emphasizing quality of scholarship that is demonstrated by the record.

Here I would quote from the University of California Personnel Manual which says, The sine qua non "is superior intellectual attainment, as evidenced in teaching, research or other creative activity." That has been far too narrowly defined by most of our research institutions.

We should give the same attention to the peer evaluation of teaching that we currently give to the peer evaluation of research.

It is a self-fulfilling prophecy to say that the evaluation of teaching is too difficult and, therefore, we won't do it. We should encourage scholarly activities aimed at improving K-12 education, especially in mathematics, science, and communication skills, a matter that Dr. Vest has already addressed.

We should not leave this connection to K-12 mainly or exclusively or, indeed, at all to schools of education, but rather engage the faculty from across the university departments to aim their efforts, in part, at improving K-12 education.

And, finally, we should encourage activities aimed at improving integration and coherence of particularly the freshman year courses in science and mathematics.

We should, indeed, deal with this as a problem of attrition that is impacting at least half of the students that go into these fields in our universities in this country.

Two years ago, there was a very useful conference—a very productive conference—at Michigan, called the Freshman Year in Science and Engineering. It's all too infrequently that faculty get together across departments to talk about freshman curriculum.

Finally, a recommendation to the government and, I think, appropriately directed to FCCSET and that is, to encourage culture changes in Federal, State and other agencies that fund and evaluate institutions to focus on the above changes in universities. This is a quote taken from a very excellent report that was recently produced by the National Science Foundation.

The National Science Foundation, indeed, in my view, has gotten out in front by producing programs that are model programs for changing the focus from purely a focus on research to programs that support research in teaching and the delivery of curriculum.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Pister follows:]

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HEARING ON THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION: ACHIEVING A BALANCE BETWEEN TEACHING AND RESEARCH

Statement of

Chancellor Karl S. Pister
University of California, Santa Cruz
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before the
Subcommittee on Science
Committee on Science, Space, and Technology
U.S. House of Representatives

March 31, 1992

INTRODUCTION

The mission statements of research universities in the United States typically embrace three areas of faculty activity: teaching, research and public service. Consequently, it follows that the criteria for evaluation and reward of faculty performance should cover the same areas of activity. What has this to do with the quality of undergraduate science (and engineering) education? My response is "everything." Evaluation and reward of performance are strongly coupled to the improvement of undergraduate education. In what follows I will briefly develop an historical perspective for examining the contemporary research university to place the so-called "teaching vs. research" issue in a context that suggests courses of action. I will conclude with some recommendations for change, both at the level of the institution and the federal government.

Some 35 years ago I recall a meeting of the faculty of the College of Engineering at Berkeley at which was discussed the following proposition:

> Should graduate students who were employed on research projects, and therefore paid a salary, be allowed to use the results of their research in fulfillment of the requirements for the thesis or dissertation?

This question speaks of another era which contrasts sharply with the academic world today, and which sets a context for my remarks. It marked the end of an era during which the impact of federal support of research had a relatively small effect on undergraduate education, while at the same time marking the emergence of the "research university" of today. Among the some 3,000 institutions of higher learning in this country, American research universities have achieved undisputed success in research, service and provision of mass education. Notwithstanding this success, they have, in my view, acquired symptoms that are brought to mind by the following quotations:

> "The institutionizing on a large scale of any natural combination of need and motive always tends to run into technicality and to develop a tyrannical Machine with unforeseen powers of exclusion and corruption."

From a 1903 essay on the Ph.D. by William James.

> "Practices that begin by filling needs become detached from their original purposes, even counterproductive to them. Having been adopted on a large scale, however, these practices take on a power of their own. We place expectations on college and university faculty members that discourage them from devoting time to students and the classroom. Tyrannical machines dominate American education."

From Lynne V. Cheney's National Endowment for the Humanities Report, 1990.

Whether or not tyrannical machines dominate, or simply skew the missions of research universities, there are such machines among us. Let me briefly sketch factors that have brought this about.

AN HISTORICAL PERSPECTIVE

The evolution of the mission of American universities has reflected important societal needs at critical times. The clear focus of the early colonial colleges was on the intellectual and moral development of a (male) student body, which would in turn contribute to the public good. Indeed, the newly appointed President of Harvard College, Charles Elliot, declared in 1869 that "the prime business of American professors...must be regular and assiduous class teaching." Note that the term "research" does not yet appear in the mission statement.

The Morrill Act of 1862 and the Hatch Act of 1887 provided unprecedented opportunities for states to develop a new kind of public institution that would support both education in the liberal arts as well as mechanical arts and agriculture. The dimension of productive service was added to the mission of public as well as private universities and their faculties. A dramatic change in the mission of American universities occurred during World War II as a result of the federal government turning to academia to create a partnership needed to pursue the war effort. Following that war, the establishment of the National Science Foundation and the expansion of support for research and graduate education by federal mission agencies set the stage for the shifting of the allegiance of faculty toward discipline and department instead of school and institution. Emphasis was increasingly placed upon pure research unencumbered by social determination or utility. At the same time, however, the question of access to higher education was being redefined and institutions were being moved from an "elitist" to a "universal access" system of higher education. The civil rights movement and consequent legislation added the elements of affirmative action and a commitment to diversity to the interpretation of the mission of universities and the work of faculty.

THE RESEARCH UNIVERSITY AND SOCIETY

The national environment constitutes a sphere of influence on the affairs of universities that is profound. Just as the federal government turned to the universities during World War II to create teams to ensure survival of the nation, so are we (particularly schools of engineering) being mobilized once again, though with less clear an objective, to assist in waging the economic war of global competitiveness and economic survival. Federal agencies have exerted substantial influence over both the content as well as the style of research and service activities in which universities are invited to participate. The use of the word "invited" is a euphemism, for it is demonstrably impossible for a research university, whether public or private, to survive today without federal support. As noted in the historical overview, this state of affairs evolved after World War II, when the NSF was created and federal mission agencies became involved in the support of graduate education in the United States in a big way. Lest I might be misunderstood, I do not deplore this situation; indeed, it has produced the best university system in the world, witness its popularity among foreign graduate students, even if relatively unappreciated by our own domestic science and engineering students. What I wish to observe is that there has been an unmistakable, and probably irreversible intervention of the federal government into the affairs of our universities. There is no ivory tower, if there ever was one.

A major impact that affects all faculty has been the pressure to become a productive scholar in the sense of discoverer and reporter of new knowledge. Sources of this pressure are funding agencies, publishers of journals, universities themselves and faculty qua faculty. A vicious circle has been created. Funding agencies are dependent upon their ability to define and secure resources to launch "new program initiatives." Faculty respondents to such programs build their cases before their peers, who make value judgments largely based upon evidence of intellectual capacity reflected in published papers. Publishers of journals, motivated by economics and prestige, are constantly seeking editors for new journals, which in turn require new manuscripts. Furthermore, research universities, and in increasing numbers, institutions that aspire to become research universities, frequently expect or require their faculty members to offset academic year salary in part from extramural sources, i.e., substitute research for teaching.

Nor does this impact only the conduct of research. A direct concomitant has been the shift in faculty loyalty and allegiance toward geographically dispersed, discipline-defined peers and away from college or school and home institution. This phenomenon was quantified in the 1989 Carnegie Foundation Survey in which it was found that 75% of the faculty at research institutions rated the sense of community at their institutions as fair or poor. In a real sense, disciplinary power has diminished commitment to an institution as researchers look horizontally for recognition, impact and stimulation. In turn, universities have contributed to the process by emphasizing peer evaluation and departmental rankings. National rankings based upon media surveys have added to the problem.

How do the faculties of American research universities feel about the milieu in which they carry out their work? Not very good, according to the 1989 Faculty Survey conducted by Ernest Boyer for the Carnegie Foundation for the Advancement of Teaching. In this survey 69% of faculty respondents at research universities agreed with the statement, "At my institution we need better ways, besides publications, to evaluate the scholarly performance of faculty." Furthermore, the survey calls attention to disturbing age-related concerns: 53% of those under 40 years of age reported that "...my job is the source of considerable personal strain...," 53% agreed that they hardly ever have time to give a piece of work the attention it deserves, and finally, 43% of those under 40 agreed that, "The pressure to publish reduces the quality of teaching at my university."

These concerns are substantiated and emphasized in the recently published NSF report, "America's Academic Future," a report of the Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond.

DIVERSITY IN COLLEGES AND UNIVERSITIES

In three years the states of California and Texas will have public high school graduating classes in which so-called minority groups of students will be in the majority. An increasing number of states will join this group by the turn of the century.

Placing this exhortation next to National Research Council 1990 data on engineering doctoral degrees conferred shows the urgency that one must attach to the "people-side" of diversity:

Of the 4,892 degrees conferred in 1990, the following characteristics appear:

91.5% awarded to males
39.4% awarded to U.S. citizens
1.5% awarded to African Americans
2.1% awarded to Hispanic Americans

A recent AAAS report, "Investing in Human Potential" examined programs designed to assist minorities, women and people with disabilities to enter and complete science and engineering programs in 276 institutions. Their conclusions, taken together with the data above and the demographics of our nation, place a clear imperative on all engineering educators. We can no longer afford to view the student pipeline problem as a marginal activity; we cannot afford to think that achieving diversity in our institutions and our profession can be accomplished by a process of assimilation into an existing, stable institutional configuration. What we badly need, in my view, is the will to examine, design and implement necessary structural changes in engineering education.

Fortunately, there is really no lack of models for reshaping the way education can be approached. Programs such as MESA in California, along with similar programs in other states, are examples of how university faculty and staff can work with teachers and students in K-14 to sustain the pipeline of students motivated and qualified to enter careers in science and engineering. The problem for these programs (not with such programs) is that they are marginal--both in funding and in occurrence. Such programs are needed for more schools and for all (not just minority) students.

Common characteristics include motivation, group activities as opposed to "rugged individualism" in learning situations, setting high standards and goals, and parental and community involvement, among others.

At the university level a great deal can be learned from the experience of students at historically black institutions. An excellent example can be found in a recent paper, "Preparing Minorities for Science Careers," by Carmichael and Sevenair, in Issues in Science and Technology (Spring 1991). This paper demonstrates the success of Xavier University in placing its graduates into mainline health-professional schools during the past decade. While provision of a nurturing environment that emphasizes success instead of jumping through increasingly difficult hoops is a cornerstone of the program, some of their experience translates directly to science and engineering curriculum designers.

As noted in the AAAS study cited above, there is a lack of understanding of diversity as an issue central to the academic core of our institutions. A second dimension of diversity has to do not with people but with institutions and their missions. Here again there is need for careful examination of structure and purpose, avoiding marginalization. The 328 institutions offering engineering programs in this country should be encouraged to explore new directions and find new roles in the engineering educational system.

"Mission diversity" is urgently needed in our engineering schools today. We need new role models to complement the so-called "research university" model. The nearly 200 engineering doctoral institutions, with minor exception, are all aspiring to become a top 20 research institution. In a recent paper in Change entitled "The New Race to be Harvard or Berkeley or Stanford," Clark Kerr noted the following:

> All 2,400 "specialized" institutions of higher education in the United States aspire to higher things...These aspirations grow not only out of internal desires but also out of the expectations of members of their communities--their alumni, their states, their related industries and professions.

A consequence of this kind of race is discussed in a recent paper of NAE President Bob White. Writing in The Bridge, he called attention to the mismatch in resources available and institutions and investigators vying for these resources. In his view, which I share, there is an over-emphasis on the production of engineering researchers, who increasingly must compete for very limited resources, at the expense of engineers advancing the state of professional practice, especially manufacturing. Similar conclusions may be drawn for other fields as well.

SOME RECOMMENDATIONS FOR CHANGE TO STRENGTHEN UNDERGRADUATE EDUCATION IN SCIENCE AND ENGINEERING

It is the view of many faculty, and I strongly share that view, that a central problem in the evaluation and reward of faculty performance is the overly narrow view taken in assessing intellectual attainment and creativity. Ernest Boyer, in Scholarship Reconsidered, urges that we move beyond the "teaching vs. research" argument and examine the quality of scholarship, assessed over four activity areas. He suggests that the work of the professoriate be thought of as comprised of four separate, yet overlapping functions. These are:

scholarship of discovery
scholarship of integration
scholarship of application
scholarship of teaching

The term "scholarship of discovery" is typically equated to "research." The search for new knowledge will unquestionably remain at the core of the mission of a research university. Yet, Boyer contends:

> There is need for scholars to work at making connections across the disciplines, placing specialties in larger context, illuminating data in a revealing way, often educating nonspecialists, too.

This, he calls "scholarship of integration."

"Scholarship of application" is embodied in the work of faculty members that flows directly from their professional knowledge. It may be, but is not limited to, the innovative practice of a profession; it may be the application of knowledge to a consequential social problem. In every instance, the same measures of accountability, as applied to the scholarship of discovery, are required.

The "scholarship of teaching" moves well beyond the commonly accepted notion of the teacher as a classroom performer, or as a tutor of a single individual, for the mere transmission of knowledge. Teaching incorporates these activities but is concerned more broadly with the synthesis and extension of knowledge, i.e., the transformation of knowledge. It is self-evident that much of what constitutes the scholarship of teaching goes on outside the classroom or student-faculty conference.

The faculty of all institutions of higher learning share, or should share, the responsibility for the synthesis, application and transmission of knowledge, i.e., the scholarship of integration, application and teaching. The scholarship of discovery is properly focused, though not exclusively, in research universities. Efforts that encourage the former categories of scholarship are most likely to improve the quality of undergraduate education. Efforts that encourage the scholarship of discovery are less likely to do so, although there can be exceptions. The reasons behind these assertions are clear and unassailable: institutional economic survival and prestige, as well as faculty prestige and honors, are directly related to the scholarship of discovery and are virtually disconnected from the other categories of faculty activity.

To further emphasize the point, I quote from a Stanford faculty member at a panel discussion on integrating teaching, research and community service (as reported in the Stanford Magazine, Dec. 1991):

> Faculty don't talk to each other about their public service. It doesn't count. It smacks too much of applied research--that's the kiss of death."

The value system currently in place in research universities is a product of both internal and external influences and pressures. The response of faculty, in my view, is both prudent and necessary for survival. Faculty are not the problem. Indeed, national surveys have made it clear that the majority of faculty in our research universities are not satisfied with the current value system for judging faculty performance--one that is strongly biased in favor of scholarship of discovery, or "research."

Federal funding policies are strongly coupled to the value system currently in place in our research universities. In particular, the National Science Foundation has already taken the lead in demonstrating how to change the culture in our institutions. For example, the Engineering Research Center Program placed emphasis on scholarship of integration and application. The Undergraduate Engineering Coalition Program emphasized both the diversity issue and the scholarship of teaching. The Directorate for Education and Human Resources is increasingly engaging university faculty to utilize their expertise and resources to improve the quality of undergraduate education, and equally important, K-12 mathematics and science education. In short, faculty in research universities are being encouraged to engage in scholarly activities aimed at improving instruction in mathematics, science and engineering.

What response can be expected from our universities? If federal agencies follow the lead of the NSF and broaden the base of funding for universities to embrace the full range of scholarly activity, simple economics will dictate the response. An important concomitant will be increased attention to teaching and the integration and application of knowledge.

I am persuaded that there is both interest and commitment among university faculty to make needed adjustments in allocation of effort among teaching, research and service.

I base this opinion on the data from Boyer's survey, a survey of 900 faculty at five University of California campuses and the enthusiasm evident at a 1990 symposium on "The Freshman Year in Science and Engineering," held by the Alliance for Undergraduate Education under NSF sponsorship. There is a strong desire for a cultural change that places greater emphasis on coherence and integration of subject matter in undergraduate education--outcomes that will flow from the scholarship of integration and of teaching.

Before the question of "What will happen to the level of effort in scholarship of discovery?" is raised, let me respond. I hope and I expect that it will ease off, and I cannot consider this to be anything but a good thing for research universities and our nation, not to mention undergraduate students. There is no basis for continuing to force all of our faculty into the mold of "discoverer" and reporter of new knowledge--there is neither the need nor the resources to make this possible at the rate at which it has been accelerating during the past few decades. What is needed is the encouragement of a full range of scholarly activities supported by federal and state agencies, together with appropriate evaluation and reward within our institutions.

Restoration of balance among the activities of faculty, as well as flexibility in permitting a range of career paths, must be the hallmark of the faculty reward system. Achieving balance at the level of the department, college or school--rather than in individual faculty--should inform institutional policy.

In closing I will draw on two statements crucial to effecting change in undergraduate education. The first appears in the NSF report cited above, while the second is found in the "Report of the Task Force of the University of California."

1. Federal, state, and other agencies that fund and evaluate education must undergo as much of a change in culture as that of academe.

2. Review of faculty teaching and evidence collected to document teaching performance should be broadened. Peer evaluation of teaching should be given the same emphasis now given to peer evaluation of research.

Mr. THORNTON. Thank you very much, Dr. Pister, for an excellent summary of a very fine paper. I enjoyed reading that.

Our next witness, Dr. Carlisle, is the Senior Vice President and Provost of Virginia Poly Tech Institute and State University at Blacksburg, Virginia.

You are certainly welcome here, as a neighbor and as a great educator. I know that the regular chairman would want me to extend his best wishes to you as well.

Dr. Carlisle, we'll make your prepared testimony a part of the record at this point, as though you had read it, verbatim, and ask you, please, to hit the high points of it.

STATEMENT OF DR. E. FRED CARLISLE, SENIOR VICE PRESIDENT AND PROVOST, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, BLACKSBURG, VIRGINIA

Dr. CARLISLE. Thank you very much, and good afternoon.

I speak here from the perspective of the large public research and land grant university, and in that sense, I think I bring a somewhat different perspective. Of course, I speak primarily out of my own experience at such a land grant university.

Also, even though ENG are the first three letters of my academic background, I am, in fact, an English professor. Whether that explains the slightly different angle I will take here, I don't know. I would like to sharpen the issues.

We are, I believe, in the late stages of a profound academic revolution in this country. In 1968, that long ago, Christopher Jencks and David Riesman identified that academic revolution and they said, very simply, this.

"The American graduate school (or research university) has become the envy of the world, a mecca for foreign students and a model for foreign institutions. It has also become one of the central institutions of American culture. Both the best and the worst in undergraduate education emanate from it."

I repeat that. In a sense, that's my theme, both the best and the worst emanate from this really rather grand achievement of the research university in the United States.

In many respects, as I've suggested, very little, in my judgment, has changed since 1968. Now, the fruits of this revolution are, in some cases' very sweet and grand, and in other cases, they are, I believe, bitter.

Most of us recognize the benefits of the large research university, and I don't think I need to repeat those. They obviously preserve, maintain, and create basic knowledge, and so on and so forth.

I think we are also beginning to understand the costs of this revolution—the costs of the achievement of the research university. So I say this, very simply. At its worst, the research model leads to a suffocating, disciplinary tyranny. It reinforces nationalized professions and individualized faculties. It leads to greater and greater attenuation of community and institutional bonds.

It weakens institutional purpose—that purpose which is usually part of a university's individual tradition and history, part of its culture. It diminishes, at its worst, mind you, the importance of instruction.

At its best, and I remind you of that, it is an extraordinary achievement.

The solution, to what I see as a serious dilemma, if not crisis, is simple—at least it's simple to say, if indeed difficult to achieve. I cast that, really, as a question—a question that demands an answer.

How can we, at major research universities, assure that undergraduates are taught well, learn effectively, and lead satisfying intellectual and social lives, and how can we, at the same time, sustain and enrich university research, strengthen graduate programs, and fulfill our broad responsibilities to the public?

I make these generalizations both knowing that they are true and not true. There is a great deal of admirable, effective, devoted undergraduate teaching and concomitant learning occurring in research universities.

But nevertheless, and even though I could cite you many departments on my own campus, I think my basic claim about the best and the worst is correct.

The balance of my testimony really speaks to three different topics—first of all, to undergraduate science education, then to the enrichment of undergraduate education, broadly, and finally, to means for changing the faculty reward system.

I will cite primarily specific examples from Virginia Tech, because I know those. They are concrete, and not because I'm making any special claims for Virginia Tech or trying to promote the university.

The problems of undergraduate science education are rather well known.

Mr. THORNTON. Dr. Carlisle, we will accept very brief commercial endorsements of your own institution.

Dr. CARLISLE. Then, I should tell you about the beautiful Allegheny Mountains, the wonderful new river, the fine—no I'm sorry. I will go on with the more studied part of my testimony.

I would cite two kinds of examples regarding undergraduate science education. Let me assume that we understand what some of the problems, limitations, and even defects of those are.

First of all, it seems to me, that there are a number of university-wide kinds of things we must do. My written testimony actually quotes President Vest. He said, I believe—I hope I'm right, he's here—to his faculty, "Let me begin with one simple statement. Professors should profess. It is hard to think of anything more illogical than to become a university professor if one does not want to teach. So if you do not want to teach, you should immediately look for another job."

I hope I'm accurate.

Dr. VEST. You are.

Dr. CARLISLE. Thank you.

And how do we do this? It seems to me that across the university, we can (and have at Virginia Tech) revise our promotion and tenure guidelines so that, in fact, we emphasize teaching. We require the demonstration of effective teaching much more broadly than we have in the past.

Now, we can teach our graduate assistants how to not only be better and effective undergraduate teachers, but we can also prepare them—we can socialize them, in effect—for entering the profession of the future professoriate.

There are also a number of examples related to undergraduate science education that I might cite that speak to programs, and I will mention only one.

Our college of engineering is part of an NSF-funded coalition called "SUCCEED." The SUCCEED Program is trying to revise in a fundamental way the way America's engineers are educated.

It focuses on undergraduate programs, it focuses on bringing design into courses earlier, it will work toward more and more technology in computing in undergraduate engineering, and at the same time, it also intends to bring more women and minorities into undergraduate engineering programs.

The next specific set of things. We have what we are calling a Virginia Tech plan for undergraduate education. It is a plan that has a number of specific examples, all of which are outlined in my written testimony. In a few seconds I will cite one or two.

The basic assumption here is that as a research university, we have to enhance and revitalize our commitment to undergraduate education in that context, in terms of that history. We cannot return a state university such as ours to an era before all of these changes, all of these achievements of the research university occurred.

So, among many other things we have, in fact, revised fundamentally our liberal education requirement for all students. It benefits science students. It benefits all undergraduates. It continues the importance of students taking science and mathematics, and it also provides an opportunity for engineering and other technological disciplines to provide liberal education courses.

We have established with state funding a new center for excellence in undergraduate teaching. We have allocated clearly additional positions to undergraduate education, and we have assigned administrators with responsibility for the improvement of undergraduate education. As I mentioned, we have revised the promotion and tenure guidelines, and there are other examples as well.

We have also introduced what we are calling the Virginia Tech plan for reforming the reward system, or what I call, and many of my colleagues across the country call "promoting multi-dimensional excellence."

My testimony outlines in far greater detail than you would like me to summarize here a specific set of actions that engage the faculty, department heads, deans, and the university administration in discussions about the reward system, about the expectations we set for people, about how we will evaluate them.

It's a two year project-necessary, I think, in order to affect the underlying culture of the research university. It is not something that is simply superficial.

I do believe that we are in a crisis. My colleagues, occasionally, claim that I exaggerate the statement, but I do believe it's a crisis.

I do believe we are at least in a real dilemma. How are we going to achieve the new balance between teaching research and, I might add, public service?

We have good models in universities. We have a number of concrete actions that have been taken, and so obviously, I'm optimistic in spite of the fact that I think we are in the late and decaying stages of a revolution

Thank you.

[The prepared statement of Dr. Carlisle follows:]

TESTIMONY

to the

Subcommittee on Science

Committee on Science, Space, and Technology

U. S. House of Representatives

Rich Boucher, Chairman

by

E. Fred Carlisle

Senior Vice President and Provost

Virginia Polytechnic Institute and State University

Blacksburg, Virginia

UNDERGRADUATE EDUCATION AND THE REWARDS SYSTEM AT RESEARCH UNIVERSITIES

Congressman Boucher, Members of the Sub-Committee:

Good afternoon. My name is Fred Carlisle. I am Senior Vice President and Provost at Virginia Polytechnic Institute and State University --also known as Virginia Tech. With me are Dr. Gary Hooper, Vice Provost for Research and Dean of the Graduate school and Carol Burch-Brown, Associate Provost for Undergraduate Programs at Virginia Tech.

I appreciate this opportunity to speak to you about the vital issues of concern to the Sub-Committee. These matters are critical to Higher Education. They are the focus of significant change at Virginia Tech.

During my remarks, I will comment on the state of undergraduate science education, but given my work with colleagues across the country to reform the faculty reward culture, I would like to speak, as well, about the faculty reward system and the several issues you have associated with it -- the way the system may be biased toward research, the way the system functions in faculty promotion and tenure decisions, the means we use to evaluate faculty achievements, and the ways we are working to reform undergraduate education and establish more appropriate balances among teaching, research, and outreach.

There has been an academic revolution in this country. It began over 40 years ago. We are now experiencing its fruits. Some are sweet, and some are bitter. We are also in the midst of a crisis brought on by that revolution. As far back as 1968, Christopher Jencks and David Riesman, in a book titled, The Academic Revolution, defined both the marvels and the costs of the dramatic changes in Universities. "The American Graduate School [or research university] has become the envy of the world, a mecca for foreign students and a model for foreign institutions. It has also become one of the central institutions of American culture. Both the best and the worst in undergraduate education emanate from it." In certain respects, very little has changed.

Most recognize the benefits. The American graduate school, or research university, is a great achievement, and we can be justifiably proud of what has emerged. The research university preserves and maintains basic knowledge and programs. It creates new concepts, philosophies, arts, and technologies. It transfers new concepts and technologies to industry and government. The Research University attracts supplemental funds in large amounts as well as other material resources. It educates and trains graduate and professional students and it certainly enriches the education of undergraduates. These benefits stand, they are very real, and I would defend them over and over.

We are beginning, as well, to understand more clearly the costs of the achievement. For too long, graduate schools have focused too much on research and scholarship and the professional aspirations of faculty. For too long, research universities have devalued undergraduate teaching. Research has become the premier activity in Universities. It has been the path to greatest advancement and prestige.

At its worst, this model leads to a suffocating, disciplinary tyranny. It reinforces nationalized professions and individualized faculties. It leads to greater and greater attenuation of community and institutional bonds. It weakens institutional purpose -- that purpose which is part of the university's tradition and history, part of its culture. It diminishes, in short, the importance of instruction.

At its best, the American research university is an extraordinary achievement. These institutions dominate international research in science and engineering and educate by far the largest numbers of science and engineering doctoral students in the world. Currently, Research I and II institutions (Carnegie Categories) represent only 5% and 2% (respectively) of all institutions offering science and engineering undergraduate degrees. Yet they award two thirds of all national science doctorates, three quarters of engineering doctorates, and over 50% of all social science and psychology doctorates. These same universities are the source of about two thirds of those students who go on to receive all doctorates.

It is important to acknowledge, as well, that American graduate and research universities prepare significant numbers of advanced degree holders in the humanities, social sciences, and the professions. Moreover, research universities like Virginia Tech -- large state land-grant universities -- educate huge numbers of undergraduates -- 30%, for example, of all science and education bachelor's degrees. And where it's done right, those students learn in a stimulating environment where the science and engineering programs -- and others as well -- are current and active in discovery and the advancement of their fields.

Nevertheless, there is a serious dilemma and crisis. Both the best and the worst of undergraduate education flow from research and graduate institutions.

The solution in certain respects is simple -- at least it is simple to describe, if difficult to achieve. The research universities must make certain that we fulfill all of our primary responsibilities in teaching, research, public service, and outreach as well as we have been accomplishing our research missons. Cast as a question: How can we assure that undergraduates are taught well, learn effectively, and lead satisfying intellectual and social lives, and now can we, at the same time, sustain and enrich university research, strengthen graduate programs, and fulfill our broad responsibilities to the public? A daunting order -- but society asks it of us. Therefore, we simply must find the answer.

I make these broad generalizations knowing well that what I'm saying is true and not true. That is not a contradiction, simply a paradox. Large universities are very different from one department to another. There is a great deal of admirable, effective, devoted undergraduate teaching and concomitant learning occurring in research universities. Just last week, for example, I visited Virginia Tech's Department of Biochemistry. The Department enrolls 250 undergraduate majors and 30 graduate students. It's one of the largest biochemistry programs in the country. The faculty integrates undergraduate instruction, graduate study, and faculty research very well. The department provides a classic example of how greatly undergraduates can benefit from departments with strong research and graduate programs. Even so -- and I could find many other examples across the Virginia Tech campus of fine undergraduate teaching -- my basic claims, about the best and the worst, e.g., are correct. Therein lies the problem and the challenge.

The balance of my testimony will speak more to answers or solutions than to problems. After all, that is what we are all interested in -- what is being done and should be done to improve the situation. I will cite examples largely from my own institution, less to promote Virginia Tech than to show you specific action for change. I will speak to undergraduate science education, to the Virginia Tech plan for all undergraduates, and to the reward system.

2.

Undergraduate Science Education

Problems:

Even though recent data shows an increase in bachelor, masters and doctoral degrees in the sciences and engineering in the past decade, the issue of the quality of these degrees remains. I would like to cite briefly a series of concerns.

1. Most undergraduate institutions offer fewer and fewer "hands-on" laboratory experiences and depend increasingly upon large lectures.

2. It has been difficult for colleges and universities to maintain state of the art instructional equipment, and it is not unusual for graduates entering the work force to find the equipment they are expected to use as professionals much more sophisticated than that they used as undergraduates. Were it not for Virginia's extraordinarily helpful Equipment Trust Fund, Virginia universities would be hopelessly behind. Next year, there will be $40M available - $8M for Virginia Tech alone. The fund is intended to provide equipment for instruction.

3. A more important matter is how we are teaching. In the face of an information explosion, we persist in a curriculum emphasizing mastery of discipline detail. We seem more interested in the ability of students to give us the "correct" answers than in teaching them how to think and how to formulate questions of their own. At a time where science problems are complex, we still concentrate on the part, and not the whole, and have little regard for teaching that causes students to learn together. We also have not utilized, nearly as much as we should, a variety of teaching technologies now available. At best, we have integrated them very slowly into our physical and natural science curriculum. A Virginia Tech report, "The Impact of Digital Technology on the Classroom Environment," established the University as a national leader in thinking about the issue. Yet, we have a great deal to learn from our own study.

4. And finally the basic problem of the culture and the reward system. Since research oftentimes results in greater rewards than teaching, many faculty over the years have placed their priorities and efforts on research. Too often, as a result, important classes have been increasingly taught by junior faculty and graduate assistants, particularly the critical introductory classes in science.

The problem with undergraduate science education results from a combination of circumstances: 1) poor early preparation and motivation in our pre-college education, 2) inadequate teaching facilities and equipment, 3) out of date teaching techniques, and 4) an imbalance amongst research and scholarship, teaching, and public service priorities.

Solutions.

Colleges and universities cannot redress all of the problems -- especially those in pre-college education. They can, however, establish closer ties with community colleges and K-12 schools. These relationships can range from added training and support of existing teachers and courses to shared curricula. In some cases, early identification of students inclined to science can lead to advanced placement programs, summer research experiences, and other direct associations.

More importantly, colleges and universities can equip the next generation of elementary and high school teachers with sound training and a new approach to curriculum and pedagogy. Since most high school science texts are written by college and university professors, university faculty could write a new chapter in science education by revising these texts and workbooks.

As important as these activities are, we have more direct control over college and university science and engineering education. We need to re-affirm our responsibilities for teaching and for student learning. Charles M. Vest, President of M.I.T., and one of the Panel members today, recently admonished his faculty:

> ". . . Let me begin with one simple statement. Professors should profess. It is hard to think of anything more illogical than to become a university professor if one does not want to teach. So if you do not want to teach, you should immediately look for another job." (Colloquium Address, Nov. 5, 1990 - as cited in America's Academic Future - NSF 1992).

5

Direct and succinct, President Vest's message is -- must be -- compatible with the role of research universities.

Our mission also includes public service and outreach. We have not recognized this satisfactorily in our expectation and reward system. Ernest L. Boyer, in his recent report, "Scholarship Reconsidered," notes that:

> "At no time in our history has the need been greater for connecting the work of the academy to the social and environmental challenges beyond the campus. And yet, the rich diversity and potential of American higher education cannot be fully realized if campus missions are too narrowly defined or if the faculty reward system is inappropriately restricted. It seems clear that while research is crucial, we need to renewed commitment to service, too.
>
> Thus, 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 is means to be a scholar. It's time to recognize the full range of faculty talent and the great diversity of functions higher education must perform . . ."

At this point, it may be helpful to cite a number of concrete examples, to show possible solutions.

1. Virginia Tech, has recently revised the criteria for Promotion and Tenure. We (and I expect other universities, as well) can rather skillfully represent and evaluate research and scholarship. We have been doing it for years, and everyone, so to speak, knows that research is what counts and that you can't evaluate teaching, anyway. The new guidelines require faculty and department heads to evaluate teaching effectiveness in a number of ways and ask them to place that section first in Promotion and Tenure dossiers. Except in Cooperative Extension assignments, we have done an abysmal job of defining, evaluating, and rewarding public service and outreach. Our new guidelines not only allow faculty achievement to count, they also require more thorough documentation and demonstration of effectiveness.

2 The University assigns many exceptional graduate students to instruction. To assure their competence, we have developed an orientation and education program in teaching method and philosophy.

It also speaks to research and the profession. The program not only helps prepare informed and effective graduate assistants; it also begins the education of the future professoriate.

3. The University has just completed a substantial revision of the University's liberal education requirement. Science and math occupy a critical portion of that curriculum, and technology - if the faculty so wishes - may play an important part in the core curriculum, as well. All students will continue to take courses in science and mathematics.

   The Head of the Chemistry Department recently wrote:

   > "While one mission of a chemistry department is to prepare students for careers in chemistry, this is certainly not the only one. In terms of sheer numbers more non-chemistry majors will take chemistry courses than majors. These non-major students have a variety of backgrounds and reasons for taking chemistry. Much has been written lately about the need to expose science and engineering students to arts and humanities. The other side of the coin, though, is perhaps equally important: in these days of great technological changes, everyone must be sufficiently versed in the sciences to be able to grasp important science-based issues and make informed judgments."

4. Colleges and universities must re-examine their teaching philosophies and specific major programs in science and engineering. The Virginia Tech college of Engineering has become part of the NSF-sponsored educational coalition, "SUCCEED," which is trying to reshape the way America's engineers are educated. This group of eight southeastern engineering colleges plans to develop and implement curriculum changes with a focus on integrating engineering design into all subject areas and on breaking down the academic barriers which too often separate engineering studies from science, math, and the humanities.

   "SUCCEED" also intends to increase the enrollment and retention of minorities and women in engineering and to fully utilize the potential of the Virginia Community College System as a source of engineering students. A program called "Partnership in Engineering Education" will unite the college with its community college counterparts around the state and throughout the southeast.

Consistent with the necessity of integrating new pedagogical technology into programs, "SUCCEED" has established a "Center for Technology and Communication" at Virginia Tech which will assist the entire coalition in developing multimedia labs for instruction. It will examine, as well, ways to better use satellite and other distance learning technologies.

5. The Physics Department is pioneering the use of mathematics and physics software and computer simulation capabilities to enhance classroom and laboratory experiences. Working with the private sector, the Department has become a test site for CUPLE, a computer simulation and multimedia program.

6. Finally, I would like to address the appropriate training and orientation of the next generation of teachers, educators and professors. As these individuals assume positions in school districts as elementary, middle and high school teachers and as college faculty, real change can and must occur.

   I cite simply one further example of science education from Virginia Tech as a type of what can be done. The Department of Geological Sciences is engaged in a cooperative venture with the College of Education and the Virginia Association of Science Supervisors and the Virginia Association of Science Teachers -- VASS and VAST. They are seeking to train both existing and future middle and high school teachers in current Earth Science topics. The Department Head states:

   > "Both VASS and VAST have stressed that they feel the state needs more properly trained earth science teachers and programs to help those who are presently handling such courses. This is especially important as we face increasing concerns about such items as resource availability, environmental degradation, clean water availability, coastal erosion, acid rain, power generation, and waste disposal and ground water pollution. We have recognized that our department has heretofore not addressed the potential for meeting the needs of students who show desire to teach earth science in the high schools and middle schools. Accordingly, we have had faculty discussions for the past several weeks, and our Curriculum Committee prepared a proposal for an "Earth Science Education Program."

3.

The Virginia Tech Plan for Undergraduate Education.

Since our society depends to such a great extent on the continual development of new technologies and new knowledge, universities -- and in particular research universities -- are at the heart of some of the most essential processes of change in American culture. The fundamental identity and character of public research universities has been largely shaped **by** the larger currents within American life -- rather than in isolation **from** them. The development of the research university is, therefore, as much a product of changing societal priorities as is the current call for a "restoration" of balance between research and teaching. The current challenge cannot, however, be answered by returning to the past and recreating the undergraduate environment prior to the growth and transformation of state universities. The social, demographic, economic, and cultural realities which shaped American education in the past have all changed. Something new is needed. Along with others, we are trying to answer a series of questions in order to achieve the "something new."

- What does the environment of the research university mean for programs of undergraduate education, particularly for the focus and quality of undergraduate teaching?
- Is the research university context compatible with the needs of a culturally diverse population of 18-21 year-olds for a basic undergraduate education?
- What is an adequate basic education as we enter the 21st Century?
- How can we maintain an effective balance between instruction and research and reward faculty for their contributions to both these missions in the midst of economic instability and often of permanent reduction in resources?

At Virginia Tech, we have undertaken a number of measures to strengthen undergraduate education. We are forging a dynamic approach to undergraduate education which builds both on the character of the school as a research institution and on the traditional charge to land grant institutions to be the "universities of the people." As a public institution, we serve a student population which is talented -- but not usually wealthy -- and bright -- but with wide variations in educational and cultural backgrounds and in its preparation for college level-work.

Some Virginia Tech students are naturally motivated and prepared to take advantage of this opportunity. Many are not. The great challenge presently facing public research institutions is not primarily to ask faculty to teach more undergraduate classes (although that is often the public perception); it is, instead, to galvanize faculty intelligence toward creating and sustaining learning environments which support and motivate a high level of student effort throughout the institution. Doing this requires faculty at all levels and ranks to work collectively, rather than primarily as individual researchers, scholars, advisors, or even instructors.

Like most research universities, Virginia Tech has many fine teachers, most of whom have received the best graduate training available in their disciplines. I want it no other way. But the prevailing culture in research universities encourages faculty members to give their primary intellectual allegiances to their national research organizations and networks rather than to the immediate university. To the extent that satisfactory learning communities are created in this context, they are often established at the graduate level -- rather than the undergraduate -- where students share a high level of motivation and commitment to learning which is, not surprisingly, similar to that of the faculty.

In the reform of undergraduate education at Virginia Tech, we are trying to learn from the success of our graduate programs and from our knowledge of the deep level of engagement faculty have with their disciplines What becomes immediately clear is 1) that faculty willingly commit themselves to work on issues which they perceive as having genuine and significant intellectual content and 2) that students and faculty develop effective learning communities only around issues of common concern. We are relying on these two rather obvious but essential insights to inform a variety of initiatives in the undergraduate program.

1. **Reform of the structure, curriculum, and pedagogy of the University Core Curriculum -- the liberal education requirement.** The new Core defines an exemplary program of liberal education which is designed to serve students and faculty into the next century. Literally hundreds of faculty members participated in discussions about the Core and made recommendations for change. The new program defines the intellectual purposes of the core curriculum in the unique context of our university and redefines each area of study in those terms. It has been formally adopted by the university The community has now entered a period of significant undergraduate curricular and

pedagogical reform. The process has engendered a new sense of vitality and interest in the undergraduate program among senior as well as junior faculty. We are, in a real sense, engaged in changing the institutional culture with respect to connections between research and undergraduate teaching at Virginia Tech.

Beyond revitalizing courses in traditional areas of liberal arts and sciences, the new program creates a means through which the faculties in Engineering and the professional colleges may participate in the liberal education curriculum. The new core establishes a vision for liberal education and a means of achieving that vision which is appropriate for our identity as a research and land-grant institution.

2. **Establishment of a Center for Excellence in Undergraduate Teaching.** Maintaining the vitality of the curriculum is only one part of strengthening the undergraduate program. Sustaining an environment which supports and rewards effective teaching is equally important. The Center for Excellence in Undergraduate Teaching will provide a university-wide base for a wide range of faculty development and classroom research projects, and its programs will be led by faculty. Some Fellows of the Center will help prepare new faculty for undergraduate teaching and provide consultation for departments involved with improving teaching effectiveness. Others will guide curriculum development related to new areas in the University Core Curriculum and the University's new Writing Program. The Center will also serve as a "think tank" on a variety of different issues. The Center faculty, e.g., might assist the university and administration think about the most effective ways of rebalancing the reward system.

3. **Allocation of additional positions for undergraduate instruction and the core curriculum.** During the recent budget crisis in Virginia, the University has given the undergraduate program and the core curriculum a very high priority by allocating a number of new positions to these areas. These are controversial, but crucial, decisions -- both to serve students well and to make necessary institutional changes. The administration has made public commitments to the undergraduate program. These have been accompanied by the appointment of individuals specifically charged with undergraduate responsibilities -- including and Associate Provost for Undergraduate Programs, a new Honors Director, and staff members in key academic support units. These staff members are deeply and visibly engaged with the undergraduate programs throughout the university.

4. **Establishment of innovative new programs to reward and recognize departments and groups of faculty members.** Most of our rewards for excellence -- whether in teaching, research, or academic advising -- are based on individual achievement and merit. Yet the health of the undergraduate program surely depends as much on the collective commitment of faculty members in a given department as it does on the exemplary work of key individuals. Decisions, for example, about the use of resources, the distribution of teaching responsibilities, released time for research and other projects all have an impact on the program's undergraduate program. At Virginia Tech, we are establishing several major annual awards which will go to departments and academic units which maintain an exemplary teaching and learning environment both for students and faculty. Public honor and reward of collaborative and collegial activity by faculty and department heads is important to building the momentum of the undergraduate program.

5. **Revision of the promotion and tenure guidelines.** Promotion and the awarding of tenure is perhaps the strongest single message the university sends about its priorities and sense of identity. Virginia Tech, like other major research institutions, has very high expectations of faculty in the area of research and scholarship. We believe this is appropriate to the mission and potential of the university. We also are setting high expectations for achievement in teaching, advising, and public service -- as I indicated earlier.

6. **Changes in academic policy to improve retention.** Some students come to the university prepared to take advantage of the unique opportunities it offers them. But many do not. Large public research universities have both strengths and limitations in trying to help students who are not performing up to their level of ability or who are trying hard but are ill-prepared for university-level work. On the one hand, we are large enough or offer many support services and academic programs. On the other hand, it is too easy for students who are in trouble to be overlooked. Virginia Tech has just completed a major study of student retention. We are implementing changes related to this study.

7. **Strengthening of the University Honors Program.** Over the last two years the number of students participating in the University Honors Program at Virginia Tech has more than doubled, and the program has become one of the most important sources of new ideas for the undergraduate programs as a whole, thanks to the energetic and imaginative leadership of its director and participating faculty. The

Honors Program has been directly linked to the core curriculum through the development of special approaches to standard, non-honors courses as well as through special sections of core courses. The innovations introduced through the Honors Program will influence the larger curriculum, so that many students are benefited.

8. **Keeping undergraduate programs and issues before the faculty and the university community.** The central administration and the deans have taken public and visible leadership roles in focusing the attention of faculty and staff on undergraduate issues and in providing support for faculty initiatives.

4.

The Virginia Tech Plan for Reforming the Reward System: Promoting Mulit-Dimensional Excellence.

Virginia Tech is engaged in a broad reappraisal of the faculty reward structure of the university: the processes, activities, and indexes through which we encourage and evaluate faculty participation in the various missions of the university. We are searching for more effective and appropriate ways of rewarding multi-dimensional excellence in faculty achievement and contribution. The need to promote good teaching and service through the reward system of the university is widely recognized both within and outside the academy. It is a topic which has been raised in significant ways at Virginia Tech through public statements from the President and Provost and through specific actions, such as revising the promotion and tenure guidelines to describe more clearly the value we place on teaching. We have endowed two professorships connected to teaching and have established an innovative new award related to these chairs, the Diggs Teaching Scholar and Roundtable, which gives our faculty an opportunity for public dialogue between some of our exemplary teachers and well known commentators on higher education in America.

We are joining with other universities in the Commonwealth and with institutions across the country to promote multi-dimensional excellence. Universities in the Big Ten, the Council on Academic Affairs of National Association of State Universities and Land-Grant Colleges, and the American Association for Higher Education are leading the movement.

Virginia Tech's project will focus on people in three academic sectors of the university most directly concerned with the faculty reward structure: the faculty. central administration and deans/department heads. Each will be called on at specified intervals to provide leadership; at other points each will follow the lead of others. What is desired is a collegial process in which all constituencies -- whether faculty or administration -- have a stake.

In the arena of faculty rewards. Departments and colleges need to be able to perceive themselves as changing with the institution. rather than in isolation from it. Thus, the focus of this project is on cultural change in the larger university environment.

<u>The Plan.</u> **Year 1, 1992/93**

1. Spring, 1992
   The President and Provost announce several related initiatives: a Funds for Excellence [1] project to examine the faculty reward system, the establishment of the new Center for Excellence in Undergraduate Teaching. and the initiation of new major awards of $12,000 each for departments which create and sustain exemplary learning and teaching environments for both students and faculty.

2. Spring, 1992
   General guidelines for the new award will be drawn up. The focus of the award will be on the quality of the teaching and learning environment which is fostered by the department as a whole.

3. Summer, 1992
   A Faculty Seminar will be convened for an intensive two week period during the summer to study and consider the faculty reward system here. The group will be charged to write a position paper by the end of the seminar on the reward system. The seminar will be limited to 10-12 influential and respected faculty members, carefully selected to encompass the range of commitments and varied points of view about faculty rewards which predominate at Virginia Tech.

4. Fall, 1992, before classes begin.
   The annual fall Deans' Retreat will focus on the faculty reward system. A substantial part of the discussion will be guided by members of the Faculty Seminar, using the position paper which they wrote earlier in the summer along with other readings and materials. The

[1] The University has made a proposal. a decision has yet to be made

deans will write short individual responses to the position paper, which will be shared during the retreat. The Faculty Seminar paper and the deans' responses will subsequently be used by the department heads in each college as a framework for examining how the reward system functions in the context of their own departments.

5. Fall, 1992
   Current baseline information about how faculty perceive the reward system will be collected through a faculty survey, utilizing questions developed by the Faculty Seminar during the course of its study in the summer.

   Based on results of the survey, we can determine at least in a general way the degree of change we wish to create in the cultural environment with respect to faculty rewards. We will repeat the survey at the end of the biennium, comparing the attitudes and perceptions of faculty groups who have participated in projects designed to modify the reward system in their departments to the larger faculty population.

6. Fall, 1992
   The President's Fall Administrators Conference will focus on the evaluation of teaching, which is a key element of the promotion and tenure process.

7. Fall term, 1992
   The Dean's Council and the Faculty Seminar will select a group of 18 department heads to respond to the developing corpus of opinion and perspective which has emerged thus far from the discussion and survey of the faculty reward system. In effect, the department heads will have the benefit of stated but exploratory points of view both from the faculty and from the deans as they consider the issues at the department level.

   This group of department heads will be charged to initiate two related projects during a three day retreat toward the end of the Fall term or the beginning of the Spring term. They will use the faculty seminar position paper, the dean's responses, results of the faculty survey, selected articles, and opinion solicited from colleagues prior to the retreat as a background for these projects. These department heads and their faculty will become leaders in their colleges in developing approaches to faculty rewards which are responsive to a wider range of faculty excellence in teaching, scholarship and service.

8. Spring, 1993
Options developed during the department heads retreat will be selected for implementation on a trial basis by their faculties, with input and planning assistance from the Deans. During the spring term, department heads will work with the faculty to plan the projects and determine how their impact will be evaluated. College-level discussion of the progress of these projects will occur on a periodic basis at department heads' meetings.

9. Spring term, 1993
The first $15,000 departmental award will be given for fostering an exemplary teaching and learning environment for students and faculty. An article about the winning department will appear in Virginia Tech Magazine. The department will be recognized at a reception sponsored by the Provost's office.

10. Spring term, 1993
The first class of Fellows (for 1993/94) of the Center for Excellence in Undergraduate Teaching are selected on the basis of proposals submitted for a variety of curriculum and pedagogical enhancement projects. These individuals will receive stipends or released time and other direct (university-level) support for their projects.

Year 2

1. Summer, 1993
A two year evaluation is done of the effects of the revised P & T guidelines on the promotion and tenure processes during 1991/92 and 1992/93.

2. Summer and Fall, 1993, continuing through Spring, 1994
Experimental projects in faculty rewards which were initiated during the department heads' retreat are implemented in at least one department in each of the smaller colleges and two departments in each of the larger colleges. Departments participating in these projects may hold one or two day-long retreats with faculty to initiate the projects.

3. Summer and Fall terms, 1993
The 1993 Fellows of the Center for Excellence in Undergraduate Teaching will initiate their projects.

4. Fall, 1993
   The President's Fall Administrators Conference will focus on the faculty reward system, reporting on the significant in-house work which has been done to that point. The conference will include outside speakers, as well.

5. Spring, 1994
   A one-day, invitational, statewide symposium on the faculty reward system will be held at a central location in April. Four-person teams of key administrators and faculty members will be invited from each of the research institutions in the state. The symposium will focus on broadening the prevailing concept of scholarship and on efforts being made around the state to reward multi-dimensional excellence, including reports on the projects at Virginia Tech.

6. A follow-up survey will be conducted of faculty attitudes toward the reward system, with comparisons made to the baseline information from Fall 1992. Comparison will also be made of faculty attitudes among those participating and not participating in current experimental projects related to faculty research (many of these projects will continue past the biennium). The survey will assist us in evaluating the faculty rewards project. We will look for indications of whether faculty believe a shift has occurred, in the balance of the reward system with respect to teaching, research and service.

7. Summer, 1994
   The project will be evaluated by participants and a report will be submitted to the Provost and President on the future of faculty rewards at Virginia Tech. This report will figure in subsequent university, college, and department level planning.

8. Presentation of the project will be made at a national conference on education, such as AAHE, AAC, or NASULGC.

Issues related to faculty rewards cut across a broad spectrum of the university's missions and culture, including, but not limited to undergraduate education. We have begun several initiatives at Virginia Tech which will place more emphasis on the role of faculty as members of the larger university community, including changes in our governance system as well as greater emphasis on undergraduate teaching and significant reform of the University Core Curriculum. The faculty reward culture must be modified throughout the entire university if various forms of faculty development, shared governance, and greater emphasis on teaching and service are to be successful.

Mr. THORNTON. Thank you very much, Dr. Carlisle.

Dr. Ferguson, who is the President of Grinnell College, Grinnell, Iowa, and representing not only that institution, but the Associated Colleges of the Midwest, Great Lakes Colleges Association, and the Central Pennsylvania Consortium.

It's a delight having you with us, Dr. Ferguson. Without objection, your prepared testimony will be made a part of the record, and I'd like to hear your summary of that testimony.

STATEMENT OF DR. PAMELA A. FERGUSON, PRESIDENT GRINNELL COLLEGE, GRINNELL, IOWA, REPRESENTING ASSOCIATED COLLEGES OF THE MIDWEST, GREAT LAKES COLLEGES ASSOCIATION, AND CENTRAL PENNSYLVANIA CONSORTIUM

Dr. FERGUSON. Thank you very much.

I also speak today not only as the president of one of the Nation's select liberal arts colleges, but from the perspective of one who is familiar with the educational environment at both research universities and liberal arts colleges.

My career as a research mathematician began as an undergraduate at Wellesley College. My doctorate is from the University of Chicago. I taught at Northwestern University, and for the 21 years before I became President of Grinnell College, I was on the faculty at the University of Miami in Florida, where for the past four years there, I was the Associate Provost and Dean of the Graduate School.

So I present these comments as one who has had a life long commitment and passion for science, as well as someone who has had teaching and administrative responsibility, at both a research institution and a liberal arts college.

The biggest difference from my experience at Grinnell and my experience at a research university is that at Grinnell everyone, including especially the faculty, as well as the administration and students, believe in the scholar/teacher model.

One of our goals at Grinnell is that students take an active role in their learning. We provide opportunities for hands-on, investigative laboratory-rich study in the sciences and mathematics.

This directly influences decisions on faculty appointments, promotions and development opportunities, curricula shape and development, and development of the infrastructure of the sciences and mathematics. These are all decisions that have an impact on the institutional balance between teaching and research.

There is a firm belief at liberal arts colleges that teaching and research are not in conflict, but rather are mutually supportive.

A number of practices which we employ at Grinnell from the moment we interview prospective faculty and which reinforce and strengthen this belief are detailed in my written testimony, and could easily transfer to other larger institutions.

In the interest of time, I'll also simply note that my written testimony contains additional recommendations which parallel those made in previous years by representatives of liberal arts colleges in hearings before this committee.

Briefly, these recommendations, which were also echoed in the NSF report just referred to by Dr. Carlisle involve changing both

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funding criteria and institutional criteria by which proposals are evaluated, which support undergraduate education. These changes would encourage a nationwide effort to bring teaching and research into better balance.

Finally, improving the quality of undergraduate science and education is such a serious challenge that it requires all of us to work together. There are over 1,500 non-doctoral educational institutions in this country. Well over half of the undergraduate degrees are awarded by these comprehensive and liberal arts institutions.

Many of our elementary and secondary teachers receive their undergraduate teaching at these institutions. Additionally, a high percentage of graduates of selective liberal arts colleges earn Ph.D.s in sciences and mathematics.

Therefore, I congratulate and thank this committee for including the perspective of four year institutions in today's hearings.

Further, I recommend that a mechanism be established to provide an ongoing dialogue among all of us with a stake in undergraduate science and mathematics to talk regularly together, in settings like this, at disciplinary conferences, through computer networks, and at specially planned meetings.

The separation between teaching and research occurs partially because we are not all talking or listening to each other in the same room.

We do need to generate a new vitality in our Nation's scientific and technological infrastructure, and we can only do this by recognizing fully the role that undergraduate education plays in this effort. There are, I would venture to say, thousands of faculty members in sciences and mathematics in campuses in every part of this country, with a devotion to teaching and research, and to producing our next generations of scientists and citizens.

We need to identify, support, and reward these faculties and the institutions in which they work. We need to do this within each and every one of our home institutions, and we need to do this at the level of national policy.

I thank you for the opportunity to make these remarks.

[The prepared statement of Dr. Ferguson follows:]

STATEMENT

to the

SUBCOMMITTEE ON SCIENCE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

March 31, 1992

by

Pamela A. Ferguson
President, Grinnell College
Grinnell, Iowa

Speaking for
The Associated Colleges of the Midwest
The Great Lakes Colleges Association
The Central Pennsylvania Consortium
Allegheny College, Reed College, Rollins College

I am Pamela A. Ferguson, President of Grinnell College in Grinnell, Iowa. I am very pleased to be invited to participate in this Hearing, and for the opportunity to address the issues related to the quality of undergraduate science education, particularly the crucial issue of achieving balance between the teaching and research responsibilities of the professoriate.

I speak today as president of one of the nation's premiere undergraduate institutions in science and mathematics. I speak also for Grinnell's peer institutions in the groups represented by The Independent Colleges Office in Washington, including member institutions of the Associated Colleges of the Midwest (to which Grinnell belongs), the Great Lakes Colleges Association, The Central Pennsylvania Consortium, Allegheny College (PA), Reed College (OR), and Rollins College (FL).[1]

The invitation I received from Chairman Boucher reflects this Subcommittee's awareness that those of us involved in undergraduate science and mathematics education are partners in a common and critical enterprise. As Martin Luther King, Jr., once said, we are "tied in a single garment of destiny." We tend to forget this as we all, at our schools, colleges, universities, and research centers, work busily on our own activities. Instead of a seamless garment, we often look like a patchwork.

I don't think we are a patchwork, but we have a new century coming along. This is a critical time to look at our common enterprise, examine what kind of garment we have on, and learn how well it is fitting our aims and objectives--for our students on our individual campuses, as well as for the nation as a whole.

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[1] ACM Beloit College, Carleton College, Coe College, The Colorado College, Cornell College, Grinnell College, Knox College, Lake Forest College, Lawrence University, Macalester College, Monmouth College, Ripon College, St Olaf College, The College of the University of Chicago, GLCA Albion College, Antioch College, Denison University, DePauw University, Earlham College, Hope College, Kalamazoo College, Kenyon College, Oberlin College, Ohio Wesleyan University, Wabash College, The College of Wooster; CPC Dickinson College, Franklin & Marshall College, and Gettysburg College

From the White House to the school house, we hear that education in America is not the best--particularly education in science and mathematics--and that we ought to be doing it better. At the undergraduate level, I don't think we CAN do a lot better unless we work together. Unless everyone with a stake in undergraduate science and mathematics education makes tough decisions now about strategic priorities--about dollars, people, space, and reward systems--effective reform will not happen. Unless all partners work together, this nation's educational shortcomings will not be addressed adequately.

You asked me to speak to the issue of balance between teaching and research responsibilities of the professoriate from the perspective of one who is familiar with the educational environment at both research universities and liberal arts colleges. I am a research mathematician, one of a generation of academic scientists who benefitted from a concerted and comprehensive national effort to attract undergraduate students to science and mathematics. My life-long engagement with science and mathematics began as an undergraduate at Wellesley College, where I received my baccalaureate degree. My doctorate is from the University of Chicago; my area of research is finite group theory, a branch of theoretical mathematics. Nothing will replace the personal thrill I feel each time I prove a new theorem. It is that thrill of discovery that keeps all scientists and mathematicians working in research. I experience an equal thrill when I teach, working with students, recognizing the balance it brings to my professional life and how it enhances my research.

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President Pamela Ferguson, Grinnell College
March 31, 1992

Until coming to Grinnell College last fall, for 21 years I was on the faculty of the University of Miami, and for 4 years held the appointment as Associate Provost and Dean of the Graduate School on that campus. I present these comments as one who has had a life-long commitment to and involvement with science and mathematics education.

From my years of experience, I understand clearly the opportunity and responsibility we now have to build a more effective partnership for reform of undergraduate science and mathematics, one built on the awareness that ours is indeed a common enterprise. To the extent we neglect undergraduate education, we hamper this country's ability to produce research scientists, to produce elementary and secondary school teachers for the next generation of those who would be scientists and mathematicians, and to produce those who as citizen/leaders will be called upon in the coming century to make critical decisions about matters scientific and technological in the private, corporate--and even in the political--arenas.

There is a public perception that the undergraduate pipeline is only important for the production of graduate students who, in time, become the nation's scientific researchers. But the public--and sometimes those who determine policies and programs that support undergraduate education--tends to forget that the pipeline also produces the non-scientists who carry with them into their work and world their collegiate notions of what science is, does, and means. In short, it is undergraduate education that largely determines the scientific literacy of America.

This is the context, I believe, for our discussions today, as we address the specific issue of the "balance of research and teaching in undergraduate communities across the country." Unless we keep focused on all students, and on the larger role of the undergraduate sector, our reform efforts will be a patchwork. We will not have a seamless garment.

This is a timely Hearing. I have followed the deliberations of the National Governors' Conference, and those of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). There has been, over the past several years, an extended and legitimate concern about the pre-collegiate sector. As urgent as those deliberations have been, I think it is time to give equal attention to the indispensable role of the undergraduate sector in serving students and the nation in the areas of science and mathematics. As the 1991 FCCSET report states:

> ...many experts believe that undergraduate science, mathematics and engineering education has suffered from a lack of attention, which has left it stagnant, diminished its quality, and led to a dull and uninspiring student experience.

There are many encouraging indications that concern is turning again to the undergraduate sector. This Hearing is one evidence of that. (It is a sorry state, however, that we have to be in a national crisis--as we are today, as we were in the Sputnik era--before people begin to take seriously the value and utility of a strong undergraduate sector.) We have yet to see, however, these nascent expressions of concern accompanied by adequate levels of financial support.

Two things are needed. First, we need an adjustment in thinking as to the place of the undergraduate sector in science and mathematics education. Second, we need a plan, a well-conceived, long-range plan, that sets our goals and objectives with respect not only to undergraduate education but to all levels of science education and research. That planning has to be done by those of us who are educators, in collaboration with those who help guide and support this common enterprise.

These are some of the challenges that influenced my decision to accept the presidency of a college like Grinnell. Why did I do this--moving to the middle of Iowa from the cosmopolitan community of Miami? To answer that question gets to the heart of the issue we are exploring today. As I was considering the invitation from Grinnell, I began asking about what works on that campus. asking questions such as: "What are Grinnell's goals for students?" "How do faculty and administrators seek to achieve those goals?" "What is the relationship between those goals and the larger society Grinnell seeks to serve?" For the purpose of this Hearing, let me give you one answer to those questions, an answer that relates specifically to learning in the sciences and mathematics and to the integration of teaching and research in the undergraduate context.

One of Grinnell's goals for students is that they take an active role in their learning. Over the years, an impressive variety of opportunities for "hands-on" learning have been developed for Grinnell students at all stages of their academic careers. (This is the learning environment that has been identified by the work of Project Kaleidoscope as being most successful in attracting students to science.) In particular, this goal of providing students opportunities for hands-on, investigative, laboratory-rich study in the sciences and mathematics directly influences decisions about 1) faculty appointments, promotions, and development opportunities; 2) curricular shape and direction; and 3) development of the infrastructure for science and mathematics. These are all decisions that have an impact on the institutional balance between teaching and research.

What attracted me to Grinnell was the possibility of working at a place where teaching and research come together in practice as well as in theory, where all professors are actively engaged in classroom and laboratory teaching. Grinnell's greatest draw for me was the educational environment wherein students work in small classes, and work one-on-one with faculty, with abundant opportunities for hands-on research. I was attracted by the personal knowledge that it was this kind of undergraduate experience that attracted me to science and prepared me to be a research mathematician.

For many generations, Grinnell students have benefitted from the opportunity to learn from such as those professors who are at working in classroom and laboratory today. Allow me to mention two outstanding Grinnell graduates who took what they learned at Grinnell, and subsequently, through their work, had an impact on the world in which we live. Robert Noyce went on (after studying at Grinnell and MIT) to receive the patent for the first integrated circuit, and thereby generated the modern revolution in electronics. Tom Cech (who also experienced the Grinnell-MIT connection) was a co-winner of the 1989 Nobel Prize in Chemistry for RNA research.

To be honest, after so many years in a major research university, I was also attracted to a place that, because of its traditions, size, and lack of bureaucracy, has been a fruitful testing ground for new approaches to teaching and learning, a place where senior faculty take full responsibility for what happens in classroom and laboratory (even for beginning students), a place where presidents and deans recognize, support, reward and even require the integrated role of faculty as teacner/scholar--where research is seen as an educational activity. Grinnell is a place, where, as Bartlett Giamatti said in a speech at Yale University:

> teaching and research not only go hand in hand but are often the same hand: the pedagogical act an investigation, the investigatory act shared with students and associates who are also colleagues, the whole a sp'endid, ongoing instance of intellectual and human collaboration.

For example, last semester--my fir^st as president--I taught a calculus course with my Grinnell colleagues that used computers to model the powerful ideas of calculus, and made learning calculus a hands-on course, incorporating problems relevant to students of today. This new course, a joint effort of a group of liberal arts institutions and funded by the NSF, is a direct outgrowth of current advances in research in calculus and in technology. But it took a creative group of faculty determined to make the connection (for themselves and for their students) between teaching and advances in basic research, and to undertake the set of activities to transplant those research advances into on-going calculus courses. I can tell you from my recent experience that introductory calculus courses at Grinnell are not dull and stagnant. I can also tell you about the absolute necessity for an academic culture that allows such creativity to grow.

Now, we all know that liberal arts colleges like Grinnell have no monopoly on programs that work in undergraduate science and mathematics. Institutions of all kinds, including those represented by my colleagues on these panels today, have achieved successes in baccalaureate science education. Personally, however, I do not think that a new set of calculus courses like those we are working on at Grinnell could happen at many research universities today. The reward systems at most universities do not often recognize people working at the intersection of teaching and research. In part, the problems with institutional reward systems reflect problems with external reward systems. The external reward systems for scientists and mathematicians still clearly favor those who focus on research. We all know well, as Chairman Boucher indicated in his letter of invitation, that "...the quality of undergraduate science education has deteriorated," and that the current academic reward system is at the heart of the problem.

Let me give you some examples of how we, at Grinnell and at the other institutions for whom I speak today, build and sustain an institutional culture in which teaching and research are integrated activities for faculty--at all stages in their careers. Following these examples, I will make specific recommendations about how such a culture can be built and sustained within the larger community of undergraduate institutions.

1. Interviewing for Commitment. In interviewing candidates for faculty positions at Grinnell, particularly in the sciences and mathematics, we ask questions about their research, and about how undergraduate students might become involved in that research.

These questions provide insights into the professional goals of that candidate, whether or not she intends to make a vital connection between her research and her teaching. These questions also signal to the candidate that Grinnell is committed to supporting her on-going efforts to integrate her work as teacher/scholar. This commitment becomes tangible upon appointment, as new faculty can work with their departmental colleagues to establish a research laboratory, one that provides space for students as well as for the individual researcher.

Prospective science and mathematics faculty members are thus challenged to be clear about their own commitment to teaching. Undergraduate science education is most successful when the commitment to teaching is personal and deep. Faculty must understand that teaching is a meaningful and important responsibility, and that scholarship is as important for their department's curriculum as it is for their own professional development.

2. Socializing the New Faculty Member. Introduction of the new faculty member to the institutional culture is a critical factor in clarifying expectations at the beginning of a career. One of our sister institutions within the ACM. St. Olaf College, has a valuable program for socializing new post-docs, begun with a grant from the Fund for the Improvement of Postsecondary Education. Through this program, St. Olaf brings a new post-doc into the Mathematics Department for one year providing mentoring from experienced faculty, and opportunities to teach both alone and with colleagues. This post-doc program provides a unique bridge between graduate school and the undergraduate campus.

3. Faculty Evaluation. At Grinnell, we follow a faculty appointment with great care, assessing the work of that faculty member after 3, 6, and 12 years, again setting this evaluation in the context of the larger institutional culture. We do not use end-of-course questionnaires. Instead a student team interviews persons who have completed courses from that professor. We also solicit statements from alumni who worked with that professor. These results are combined with a faculty peer-review (of both teaching and scholarly performance) from the academic department and external references about the quality of the research and professional activities of that person. This again is a time-consuming process, but for us, as we seek to develop a common commitment and vision about our work as the community of Grinnell, this process becomes crucial to developing a faculty that works cohesively to achieve common goals.

4. Participating in the Intellectual Community. This commitment to a common vision of our work is expressed in faculty development opportunities. Let me describe one that I am particularly pleased with, one which was begun by my predecessor, President George Drake, who worked with President Hunter Rawlings of the University of Iowa. They initiated a program in which our faculties develop joint summer seminars to study specific intellectual topics of common interest. Graduate students from Iowa and undergraduates from Grinnell are also included in the seminar. What faculty have learned in these joint projects is that while the institutional ethos may differ, good teaching requires an insistence on active learning in the classroom. A culture that expects students to ask questions will also expect the teacher to make connections to

other learning experiences of the students. This obviously places special demands on the faculty leading the class. Offering bite-sized, pre-packaged lectures based on out-dated text books does not work if you want students to be involved in the discussion, and to make connections between the lecture and work they are doing in classroom and lab.

The Calculus Reform effort that I described earlier is another example of how faculty can work together as peers in addressing common problems, focused in particular on the problem of integrating advances in knowledge and technology into the process of teaching and learning. It is also an example of how to build a culture that says working on curriculum is a legitimate activity for undergraduate faculty--indeed, a responsibility. Engagement with the larger community, within and without the campus, is essential to nurturing the academic scientist. I myself became a scientist because of the opportunity to become a member of a larger intellectual tradition.

RECOMMENDATIONS. This leads me directly to my recommendations for the effort to bring undergraduate teaching and research into better balance in colleges and universities across the country. Work at the intersection of research and education is just becoming a recognized legitimate activity for the scientific community. This work needs to be encouraged--at institutions, within disciplinary and educational associations, and most particularly, by NSF and the other FCCSET agencies that provide the financial support for undergraduate reform efforts. In large part, it is this support that establishes the parameters for individual institutional reward systems.

RECOMMENDATION 1:

That a criterion for all awards from federal agencies that support undergraduate activities be redefined to recognize more explicitly that work proposed to be done at the intersection of teaching and research will merit equal consideration to work that is purely basic research or that which is purely pedagogical in nature. For the NSF, this would mean revising the definition of criteria listed in GRESE (see Exhibit A) by adding special emphasis within criterion #4. Proposed wording for such an addition would be:

> *Criterion (4), effect on the infrastructure of science and engineering, permits the evaluation of proposals in terms of their potential for improving the scientific and engineering enterprise and its education activities in ways other than those encompassed by the first three criteria. This criterion also permits the evaluation of proposals from the perspective that research and teaching represent complementary, rather than opposing components, particularly in undergraduate programs.*

Individual program guidelines would include the following specific institutional characterisrics to be considered in the evaluation of proposals. These might include:

a) an analysis of the sponsoring institution's commitment to carrying out the project, and explicit willingness of the institution to allow--and even to encourage--the grantee to influence science and mathematics education within that institution, and within the larger education community;

b) evidence that the institution has made or is making structural changes campus-wide in teaching assignments (including class sizes), general allocation of institutional resources committed to developing a learning environment that is hands-on, and has an appropriate range of faculty development opportunities in place for faculty at all stages of their careers; and

c) an analysis of criteria for and evidence used in hiring, promotion, tenure decisions, salary determinations that demonstrate an increasing commitment to teaching at the undergraduate level. Institutions should be held accountable for the effectiveness of teaching; evaluation of teaching must be central to personnel decisions. There should be clear evidence that reward systems are in place for those who work with non-

science majors, for those who involve majors in their research, and for those who work at the intersection of research and teaching.

RECOMMENDATION 2

That a mechanism be established to provide on-going dialogue among all those with a stake in undergraduate science and mathematics to talk regularly at disciplinary conferences, through computer networks, and at specially-planned meetings.

SUMMARY. I would be remiss in my responsibility as a representative of Grinnell and our peer institutions if I did not emphasize that the undergraduate experience in science and mathematics cannot be compartmentalized into neat little "reformable" packets. Reform efforts must give attention to priorities for faculty development activities, to delegation of teaching responsibilities, and to bringing teaching and research together in practice as well as in theory. Reform efforts must be undertaken from the awareness of the inter-connected nature of the undergraduate experience--and that concern for students has to be at the center of ur reform efforts.

As the 1989 Report of the National Advisory Group of Sigma Xi states:

> In searching for the roots of the crisis in undergraduate education [we] hit repeatedly upon the theme of accessibility for students; access to instruction that generates enthusiasm and fosters long-term learning; access to a curriculum that is relevant, flexible, and within their capabilities; access to a human environment that is intellectually stimulating and emotionally supportive; and access to a physical environment that supports the other three dimensions. These crucial components are strongly interrelated; weakness in any one diminishes the quality of undergraduate education. (p.5)

We need to generate a new vitality in our nation's scientific and technological infrastructure, and we can only do this by recognizing fully the role that undergraduate education plays in this effort. There are, I would venture to say, thousands of faculty members in the sciences and mathematics in campuses in every part of this country with a devotion to teaching and to research, and to producing our next generation of scientists and citizens. We need to identify. support, and reward these faculty, and the institutions in which they work. We need to do this within each and every one of our home institutions. We need to do this at the level of national policy. I believe the recommendations that I have made, if given serious consideration. can play a role in shaping a national culture for redressing the current imbalance between teaching and research. The responsibility is ours.

I thank you for the opportunity to present these remarks.

EXHIBIT A

II. PROPOSAL PROCESSING AND REVIEW

Proposals received by the Proposal Processing Unit are assigned to the appropriate NSF program for acknowledgement and review. All proposals are reviewed carefully by a scientist, engineer, or science educator serving as an NSF Program Officer, and usually by 3 to 10 other individuals who are experts in the particular field represented by the proposal. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal or, giving reasons or not, persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Some Program Officers obtain comments from assembled review panels or from site visits before recommending final action on proposals. Recommendations for awards are further reviewed by senior NSF staff for conformance with Foundation policy.

When a decision is made, verbatim copies of reviews, excluding the names of the reviewers, summaries of review panel deliberations, if any, a description of the process by which the proposal was reviewed, and the context of the decision, (such as the number of proposals and awards, and information about budget availability) are mailed to the Principal Investigator/Project Director. The Principal Investigator/Project Director may also request and obtain any other releasable material in NSF's file on the proposal.

The National Science Board established the following criteria for the selection of research (including projects to improve the teaching and learning of science and engineering) projects by the National Science Foundation:

"In order to provide for the fair and equitable selection of the most meritorious research projects for support, the Foundation has established criteria for their review and evaluation. These criteria are intended to be applied to all research proposals in a balanced and judicious manner, in accordance with the objectives and content of each proposal. Four criteria for the selection of research projects by the National Science Foundation are listed below, together with the elements that constitute each criterion.

1. *Research performance competence* – This criterion relates to the capability of the investigator(s), the technical soundness of the proposed approach, and the adequacy of the institutional resources available.

2. *Intrinsic merit of the research* – This criterion is used to assess the likelihood that the research will lead to new discoveries or fundamental advances within its field of science or engineering, or have substantial impact on progress in that field or in other scientific and engineering fields

3. *Utility or relevance of the research* – This criterion is used to assess the likelihood that the research can contribute to the achievement of a goal that is extrinsic or in addition to that of the research field itself, and thereby serve as the basis for new or improved technology or assist in the solution of societal problems.

4. *Effect of the research on the infrastructure of science and engineering* – This criterion relates to the potential of the proposed research to contribute to better understanding or improvement of the quality, distribution, or effectiveness of the Nation's scientific and engineering research, education, and manpower base."

Criteria (1), (2), and (3) constitute an integral set and are applied in a balanced way to all research and science education proposals in accordance with the objectives and content of each proposal. Criterion (1), performance competence, is essential to the evaluation of the quality of every proposal. It covers the investigator's record of past research accomplishments, including, where significant, communication of findings and sharing of data and other research products. The relative weight given Criteria (2) and (3) depends on the nature of the proposed work; Criterion (2), intrinsic merit, is emphasized in the review of basic research proposals, while Criterion (3), utility or relevance, is emphasized in the review of applied research proposals. Criterion (3) also relates to major goal-oriented activities that the Foundation carries out, such as those directed at improving the knowledge base underlying science and technology policy, furthering international cooperation in science and engineering, and addressing areas of national need.

Criterion (4), effect on the infrastructure of science and engineering, permits the evaluation of proposals in terms of their potential for improving the scientific and engineering enterprise and its education activities in ways other than those encompassed by the first three criteria. Included under this criterion are questions relating to scientific, engineering, and education personnel, including participation of women, minorities, and disabled individuals; the distribution of resources with respect to institutions and geographical area; stimulation of high quality activities in important but underdeveloped fields; support of research initiation for investigators without previous Federal research support as a Principal Investigator or Co-Principal Investigator; and interdisciplinary approaches to research or education in appropriate areas.

Any specific criteria that apply to individual programs, while falling within the general criteria present in this section, are contained in relevant program announcements or solicitations.

Proposals that involve cooperative activities with Warsaw-pact countries may also be subject to internal U.S. Government review for potential national security concerns.

Mr. THORNTON. I want to thank each of you for a very fine summary of your excellent testimony.

It seems to me that there is a great deal of agreement by members of the panel, but also some areas where additional comments may be helpful in fleshing out the discussion.

The thing that really concerns members of the committee, I believe, is whether the emphasis upon research has led to some of the highest qualified intellects at a university from being actively involved in teaching.

I think there will be possibly a divergence of opinions on this, ranging from the research universities, where it may be less common for the distinguished professor to routinely take a freshman course, and to give incoming students an opportunity to hear from the best mind available on the campus.

What is your experience at each of your institutions?

As a sidelight, not that I was the best mind, but I wanted to start something. So, I taught each year that I was president of the university. As a result of that, the chancellors began teaching and, as a result of that, the distinguished professors began teaching general summary courses, as well as doing the research.

What about your institution, Dr. Vest?

Dr. VEST. Well, since you mentioned that we each got at least one opportunity to brag a little bit, I'd like to tell the story that two years ago, one of our professors was literally teaching a freshman physics laboratory when it was announced that he'd won the Nobel Prize.

Mr. THORNTON. That is a marvelous story.

Dr. VEST. We, at MIT, are, of course, blessed with a very different student to faculty ratio than some of the other institutions around here. We do pride ourselves in getting first rate faculty as lecturers, particularly in the large introductory classes.

We do, of course, do a lot of recitation and laboratory instruction with graduate student teaching assistants. We do, however, in some of the main line departments, including physics, manage to teach all of our laboratory courses with professors and, by and large, in the department of biology, we do as well. Every one of our faculty members are expected to teach at least one course per term.

The thing that we have tried to do over the last two years, and we're gaining success, is to get each of our freshman in association with a senior faculty member or administrator through what we call freshman advisor seminars, whereby in groups of six to eight, the freshmen will spend their freshman year in a seminar format, with a faculty member, and almost all of our deans, and vice presidents, et cetera, participate in that.

I do have to admit with a red face, that I have not found my schedule yet permitting that I teach a course. My predecessor, Paul Grey, did once, and he had only one piece of advice for me, which was, don't try it.

Mr. THORNTON. I perhaps should admit that the courses that I taught were team taught.

[Laughter.]

Mr. THORNTON. It was not always possible for me to be in attendance, but we had a two or three person team teaching the courses, and always at least two of us were there.

Dr. VEST. If I could just comment, very briefly—and not to take too much time from my colleagues—but we happened to be going through salary decisions at the institute this week. I was particularly pleased that the Dean of Science walked in.

Each dean has a certain amount of money that can be distributed for merit raises, and each dean has a separate little pot of funds that can be used to top that off in areas of importance.

He had literally asked each of his department heads to produce a list of the 10 people that they felt had had the greatest accomplishments in the past year in research, and the 10 people that had the greatest accomplishments in the last year in teaching.

Those discretionary funds were divided equally between the two, and I believe, Karl, you are an expert on reward systems. It doesn't take too long for that kind of a message to get around.

Mr. THORNTON. That's a very splendid message.

Dr. Pister.

Dr. PISTER. Well, since Dr. Vest told an MIT story, then I presume I have permission to tell a Berkeley story.

Mr. THORNTON. Indeed.

Dr. PISTER. I remember hearing from a freshman student his absolute amazement when he found that the tall gentleman sitting in the aisle listening to freshman chemistry lectures, who was preparing himself to teach, not the lecture course, but a freshman chemistry laboratory was Nobel laureate and former AEC Chair, Glenn Seaborg.

So, I tell that story to make the point that on our university campuses, everyone is above average, but some are more above average than others.

I think the more above average in other folks like the Seaborgs and like your physics colleague are people who have succeeded because of their enormous talent and energy. That's not the group we are talking about.

The group, in my view, at research universities, that is put at greatest risk is the great majority of us who are not above the above average group, and the pressure that young faculty feel today, especially, to get engaged in the research game. That research game is a business, because the institution, in most cases, will not survive, economically, unless the faculty members play in the business.

That's the kind of pressure, I think, that demeans the academic life. I think it is something that Federal agencies and universities have to take very seriously.

If I'm permitted one more story, I think the State of California stands out as an excellent example in funding academic year salaries of its faculty, in both its U.C. system, and its California State University system.

No faculty member in the State of California from a public institution has to worry about his or her nine month salary. That's a pressure that colleagues in many other states— most other states— have to face every day.

Mr. THORNTON. Thank you very much.

Dr. Carlisle.

Dr. CARLISLE. Thank you. I feel a bit in the same situation I did at a panel over in Arlington a year or two ago, when I was fifth, and to my left, there was Bob O'Neal, the President of UVA, et cetera, et cetera. Every one of them invoked Thomas Jefferson.

Then they got to me and, for the audience, I invoked Justin Morrill, and only got blank looks throughout.

Mr. THORNTON. May I paraphrase for you the statement that he made about 130 years ago in saying, "In today's high technology world, the world is moving so rapidly that we must use our best efforts to maintain our ability to discover and to apply that discovery. If the world moves at ten knots, and we at only six, we will be left in the lurch."

Justin Morrill, as everyone here knows, was leading the effort for the land grant college system at the time of that remark.

Dr. CARLISLE. It's a wonderful remark. I'm instructed by it. Thank you.

Let me make two or three or maybe four quick points in reply to your question.

First of all, I think in a place like Virginia Tech, the situation is very mixed about whether the finest senior faculty, the finest minds, even among the junior faculty are teaching undergraduates.

I met just last week with the biochemistry faculty. That is a faculty which I believe has very well integrated undergraduate instruction, graduate study, and faculty research so that faculty research in laboratories becomes one of the main means of instructing undergraduates.

The facts are much like that in a number of departments, and in other departments, it is not the case. But what strikes me most is the way that it is so deeply imbedded in the culture. Faculty people I talk to, time after time, breakfast after breakfast, say to me, yes, but we know what really counts.

Therefore, it seems to me their intuitive commitment is then to research, to some extent, at the expense of undergraduate education. But the same faculty probably, in some cases, do fine jobs teaching undergraduates.

Second, it seems to me, one of the ways to begin to get at this and permit the kind of flexibility President Vest talked about, the kind of multi-dimensional excellence we and my land grant colleagues talk about is to place responsibilities on departments for achieving the primary classic three missions of the university, rather than to place all three of those responsibilities on individuals.

That way, departments are responsible for achieving every one of our missions well, and faculty can then be given differential kinds of assignments. We plan to begin a program of recognizing and rewarding departments who do that, who establish a fine learning environment, both for undergraduate students and faculty.

As far as teaching goes, I do teach, from time to time. I taught a course last spring—a course in our liberal education program—all by myself. By May, the students had run up my back at that point, and they had overtaken me. Next fall, I will be teaching an honors colloquium.

I have asked virtually every person in my office. I lean on the deans, and suggest that they, too, teach from time to time, and teach undergraduates to show that, yes, we tell you this, we mean it, and we are also trying to help out.

Mr. THORNTON. I admire you for teaching the course without the benefit of a team to assist in it. I was there occasionally alone, and with an honors group, it sometimes gets pretty close.

Dr. CARLISLE. This is true, but they are bright enough to be understanding about my own limitations.

I have faculty people ask me how I keep up and, of course, I say, I don't. Late in the semester last year, I truly felt that I was not doing either job as well as I would like, but I was having a lot of fun.

Mr. THORNTON. Well, as a matter of fact, the thing that I liked best about it was that it seemed to set a tone throughout the university that teaching was truly very important.

There's another thing—well, I want to hear from you, Dr. Ferguson, then I have a couple more questions, and I'll recognize Mr. Fawell for such questions as he may have.

Dr. Ferguson.

Dr. FERGUSON. Well, yes, and again, my perspectives of a course at Grinnell is a little different because, again, we're an undergraduate institution.

So, therefore, one of the clearest ways you send a signal that teaching is important is that every one teaches the same amount. We don't use an inducement to get the people we most like by offering them a lower teaching load. I think that that's totally appropriate, at certain kinds of institutions.

I think, though, to echo maybe it was Dr. Pister's views where everyone is trying to be Harvard or MIT, that many institutions persist in doing this, where they are not going to be those institutions.

I think one of the strong ways we reinforce the importance of teaching is that everyone at Grinnell teaches the equivalent of five courses a year. It still leaves you time for research. They publish regularly, but it also sends a uniform signal that somehow "there's not a two-tiered system."

I taught. It was my first semester as president last semester. I taught a calculus course, which is an introductory course. I thought I should be in with the freshman to learn what it was like.

I learned a tremendous amount about what innovative, exciting teaching with really great technology can be like. I loved teaching at the previous institution where I also regularly taught while I was dean, but where we didn't have that wonderful technology to change the kind of experience.

It may have sent a signal but, candidly, I also did it for the selfish reasons that I had a lot to learn about the institution.

I think any administrator who wants to know what's really going on in an institution has to spend some time in the classroom, whether it's in a team-taught or an honors colloquium, or else you miss out—things change very rapidly. Students do change.

Mr. THORNTON. Thank you very much, Dr. Ferguson.

A couple—maybe one question including two things— first, I'm pleased to report that this is something for which I can claim no credit from the University of Arkansas. I doubt that I would have had the courage to implement this.

The dean of our college of education, Dr. Roderick McDavis, has just announced that the College of Education will no longer award a four year bachelors degree in education, and that students who wish to become teachers must take a four year course in an appropriate discipline, whether it be engineering, science, history, english, or whatever it may be.

Only after completing their undergraduate work in a discipline will they be eligible to enter the college of education for a graduate degree, which will teach them how to apply the methods needed to transmit that information to students K-12.

I'd like to have each of you comment on that approach and also to amplify a bit on the role of merit pay assessments in emphasizing teaching and how you address that.

Dr. Vest.

Dr. VEST. With regard to your first comment, I strongly salute it. I hope that that sets a great precedent across the Nation.

I'm also pleased to note that a small, but clearly increasing number of our MIT seniors are beginning to opt for careers in secondary schools and working together with Wellesley and other institutions nearby, gaining their certification in addition to their undergraduate disciplinary degrees.

Indeed, last year's senior class chose this as the project that they wanted to fund, making available a little bit of a fellowship to help with the additional tuition that was required to gain certification.

With regard to merit pay, I think all of us at the table would agree that this gets to the very core of the question that is in front of us.

I have no magic answers, but at the Institute, we have taken some specific steps to enhance the recognition of teaching accomplishment when we make merit pay increases, and also through the tenure and promotion system, first of all, by requiring that essentially a fixed or certain level of the case books and arguments that are prepared for each individual address the matter of teaching.

The vast majority of our faculty are evaluated by the students according to set criteria. Wise department heads and deans look at those things very closely.

But I would certainly not claim that we have yet achieved the balance between measurement and consideration of teaching accomplishment and research accomplishment that I and my colleagues would like to see in the future, but I believe that the gradient is in the right direction.

Mr. THORNTON. Thank you very much.

One reason for this question is that just recently, a week ago, as a matter of fact, the Department of Education released the initial findings of a study entitled, "How Teaching and Research Activities Affect Faculty Compensation at Four Year Colleges and Universities." It examined data from 4,300 full-time tenure track faculty from four year institutions.

Regrettably, from our standpoint, the report revealed the following, that the more time spent on teaching, the lower the salary compensation, and the more time spent on research, the higher the salary compensation.

So, as we deal with merit pay, I think we need to recognize that the field is skewed, somewhat, at the present time, toward rewarding research.

Dr. Carlisle—oh, Dr. Pister.
Dr. PISTER. May I have an opportunity to answer that one?
Mr. THORNTON. Yes.
Dr. PISTER. First of all, I certainly support certification on top of disciplinary specialization first. It's certainly a trend that is commendable and, I hope, will become universal in this country.

The question of rewarding through merit or promotion faculty performance is unquestionably skewed toward research. Your data just showed that. Every one of us that's had any administrative experience knows that to be a fact. The degree of skewing depends on the institution and, indeed, to a certain extent, the discipline within an institution.

In my view, the response to this ought to be a broader understanding and interpretation of creative scholarship. Ernie Boyer's survey calls attention to this.

Everyone of us usually looks at a multi-dimensional faculty performance measure, but, in fact, in the last forty years, at least, it has become almost standard to place almost the entire burden of accomplishment for a faculty member in the research creativity area at the expense of scholarship of teaching or scholarship of application of knowledge, or even, I would add, the integration and synthesis of knowledge.

If you are not a discoverer, if you are not finding a new element, or you are not finding a new algorithm, or whatever it is, you are seemingly not doing research—something that I think if carried to the limit, would have killed our medical schools long ago.

Indeed, it's had a profound effect on the teaching of engineering in this country, as many of us who have been in engineering have realized our loss of competence in manufacturing, to a certain extent, can be correlated to, I think, teaching the profession of engineering too closely to the model of science, and not to a profession.

So we need to reverse that and that is part of the cultural change that our institutions and our Federal agencies that fund us must take into account.

Mr. THORNTON. Are any of you familiar with the March 25th Chronicle of Higher Education article discussing Syracuse University? I'm enjoying the conversation here with several of you.

Dr. Carlisle, would you like to address the question I first raised, and then go ahead and wind up with the Syracuse University example, of what we can learn from that.

Dr. CARLISLE. I may not speak as much to that as you want me to. To remember your question, I'm acting like a student now?
Mr. THORNTON. Yes, sir.
Dr. CARLISLE. Your question was, am I familiar with it?
Mr. THORNTON. Yes.
Dr. CARLISLE. If not, can I answer an exam question on the Syracuse model.
[Laughter.]
Dr. CARLISLE. But that's okay, that's okay.

Let me speak to two things, and then speak to, I think, what is happening, certainly, at Syracuse. I know a little about that. I read a letter from the president of Syracuse on that, and a little bit about what is happening at a number of land grant universities across the country.

As to your question about five year teaching certification programs, that has been a pretty strong movement across the country over the last five or ten years through the so-called "Holmes Group," and I do think it will, in effect, take over as the dominant model, at least at large institutions such as ours, at state universities, and perhaps at the privates, as well. It does make sense, so I really endorse what both my colleagues have said, and don't need to say a whole lot more about that.

Merit pay—you have the facts. Dr. Pister has indicated the case at research universities. Certainly, it is the case at Virginia Tech as well, that we have skewed to, I think, a mistaken degree, the emphasis on research.

I've noticed—I've been at Virginia Tech three years, but I've been doing this kind of a job for seven. I've noticed even in the three years I've been at Virginia Tech, a change in the promotion and tenure files that I read, and I read all of those that come to the university.

During my first year they were, as you might expect, out of 30 pages, 25—I'm exaggerating—were devoted to research, to demonstrating how effective an individual's research was. There were some token demonstrations—maybe a little more than that sometimes about teaching and almost nothing about service, except for cooperative extension people.

Through conversation, through emphasis, through a revision of the guidelines, I'm seeing just in three years a change. First of all, teaching comes first in the dossier that comes to the university committee, and faculty are now required to demonstrate at some length and in several ways their effectiveness as teachers. They still, of course, say almost as much as they've always said, and very well, about research.

My sense is that this will begin to change the evidence that we use for salary increases, and it is one means, at least, of beginning to modify the cultural kind of just instinctive commitment to give more money to the prestigious researcher than to the fine teacher.

I think—and my last comment about that—I think that the real nub of things lies with department chairs or department heads, blessed with faculty, because the surveys I read suggest that faculty are ready for the kind of change that, in one way or another, we are all talking about. Deans are. My colleagues across the country are.

I find my sentence getting me to the point of answering the question, why then—what's holding us back? The department head—no I don't quite mean that, but I do think, to some extent, unless the department heads really come around, and believe that presidents mean what they say about the balance, I think change will be much slower.

Now, notice the way I evaded your question about Syracuse by taking so much time.

Mr. THORNTON. I'm very pleased that you've demonstrated a skill that I thought was reserved to lawyers.

[Laughter.]

Mr. THORNTON. As a matter of fact, I appreciate your candid observations there.

Dr. Ferguson.

Dr. FERGUSON. Yes, let me say that, gee, I know the answer to the Syracuse question, in the sense of being able to recall a little bit more what was in the article, primarily simply because Syracuse and the University of Miami, where I used to work, and enjoyed working very much, in many ways, were similar.

They are both private institutions. They are both expensive, and they are both largely tuition-driven. They are fine institutions, but they are not MIT, as far as research dollars acquired.

So I read with some interest the fact that they were taking this view of being now a student-centered research institution, by adding some words at the beginning. I also read with—and I congratulate everything they are trying to do there. I know they are trying to do that at Miami, too.

I'm also extraordinarily sympathetic, after 21 years as a faculty person at Miami, and only five of those years as an administrator, with the skepticism indicated in that article by some of the faculty—not a lack of good will, but not really being sure they mean it.

There was a wonderful story, a person cited of someone who had fair research and great teaching, and got tenure, and three years ago, he felt it would be the other way around.

Well, at the risk of doing what I promised myself I wouldn't do before I came here, let me say the following from my dual perspective. I am sure there were people at my previous institution who did not get tenure because they weren't good teachers. I'm sure there were, but I don't know the name of one of them.

I do know the names of lots of bad teachers who were pretty good at research who did get tenure. So, while I applaud what is going on at Syracuse, I think it is going to take awhile, and it is going to take a lot of symbols being sent forth.

As far as the point about education, again, I think what Arkansas is doing is wonderful. We, at Grinnell, again, don't give graduate degrees, but because we felt so— and in fact, the only professional program we have is education, we do have a department of education, but because we believe so strongly that four years of undergraduate experience is important, we give a free ninth semester, where students can come back.

We pay their tuition and expenses so that they can get accreditation and internship in that free ninth semester. We've been doing that for years.

Mr. THORNTON. Thank you very much, Dr. Ferguson.

The gentleman from Illinois, Mr. Fawell.

Ms. FAWELL. I'm going to pass at this time. I have enjoyed listening to the testimony, and I look forward to reading the entire transcript.

Mr. THORNTON. Thank you, Mr. Fawell.

Let me just relate, Dr. Vest, to your quotation from a noted philosopher, Pogo Possum, at the beginning of your testimony, and state that he also is quoted as saying, "We have met the enemy, and he is us."

In some sense, we do have the future of our educational enterprise in the hands of people who are included in this panel and in the next panel, because it's very important not to separate the function of teaching from the function of research.

Dr. Carlisle.

Dr. CARLISLE. I wanted to make one—I sense you are closing, and I don't want the last word, but I thought—I'd like to get back to Blacksburg tonight without having a lot of department heads waiting at the edge of town for me.

Mr. THORNTON. Okay.

Dr. CARLISLE. So I thought I ought to clarify, one of my colleagues has reminded me that part of the dilemma that we are in has to do with, on the one hand, a commitment to national professions, and to recognition through those national disciplines; and on the other hand, the responsibilities one has to the university as a community, and to its instructional and communal obligations.

Department head is at the intersection of those two sometimes conflicting worlds that a faculty member must live in. It's hard being a department head. I was one, once. I think that's why I place the burden on the department heads, because they've got to find the way to help faculty balance those two sometimes conflicting demands.

Thanks.

Mr. THORNTON. I appreciate that addition and, indeed, agree with the assessment that the department head is really that point at which these forces tend to be resolved or not resolved.

I want to thank each of you for your fine testimony. It's been very helpful.

Oh, would you like to ask any questions?

Mr. NAGLE. Certainly—absolutely.

Mr. THORNTON. The gentleman from Iowa.

Mr. NAGLE. I'd first like to point out that we have Grinnell College here. For those of you who think the Big Ten is everything this week, you should be reminded that, historically, the first football game Grinnell ever played, they beat the University of Iowa.

[Laughter.]

Dr. FERGUSON. That was about the last game we won, too.

[Laughter.]

Mr. NAGLE. Academically, Madam President, you've been under some suspect. You've started to win some games, and it made us all nervous.

The thing that I wanted to focus on, if I could just for a second—I don't know what you've covered before I got here — but this—I don't want to say ineptitude, but this inability, seemingly, to bring undergraduate students through the process in science and math, chemistry, particularly, if we are talking about Grinnell, in a broad sense, given the success that smaller colleges have had versus larger universities, and not wanting you to offend larger universities, is there anything we should be looking at as a Congress, in terms of enhancing undergraduate science and math education, that our larger universities and smaller universities seem to be having more success with?

Dr. FERGUSON. I think, yes, I understand all the very strong, healthy tensions, and the absolute need for the department head at a larger institution to be helped to deal with the tension that does not exist at the smaller institutions, so not everything will transfer.

But I think, to the extent that this committee can urge various funding agencies to provide—and this is not just one more request for funds—but to put undergraduate education on the national agenda to make it intellectually respectable and exciting.

The NSF funding, for example, of calculus reform has transformed the national meetings of the American Mathematical Society versus what they looked like ten years ago.

It's the broadening of the intellectual enterprise that Ernest Boyer has talked about, and that Dr. Pister has referred to, that I think that the Federal funding agencies, in their allocations of funds, and this committee, in having hearings like this, can help institutions raise people's awareness of indeed the fact that the administrations do value undergraduate teaching. But that has to be made part of a national agenda, not just a campus-wide activity.

Mr. NAGLE. But the contrast—the thing I'm consistently told, Dr. Ferguson, and I'm picking on you, because I think I know the answer—the thing I'm consistently told, of course, is the fact that smaller colleges produce so many more successful candidates—Ph.D. candidate levels—than your institution, Grinnell, which I'm of course intimately familiar with.

Is there a secret as to why more people are coming through your process as opposed to coming through the larger universities?

Dr. FERGUSON. Sure, because we're student-centered, because we judge ourselves in terms of alumni, because we believe very strongly in hands-on, investigative experience in the classroom of curricular innovation. We send our senior faculty in to teach.

I think that exciting, involving curriculum and giving faculty the development time, we devote significant funds at Grinnell to give faculty development funds to develop new courses, new curriculum, to provide opportunities for people from different disciplines to talk together.

Those aren't big dollars. I mean, it's a significant amount. I think we spent about $100,000 of our money last year. That's less than the cost of a start-up for half a chemist at MIT, but it provides that needed time and ability for people from disciplines to talk to one another.

I think that those are strong signals that can be sent, too. But I think it's that kind of emphasis.

Mr. NAGLE. Dr. Carlisle, Dr. Pister, Dr. Vest, any response?

Dr. PISTER. I agree. One of the problems at a large institution—research-centered institution—is that students look at the life of a young faculty member and say, hey, that's not a life I want to lead.

It's a very—it's a tremendously rewarding life, but it's an enormously high pressure life that, at the beginning, doesn't seem to be paying off.

It does pay off in the long run. I think those of us who have been through decades of academic life—I wouldn't do it any other way, if I could live my life again. It's a marvelous opportunity to serve society, and to find personal reward.

But today, the young faculty member, coming into the system, has a very different experience than I did forty years ago. The pressure is enormous, compared to what it was forty years ago.

I was able to get tenure at Berkeley, never having written a research proposal. That would be unheard of today, in most of our research institutions. Life was simpler.

Not that our whole society has changed, but I'm saying that Dr. Ferguson's remarks about hands-on involvement in students is the real answer to motivation and getting the more domestic students to go on to graduate school in the country, a matter that is in need of a great amount of attention in this country.

Mr. NAGLE. But some practical questions, if I could.

Dr. PISTER. Sure.

Mr. NAGLE. And, then, Dr. Carlisle, I'd welcome your response; Dr. Vest, I'd welcome yours on how you do that, I mean, just in terms of steps for the Congress—one, two, three, because I agree with you. I think the pressure—

Dr. PISTER. I think—and there may be some disagreement on this panel on this matter—I think the funding agencies have to look at the tripartite missions of their research universities that they are funding—teaching, research, and service.

You've given a great deal of attention to research, and only in very recent times has there been any attention at all to the matter of teaching in our research institutions.

I think the NSF has been a leader in setting up programs to enhance the quality of teaching undergraduates in math, science, and engineering.

Dr. VEST. I would particularly second the comments on the importance of hands-on experiences in learning about science. Every bit of data I've ever seen shows that that is important in retaining the interests of students and in enhancing and enriching their understanding of the fields.

That is the biggest challenge, I think, that those of us representing large universities face. It's becoming increasingly difficult to do that.

I mentioned earlier in my testimony that one way, over the years, that MIT has attempted to improve that situation somewhat is through an endowed program to involve undergraduates directly with faculty and graduate students in research activities. It's a very key component of much of the learning of our undergraduates.

It might interest you to know that that program came about because a very famous person in this country, Edwin Land, the developer of Polaroid photography and Polaroid corporation, saw this as a crying need, and devoted a significant part of his personal wealth, anonymously, I might add, to make this kind of education possible.

I also believe, and I hope not naively so, that the Federal Government could assist us in doing more development in this area.

Some of the things I've seen around the country in developing language skills through the use of interactive video, and so forth, I think, can be moved over into the learning domain in science.

A number of us in the room, I think, are aware of various experiments that have shown that some self-paced, computer- assisted learning in some of the core undergraduate areas of science have made tremendous impact on students, particularly in the very large schools.

So, there are some ways in which I think we can begin to mimic and learn from the experience in smaller instructional organizations.

Mr. NAGLE. Dr. Carlisle.

Dr. CARLISLE. First of all, I agree, wholeheartedly, with Dr. Pister's comments about funding, and that certainly is an area where, recently, NSF and the Congress have been helpful, and where I believe, in the future, it can both can be even more helpful.

Let me mention three things as illustrations of what I think might be done to encourage the better students to go on into university-kinds of activities, or at least to go on into graduate programs.

First of all, there is something we have done, or are doing, a second one we are about to do, and a third we must do.

The first is that we have completely revised and regenerated, in a substantial way, our honors program, so that more faculty are involved, and many more students are engaged. I think this is a way of personalizing undergraduate education for the most able.

Also, it is a way of encouraging them to think about graduate work and academic institutions as their professions.

Second, the SUCCEED Program in engineering, that I mentioned earlier is an example, it seems to me, of an NSF- funded program that will directly affect and improve, assuredly, the teaching of undergraduate engineering, and will also diversify the population of students in undergraduate engineering.

Third, is something we must do. We've talked about it. We have not yet done it, and we can learn here, certainly, from other universities, but particularly from liberal arts colleges. We really need to introduce into our university a somewhat, at least, coherent freshman year program that will help personalize the freshman year, help give it some kind of sense, other than its hugeness and fragmentation that so many young people, at least, could experience in coming, even, to Blacksburg.

That's something that we will be working on over the next couple of years.

Mr. NAGLE. Don't we though, with our policies of how we fund research from a Federal level, don't we actually contribute to the impediment of this process by requiring the measure of success of a professor of science or math to generate research dollars for his institution?

I mean, are we contributing to the dilemma that you have in terms of bringing the larger institutions to these people through the process? And, if we are, how do we correct that?

Dr. CARLISLE. I guess, since my mike's on, I think, that's probably the case. But I think what you are referring to is—and I'm going to pass this on to somebody else in a moment—what you are referring to, it strikes me, is part of a fundamental change in the way higher education has been funded over the last 25 years.

The funding structure has changed in a significant way and that, indeed, drives, to some extent, the rewards system. The funding structure may not change, but the way the funding is directed could help change the reward structure or the expectations we set for faculty, much the way that Dr. Pister was talking about.

Dr. PISTER. I think, in addition, the problem is complicated by the fact that the number of institutions and individuals competing for the funds has increased at a much faster rate than the availability of funds, so that the funding patterns that were possible to leave—I would put it this way—to leave the research university faculty in a state of reasonable equilibrium in the late 1950s and 1960s— we've passed that period.

Now, a faculty member, typically, has to devote, in my view, an unreasonable amount of time, in the competition process, often unsuccessfully and, indeed, in the case of a young faculty member, too often unsuccessfully, so that we have a lot of overhead, a lot of waste going on, and faculty having to try to compete for limited dollars.

Bob White, the President of NAE, in a paper he wrote, called attention to this. We are putting pressure on engineering faculty to compete in this arena instead of getting them off to do things that would help the economic competitiveness of the United States through more attention to their professional obligations.

So I think it is both the dollars available, what the dollars are for, and the competition for those dollars that's contributing to this problem. So our mission agencies need to rethink what they are going to spend their dollars for.

Mr. NAGLE. The Chairman is being very kind to me.

Dr. Vest, do you wish to contribute?

Dr. VEST. I agree very much with what Dr. Pister has just said, and in my own testimony made the point that one thing that, in my opinion, we do not want to do is to cut back on the availability of research funding, thereby exacerbating the various problems we are talking about.

I think we did agree, at the beginning of the session that the research productivity and function of our great universities is an enormous national strength.

What we are talking about is trying to achieve a better internal balance, but we certainly do not want to throw the baby out with the bath water, as one might say.

I also would make one statement that I'm not at all sure whether my colleagues would agree with or not. I, personally, believe we would make an error if in changing the thrust of some of the Federal funding to enhance undergraduate education, we were to begin to walk colleges and universities out on the same limb, whereby suddenly faculty would become responsible for bringing external funding in to support their teaching, for heaven's sakes. That would go in the wrong direction.

Therefore, as a policy matter, I would submit that the wisest course is to make increasing amounts of money available to develop experimental programs, to develop curricular materials, to try out innovative collaborations among universities, and so forth, but not to, in a sense, walk us out on the same limb of dependency that we have.

Mr. NAGLE. Let me ask you a question that may make everybody in the room nervous. It seems to me—and you immediately get in a great deal of difficulty if you say this, but I'm going to say it anyway.

But let me say to the four of you, you know, I know we have this peer process of review for research grants, but it seems to me that we are requiring the potentially teaching faculty/research faculty to spend an inordinate amount of time in pursuing of research, perhaps at the expense of undergraduate education.

Have we swung the pendulum so far towards the peer process of review and the peer process of application of research grants that we've got the pendulum too far on one side?

I mean, I remember talking to the head of a department at the University of Iowa where a quarter of his time is spent administering the department, and half of his time is spent, you know, making applications for grants, and the remaining quarter is spent one-twelfth teaching and one- twelfth doing his own research projects.

So, I mean, everyone says you can't attack the peer process, but I'd like to raise the question this afternoon, is that peer process contributing to a disbalance of emphasis on research at the Ph.D. level to a lack of emphasis on education at the undergraduate level, and are there papers or thoughts or any review in the scientific community, or in the academic community as to how we might strike a better balance?

Dr. VEST. One very quick comment, and then I'll turn to my colleagues.

I think that many of us believe that the fundamental issue is that in an era of relatively fixed Federal funding for research and higher education, that part of the problem is that far too many institutions have tried to march to the same drum.

I think there was general agreement across the table earlier that we must get away from the philosophy that every institution aspires to be a Ph.D.-granting research university.

We must be realistic about the number of schools of that type that we can afford in the country, and we must, I think, engender a greater public and professional respect for the variety of kinds of institutions that we make available to our young people.

Mr. NAGLE. Why do you make that assumption that some universities have to be research institutions and some universities have to be teaching institutions? What is the genesis of that conclusion?

Dr. VEST. Well, I believe that we have a wide variety of aspirations among young people, and not everybody needs to be exposed to the deep research enterprise. I think we need more attention paid to technical schools, to community colleges, to fitting people's talents to the outcome.

I think that we cannot afford for every institution to be in the same mold, nor should we. Grinnell is very different than MIT, and MIT is very different than Berkeley and Santa Cruz.

I think we should celebrate that difference and respect what each kind of institution can do well, and let students, sort of by the free market, if you will, flow to where they will get the most beneficial experience for themselves.

Mr. NAGLE. Yes. Go ahead.

Dr. FERGUSON. I'd like to agree with that; but, nonetheless, while we're marching to a different drummer, you guys are setting the tune.

People go into a discipline because they love the discipline. I identified myself, nationally, as a mathematician, not as a mathematician at a place "x."

As long as a huge portion of the NSF budget is going to research—and believe me, I'm not knocking research—but as long as that is where it is, that's where the prestige is.

None of us went into the scientific fields because we wanted to get rich. A lot of it is tied up with wanting to belong to this nationwide or worldwide collection of scholars.

So, I am in no way knocking research. But as long as most of the money that the Federal Government gives is for research, do not be surprised when most institutions and faculty are judging themselves that way.

If we are serious about improving undergraduate science education, you have to give more than seven percent of the NSF's budget to changing cur ·:ulum, to instrumentation, because otherwise, you are sending a mixed message to a very smart group of people.

It isn't that the faculty at Grinnell do not want to be on the faculty at MIT, nor do the faculty at VPI want to be, necessarily, at MIT, but they do need to still be part of the national agenda.

I think as long as the government is putting all those dollars in research—and, again, it's not a knocking of research—you can't be surprised when undergraduate education hasn't made quantum leaps forward.

Mr. NAGLE. What I don't understand about the academic community is why you, who are supposed to be in the forefront of research, are willing to accept a budget allocation as a given, and why I do not see more scholarly papers in review of the peer process, and where that peer process is driving us in terms of research allocation, and also why we are not questioning, generically, the allocation of resources.

I mean, I just don't see the creative thought coming from a community that should be known, first, not for its science, but for its creativity. I don't understand that.

Are there some papers out there that I haven't seen, or some research documents that I haven't seen, or some discussions taking place in some symposiums that I haven't had an opportunity to visit on this whole question, and if not, why not?

Dr. FERGUSON. Yes, I think there are. For example, the Gordon Conference is going on right now. Those are usually just about research topics. This week, it's devoted to talking about undergraduate education.

I think we are moving in that direction, but I agree, and I think this was in the NSF Young Scholars Symposium Report, which I know Denice and several others of the other panel talked about—about the need for the academic community to consider exactly these kinds of questions.

Mr. NAGLE. Anybody else?

Last question, are there some unique things that we are not doing? I promise, this is the last one, Mr. Chairman. Are there some unique things that we are not doing or that we should contemplate doing, in terms of attracting minorities, and within that, just generically, by definition, I would include women—to the scientific fields?

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Because when I looked at the pool of resource talent available, coming out of the high schools in the next decade, it appears to me that we are going to have a tremendous shortage, particularly in terms of captivating the intellectual talent of the Hispanic community, the Black community, the Vietnamese community, as well as women and other minorities.

I don't mean to exclude anybody by failing to identify them, but are there some things that we should be doing that we're not doing—some funding focuses that we should have that we don't have, or some projects, in any way shape or form, with regards to that direction?

Dr. PISTER. May I take that question, and then, Mr. Chairman, beg to be excused so I'll be able to get back to my job. I don't want to be an unemployed academic.

Mr. NAGLE. I promise this is the last question.

Mr. THORNTON. There's always room in politics.

[Laughter.]

Dr. PISTER. I think there is something, very definitely, that can be done by Federal agencies. Once again, I have no particular arrangement with the National Science Foundation, but I'd like to say that I think NSF has taken a leadership role, here again, in emphasizing programs that are aimed at diversity in engineering and science education, beginning at K-12.

I think the main thing that has to be done is for the budget allocators to work with us to change the institutional culture. We have tended to treat the question of diversity by marginalizing it in our institutions.

We set up programs that are, basically, at the edge. If you need to bring women into engineering, you set up a program that's at the edge of the function of the school or college, called a special program for women in engineering, and you make the women students feel comfortable because they are part of that program. Gradually, they are assumed to be integratable or assimilated into the mainstream male culture, in this case.

The same thing is true of our minority students. We started there. We had to make a start with under-represented minorities and women, using this marginal model. But I contend that, particularly because of the nature of the population, the ethnic composition change in the population, we can no longer afford to do this.

We have to mainstream our programs aimed at diversity. We can no longer expect, as the sociologist would say, to move toward the homogeneous ideal. It just won't happen.

So, I encourage you to look at ways to force institutions to make the question of diversity of the faculty, the students, and the staff a main structural problem for the institution.

May I be excused, Mr. Chairman?

Mr. THORNTON. I'm sorry, Dr. Pister. I think that does conclude the time for this panel.

I want to thank my colleague from Iowa, Mr. Nagle, for his fine questions, and commend each of you for your responsiveness. I would like to ask, if you would agree, that if the staff decides some additional points need to be covered, if you would respond in writing to such questions as they may address.

I thank each of you for your testimony.

The second panel will come forward.

The hearing will resume.

We now, having identified that the real focus of this hearing should be upon those people who serve as chairmen and department heads—I notice that we have two department heads or chairmen and an associate dean, and an associate professor in a department, so now is your time to help us to understand the nature of the problem that we have and the nature of the solutions we should be seeking.

Our panel number II is going to include Dr. Homer Neal, who is the Chairman of the Department of Physics, University of Michigan, Ann Arbor; and Dr. Samuel Ward, who is the Department Head, Professor of the Department of Molecular and Cellular Biology, Professor of Ecology and Evolutionary Biology at the University of Arizona, Tucson, Arizona; Dr. Jack Lohmann, Associate Dean of the College of Engineering, and Professor of Industrial and Systems Engineering of Georgia Institute of Technology—Georgia Tech, is the way we think of them in the Southeast Conference—in Atlanta Georgia; and Dr. Denice Denton, who is Associate Professor of the Department of Electrical and Computer Engineering, University of Wisconsin, Madison, Wisconsin.

We will follow the same procedure as in the last panel. I will ask, in each case, that your prepared testimony be submitted into the record, verbatim, and ask each of you, if you will, to hit the high points of that testimony so that we can go forward with the questions.

Dr. Neal.

STATEMENT OF DR. HOMER A. NEAL, CHAIRMAN, DEPARTMENT OF PHYSICS, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN

Dr. NEAL. Thank you very much, Mr. Chairman.

I'm, again, honored to have been asked to share with you my views on the state of undergraduate science education in this country.

In the report of our National Science Board Committee in 1986, we found that there were indeed very serious problems of quality in undergraduate science education, and we proposed a series of corrective steps.

Many of these have been implemented, either directly or indirectly, by the National Science Foundation, by other Federal agencies, by private foundations, and by States and universities, and there is evidence of considerable progress.

Other recommendations put forth in our report have yet to be realized, and I would like to take this opportunity to direct attention to the fact that these proposals do retain, even today, a high degree of currency, despite the remarkable world changes that have taken place since the recommendations were made.

I believe I can best serve you today by reviewing a few of the areas where progress has been made in undergraduate science education over the past five years, highlighting some of our previous recommendations that remain unimplemented, and sharing views on what should be done in the years ahead.

As a prelude to my remarks, though, I note that quite often when one speaks of achieving balance between teaching and research, one generates the mental image of the proverbial scale of justice, with teaching on one side and research on the other. The image causes some to immediately see a perceived resolution of the problem of balance; namely, to simply move resources from one side to the other. But unless considered with great care, such an approach can be counterproductive. There are at least two reasons why this is so.

First, teaching and research are intimately connected. We are literally dealing with a living organism that will not necessarily be more effective if we cut off one of its legs and give it an additional arm. To carry the analogy one step further, I believe that it is important that we focus on the health of the entire organism.

Indeed, as many of the panelists before me have pointed out, removing support from research at our colleges and universities—even for the express reason of providing additional support for teaching—may simply further detract from the quality of teaching, as our faculty would then be forced to commit even more of their time attempting to secure funds to permit them to carry out their research.

In the area of condensed matter physics, for example, new faculty are already, on average, having to submit on the order of more than a half-dozen proposals in order to acquire initial funding from even one proposal. It is in no one's best interest to reduce this success rate even further.

One of the great success stories of this country has been its graduate programs. They are the envy of the world. Students from around the globe come here for advanced study, and graduate education may be one of the Nation's most important exports.

Our research and graduate programs are outstanding, but vulnerable, and we must be very careful not to destroy them in our legitimate quest to improve undergraduate education.

The committee staff asked me to comment on whether deficiencies in the undergraduate programs at our major universities occur because more attention is paid to research than teaching, when important decisions are being made regarding tenure, promotion, and the setting of salaries.

Indeed, research achievement is almost always the principal criterion for judging the promise and stature of a faculty member at our major research universities, and I strongly believe that thi· is as it should be.

American universities have as their critical mission the advancement of knowledge, and they will continue to be effective in this endeavor only if they accord the highest recognition to the creativity of the human mind in attacking problems at the disciplinary level.

But teaching is also very important, and any institution that does not take teaching effectiveness into account in evaluating and rewarding faculty is failing to serve both its students and itself.

Most faculty enjoy teaching—and the opportunity to influence the lives of bright young people is one of the reasons they chose to work at a university, rather than in industry or at a national laboratory. A professor's effectiveness in teaching should be taken into account in all critical decisions affecting him or her.

The second reason why there is not a simple tradeoff between research and teaching emerges when we attempt to quantify what we mean when referring to the balance, or lack thereof, between research and teaching.

Of the 2,500 or so colleges and universities granting the baccalaureate in the U.S., there are probably only 100 or so with research enterprises so large that one might postulate that there is risk of the teaching programs being compromised by the research. This might involve 20,000 science faculty out of a total of almost 200,000.

Moreover, roughly 90 percent of these faculty are probably tenured and would not be directly affected by tenure and promotion criteria.

Thus, we could be assessing conditions that might impact only roughly one percent of the science teaching workforce— although it's a very, very important one percent.

Regarding matters such as salary and other recognition, the population of affected science faculty is some fraction of 10 percent, one would guess, and this fraction, I believe, is declining since an enormous number of major universities, my own included, are embarked on numerous projects to improve their undergraduate programs.

So, I, for one, am somewhat reluctant to join in any condemnation of our universities for ignoring undergraduate science education in favor of research.

Indeed, I want to recall that it was at the Federal level that all NSF undergraduate programs were wiped out less than a decade ago. We are still trying to recover from the terrible impact of that action.

None of these considerations, however, diminishes the need for universities to be ever alert for ways to improve their undergraduate teaching, including ways of involving undergraduate students in ongoing research, efforts in updating curricula, and ways of taking advantage of advances in instructional techniques.

Also, the remarks above are not meant to argue that there are no problems in undergraduate science education. There are definitely problems, and we need to dedicate ourselves to finding the proper solutions.

A few words about progress at the NSF—the Research Experience for Undergraduates Program, initiated in 1987 by the Science Foundation, has been very successful. This activity was strongly suggested by our Board Committee, and the then-director of the Science Foundation, Eric Bloch, moved to implement it even before the work of our Committee had been completed.

It has already touched the lives of the order of 14,000 bright undergraduates across the country, and has given these students the opportunity to work directly with faculty on current, ongoing research programs.

It, I think, is a fine program. It makes a lot of sense. It is a way of bringing these students into direct contact with professors in their professional home.

I certainly urge Congress to continue support for this program, and even to take advantage of opportunities to strengthen it in the years ahead.

The various curriculum development activities at the Foundation are also achieving success. Two examples, as I've mentioned in my written testimony, are the engineering curriculum and the calculus curriculum.

I should point out that the USEME Office has been established and seems to be functioning quite well. I understand that it now receives more proposals than any other division in the National Science Foundation.

It serves a very appropriate role as a coordinating focus for a wide variety of undergraduate science education initiatives, and it is impressive to realize that it's only been in existence for a very short period of time.

Nevertheless, I am concerned about the overall level of NSF activity in the undergraduate sector. Our study called for a base funding level for selected undergraduate initiatives, a supplement of $100 million per year. From my review of what has been initiated at the NSF in connection with our report, only about half that amount seems to have been provided.

We were very conservative in our estimates of the actual needs, and I am not at all surprised that serious national problems in the undergraduate science education are continuing, given the reduced level of support.

Moreover, while addressing the issue of balance, I must admit to being puzzled by the fact that of the education and human resources budget, evidently less than 15 percent is being provided to undergraduate activities.

It is very appropriate that we all be concerned about what is happening at the school level, but we must not forget that undergraduate education is a critical section of the talent pipeline—and that it even ultimately influences our ability to deal with issues at the pre-college level.

Mr. Chairman, in my notes, I have a few paragraphs discussing a new initiative—the suggestion that there be created a series of national centers for undergraduate science education. But in the interest of time, I will skip that and perhaps return to it in the—

Mr. THORNTON. Of course, the Visiting Fellow Program is a part of that initiative.

Dr. NEAL. Yes, that's right. Would you like me to comment on that?

Mr. THORNTON. Yes, please, go ahead.

Dr. NEAL. Under proposed new initiatives, I am suggesting that the Foundation and Congress consider the creation of a few national centers focused on addressing well-defined issues in undergraduate science education.

I was a member of the NSF Physics Advisory Panel, many, many years ago, when we were considering the creation of the Santa Barbara Institute for Theoretical Physics. Later, I was a member of the National Science Board when we had the opportunity—the requirement—to review that entity after five years.

I have been impressed by what can happen when a dedicated unit is created to look at a general area of intellectual concern.

This has led me and several of my colleagues at Michigan to the conclusion that the NSF or other agencies should establish a series of national centers in the U.S. devoted to undergraduate science education.

The centers should have as their central core a visiting fellow program—just like the Santa Barbara institute— where outstanding scientists and educators spend a year in residence at the host institution, carrying out their work, organizing workshops, following up on the outcomes, disseminating results, and testing ideas for their general applicability.

We believe that only in such intense settings can new directions in undergraduate science education emerge and then be immediately challenged and honed by the most talented and interested scholars in this area.

Other advantages of such a program—ones that are especially appropriate to the hearing today—are the signals given both to the local institution and around the country that undergraduate education is important—even important enough to justify having small groups of the best minds in the country to set aside dedicated time to plan the needed initiatives.

Being selected as a fellow at one of these centers could be a distinct honor, giving the individual added stature at his or her home institution.

We've learned over the decades that strategies of this type do work in the research arena. There is absolutely no reason why they should not be tried in science education.

Indeed, while paying full respect to the important contributions of our colleagues in education, I need to note that one of our shortcomings in undergraduate science education is the failure to create sufficiently attractive possibilities to entice our very best scientists to devote their attention to science education issues. In the proper environment, they would be happy to do so.

Given these considerations, my recommendation is that the next wave of initiatives in undergraduate science education should include centers designed to provide an institutional framework for attacking the front-line problems in science education.

I should also note that our study called for the creation of a program within the NSF to support comprehensive, multi- discipline, curriculum development projects. This remains, in my opinion, another important area for consideration as the Foundation's undergraduate programs evolve.

Thank you, Mr. Chairman, for the opportunity to share these views with you.

[The prepared statement of Dr. Neal follows:]

TESTIMONY PRESENTED TO THE

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING ON THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION:

ACHIEVING A BALANCE BETWEEN TEACHING AND RESEARCH

March 31, 1992

by

Homer A. Neal
Department of Physics
University of Michigan
Ann Arbor, Michigan

Mr. Chairman and members of the Subcommittee on Science, I am again honored to have been asked to share with you my views on the state of undergraduate science education in this country.

In the report of our National Science Board Committee in 1986, we found that there were indeed serious problems of quality in undergraduate science education and we proposed a series of corrective steps. Many of these have been implemented, either directly or indirectly, by the Foundation, by other federal agencies, by private foundations, and by States and universities, and there is evidence of considerable progress. Other recommendations put forth in our report have yet to be realized, and I want to take this opportunity to direct attention to the fact that these proposals retain a high degree of currency, despite the remarkable world changes that have taken place since the recommendations were made.

I believe I can serve you best today by reviewing those areas where progress has been made in undergraduate science education over the past five years, highlighting our previous recommendations that are yet to be implemented, and sharing views on what should be done in the years ahead.

As a prelude to my remarks, I note that quite often when one speaks of achieving balance between teaching and research one generates the mental image of the proverbial scale of justice, with teaching on one side and research on the other. The image causes some to immediately see a perceived resolution to the problem of balance, namely, to simply move resources from one side to the other. Unless considered with great care, such an approach can be counterproductive. There are at least two reasons why this is so. First, teaching and research are intimately coupled. We are literally dealing with a living organism that will not necessarily be more effective if we cut off one of its legs and give it an additional arm. To carry the analogy one step further, I believe it is important that we focus more on the health of the entire organism.

Indeed, removing support from research at our colleges and universities -- even for the reason of providing additional support for teaching - may simply further detract from the quality of teaching, as our faculty are forced to commit even more of their time attempting to secure funds to permit them to carry out their research. In the area of condensed matter physics, for example, new faculty are already, on average, having to submit more than a half-dozen proposals in order to acquire initial funding from one. It is in *no one's* best interest to reduce this success rate even further.

One of the great success stories of this country has been its graduate programs. They are the envy of the world. Students from around the globe come here for advanced study, and graduate education may be one of our nation's most important exports. Our research and graduate programs are outstanding, but vulnerable, and we must be very careful not to destroy them in our legitimate quest to improve undergraduate education.

The Committee staff has asked me to comment on whether deficiencies in the undergraduate programs at our major universities occur because more attention is paid to research than teaching, when important decisions are made regarding tenure, promotion and salary. Indeed, research achievement is almost always the principal criterion for judging the promise and stature of a faculty member at our major research universities -- and I strongly believe this is as it should be. American universities have as their critical mission the advancement of knowledge, and they will continue to be effective in this endeavor only if they accord the highest recognition to the creativity of the human mind in attacking problems at the disciplinary level. But teaching is also very important, and any institution that does not take teaching effectiveness into account in evaluating and rewarding faculty is failing to serve both its students and itself. Most faculty enjoy teaching -- and the opportunity to influence the lives of bright young people is one of the reasons they chose to work at a university, rather than a national laboratory or in industry. A professor's effectiveness in teaching should be taken into account in all critical decisions affecting him or her.

The second reason why there is not a simple tradeoff between research and teaching emerges when we attempt to quantify what we mean by balance, or lack thereof, when referring to research and teaching. Of the 2500 or so colleges and universities in the U.S., there are probably only about 100 with research enterprises so large that there is a reasonable risk of their teaching programs being compromised by them. This might involve roughly 20,000 science faculty out of a total of almost 200,000. Moreover, roughly 90% of these faculty are probably tenured and would not be affected directly by tenure and promotion criteria. Thus, we are assessing conditions that might impact approximately 1% of the science teaching workforce -- albeit a very, very important 1%. Regarding matters such as salary and other recognition, the population of affected science faculty is some fraction of roughly 10%, and this fraction I believe is declining since an enormous number of our major universities, my own included, are embarked on numerous projects to improve their undergraduate programs. So I am very reluctant to join in mass condemnation of our universities for ignoring undergraduate science education in favor of research. Indeed, I want to recall that it was at the federal level that all NSF undergraduate programs were wiped out less than a decade ago. We are still trying to recover from the terrible impact of that action.

None of these considerations, however, diminishes the need for universities to be ever alert for ways to improve their undergraduate teaching, including ways of involving undergraduate students in ongoing research, efforts in updating curricula, and ways of taking advantage of advances in instructional techniques. Also, the remarks above are not meant to argue that there are no problems in undergraduate science education. There are definitely problems and we need to dedicate ourselves to finding the proper solutions.

Progress at the NSF:

The Research Experience for Undergraduates Program, initiated by the NSF in 1987, has been very successful. This activity was strongly suggested by our Board Committee, and Director Bloch moved to implement it even before the work of our Committee had been completed. It has already touched the lives of over 14,000 bright undergraduates across the country, and has given these students the opportunity to work directly with faculty on current, ongoing research programs. It is, as in many of these matters, difficult to say how many new scientists we will have 10 to 15 years from now as a result of this program. But it makes just so much sense that we take this extra step in bringing students together with faculty in the faculty member's professional home. This program is another example of why the tradeoff between research and teaching is not a simple one. I urge Congress and the NSF to continue to support the REU program, and to take advantage of opportunities to strengthen it based on what is learned as the program is continually reassessed.

The various curriculum development activities at the Foundation are also achieving success. A nationwide marshalling of attention on the need to revise the calculus curriculum and the engineering curriculum are two examples of where a modest leadership effort by the Foundation has had an impact on the entire country. Moreover, in just the past year we have seen the introduction of a broad-based course and curriculum development program at the Foundation.

The USEME Office recommended by our Committee has been established and is fully functional. I understand that it now receives more proposals than any other Division in the Foundation. It serves a very critical role for a wide variety of undergraduate science education initiatives.

Nevertheless, I am concerned about the overall level of NSF activity in the undergraduate sector. Our National Science Board Study called for a base funding level for selected undergraduate initiatives of $100 million per year. From my review of what has been initiated at the NSF in connection with our report, only about half of that amount has been provided. We were very conservative in our estimates of the actual needs, and I am not at all surprised that serious national problems in undergraduate science education are continuing, given the reduced level of support. Moreover, while addressing the issue of balance, I must admit to being puzzled by the fact that of the EHR budget evidently less than 15% is being provided to undergraduate activities. It is most appropriate that we all be concerned about what is occurring at the school level, but we must not forget that undergraduate education is a critical section of the proverbial talent pipeline -- and that it even ultimately influences our ability to deal with issues at the pre-college level.

Proposed New Initiatives

An area where I believe more activity is needed is in the establishment of a few national centers focussed on addressing well-defined issues in undergraduate science education. As a member of the NSF Physics Advisory Panel during the days when the creation of the Santa Barbara Institute for Theoretical Physics was under discussion, and as a member of the National Science Board when the five-year review of that entity took place, I have been impressed by what can happen when a dedicated unit is created to look at a general area of intellectual concern. This has led me and several of my colleagues to the conclusion that the NSF or other agencies should establish a series of national centers in the U.S. devoted to undergraduate science education.

The centers should have as their central core a visiting fellow program, where outstanding scientists and educators spend a year in residence at the host institution, carrying out their work, organizing workshops, following up on the outcomes, disseminating results, and testing ideas for their general applicability. We believe that only in such intense settings can new directions in undergraduate science education emerge and be quickly challenged and honed by the most talented and interested scholars in this area. Other advantages of such a program -- ones that are especially appropriate to the hearing today -- are the signals given both at the local institution and around the country that undergraduate education is important, even important enough to justify having small groups of the best minds in the country to set aside dedicated time to plan the needed initiatives. Being selected as a fellow at one of these centers could be a distinct honor, giving the individual added stature at his or her home institution. Nationally, a major cause for the lack of effort put into undergraduate science teaching is the lack of recognition and respect given to the teachers by the "system". Activities that increase recognition and respect should be taken very seriously.

We have learned over the decades that strategies of this type do work in the research arena. There is absolutely no reason why they should not be tried in science education. Indeed, while paying full respect to the important contributions of our colleagues in education, I note that one of our shortcomings in undergraduate science education is the failure to create sufficiently attractive possibilities to also entice our very best scientists to devote their attention to science education issues. In the proper environment, many would be eager to participate.

Given these considerations, my recommendation is that the next wave of initiatives in undergraduate science education should include centers designed to provide an institutional framework for attacking the front-line problems in science education

I should also note that our study called for the creation of a program within the NSF to support comprehensive, multi-discipline, curriculum development projects. This remains, in my opinion, another important area of consideration as the Foundation's undergraduate programs evolve.

Thank you for the opportunity to share these views with you.

Mr. THORNTON. Thank you, Dr. Neal.

We will next hear from Dr. Samuel Ward. Your paper, together with a lot of very good supporting data, will be made a part of the record, and I would appreciate your summarizing or highlighting that presentation to us.

Dr. Ward.

STATEMENT OF DR. SAMUEL WARD, PROFESSOR AND DEPARTMENT HEAD, DEPARTMENT OF MOLECULAR AND CELLULAR BIOLOGY, AND PROFESSOR OF ECOLOGY AND EVOLUTIONARY BIOLOGY, UNIVERSITY OF ARIZONA, TUCSON, ARIZONA

Dr. WARD. Thank you very much, Mr. Chairman.

I represent the University of Arizona. That's in Tucson, not in Tempe. We are the land grant institution in Arizona and, therefore, serve the wide range of responsibilities for both service and education that land grant institutions do.

I would also like, off the record, please, to express my condolences to the Chairman for the performance of another side of our university's two basketball teams which are not with us in the Final Four, as opposed to my neighbor to the left.

Mr. THORNTON. Yes, I regret that that has happened. It just shows that you can't always win.

Dr. WARD. It's because we're investing all our efforts in training undergraduates in science at the University of Arizona.

Mr. THORNTON. Our efforts are in academia, yes.

Dr. WARD. I would like to focus on biology education at the university and a number of programs that we've initiated that I believe address a number of these questions.

I should point out that I come as a newcomer as a department head for just a few years, and have been learning and listening with interest to the previous speakers about their longer ranges of experience.

But we've started with a program to attempt a balanced teaching and research by really trying to argue that that distinction ought to be irrelevant.

The research and teaching are really two sides of the same coin, as our new president at the University of Arizona, Manuel Pacheco, has said, in that proper teaching should, in fact, involve the doing, the hands-on process of science, and therefore, should interact with research.

Therefore, the fact that we conduct this debate shows really how poor our teaching has been, that we simply have to say that we aren't trying to separate these two.

So, what we've done at the university, as so many universities—and you've heard elsewhere—is to try and expand the opportunities for undergraduates to do individual research in laboratories.

We've done that in a coordinated program that now has expanded across the campus to include more than 165 faculty in biology, in 26 different departments, representing six different colleges.

In this program, students can apply and begin working the summer as early as their freshman year. We also accept students—not just biology majors—but students from other disciplines as well, with the realization that part of, I think, our largest failing in science education is to educate the non-scientists.

What we've discovered in three years now with this program, is it's had an enormous impact on the students and, in fact, on the faculty and, to our somewhat surprise, actually on the university as a whole.

Because what we've done is achieved, at least to a certain extent, one of the things that Dr. Pister commented about. This program has actually created a sense of community across the campus that spans the colleges of agriculture and medicine, for example.

It's gotten faculty in the college of medicine, who normally have no formal responsibilities for undergraduate education, to be interested in these students and discover that there is an extraordinary collection of students at a big state university like Arizona that has 28,000 undergraduates.

What we discovered, as many have known before, is that a research lab is an extraordinarily educational opportunity. A student can come into a laboratory that consists of graduate students, postdoctoral fellows, technicians, other faculty, other students, and work together as a team, both to learn how they can contribute, and also achieve the benefit of a mentoring environment with a lot of roles and people to support them.

We found our program includes participation of more than half women, 18 percent minority students. These students have benefitted enormously, because one of the reasons that they drop out of science so rapidly, is that they don't have the encouragement—that they, in fact, have the ability to do it, but they don't have the self-confidence.

In a laboratory like this, we can really increase the number of these students, and that's had a very large impact. It changed the career paths of a large number of these students.

So I think this is one of the special opportunities that a large research university can offer to its undergraduate program that really is distinctive.

If you ask, then, what do the faculty gain from this? Why do the faculty participate? That gets back to this issue of academic rewards. We've talked at great lengths from the previous panels about the disbalance of rewards in teaching and research.

Here, again, the faculty, we estimate, are contributing more than $10,000 hours to this program, as direct instruction to these undergraduates. They do this, partly, because this is science teaching as they like, it's hands-on, they can work directly with the students.

The students themselves are excited. They are bright. They are energetic. They are fun. They ask all those questions that the rest of us are too smart to know to ask. They didn't know they weren't supposed to ask those questions. So, that's had enormous benefit.

But we have a difficult problem rewarding this academically. This comes back to the question that all of us struggled with, which is how do you evaluate this teaching? How do you compare the teaching that a faculty member does with two or three students in their laboratory to a faculty member who gives the introductory biology lecture to 500 students?

We have a State legislature and Board of Regents that looks hard at student credit hours. To them, the faculty member teaching 500 students in a classroom is 500 times more valuable than teaching one student in your laboratory, when to that one student, you may change their whole career.

So I think we have a difficult time deciding how to evaluate that diversity of teaching activities that we would like to encourage at a large university.

Second, I think the other barrier to establishing this effectively, which has been addressed by many of the previous speakers, is the difference between the extrinsic rewards of teaching and of research.

Research is recognized nationally, internationally. It brings you money. It brings you prestige. It brings you invitations to international meetings in nice places around the country.

Teaching, on the other hand, is normally recognized only on a local level. I think, on an optimistic note, that's what is changing rapidly.

The investment that you have encouraged in the National Science Foundation—to support teaching, to support innovative teaching, to recognize teaching by grant support— is having a huge impact directly on teaching.

But it's having a larger impact on changing the value system of the academics to where people can recognize that.

In biology, we have another enormous advantage that the Howard Hughes Medical Institute has made a large investment in biology instruction.

Over the past four years, they've invested $173 million in biology instruction, in colleges of all kinds throughout the country.

That's, of course, had a direct impact on teaching. We've developed, and our program is, in part, funded by that. We have developed a number outreach programs to high schools and elementary schools, using those funds as well.

But even more so, the Howard Hughes Institute, because of its history of supporting the most prestigious research in molecular biology and genetics—when the Howard Hughes Institute says that it's okay to teach, and we'll support you to do it, it has also changed the value system of the research community.

That's also happening by the professional societies. That's also happening in the National Academy of Sciences. The National Research Council has sponsored a number of really excellent studies—one on biology education called, "Fulfilling the Promise" which has served as a model for biology education at all levels and, in part, because it blames everybody equally.

The teachers are at fault. The schools of education are at fault. The textbook manufacturer is at fault. But most at fault are the professional scientists, because we have ignored the problem of high school and K-12 education.

Many of us are changing this, partly as a result of that study of the National Research Council funding an additional council to investigate the most effective mechanisms to improve biology high school teaching.

I'm Chairman of that National Research Council committee, which is investigating programs all over the country to find those that work, and choose those and recommend how professional scientists and the rest of us can help improve science teaching, not just to the pre-service level, but at the large number of teachers who are already out there, that need an enormous amount of help.

So, I think all these activities can be effectively integrated at a university, and I think our value system really is changing to reward these kinds of things.

The recommendations that I would make to this council is that we encourage all the agencies to require educational components to their research grants.

One of the conclusions of the PYI study and others is that by separating these two and the way they are funded, it has helped perpetuate this artificial distinction.

The kinds of programs like the REU grants, the programs that NIH has put in, where it's easy to get supplements to encourage undergraduates in your labs—these are all extremely effective and, therefore, tie the two activities together.

Second, we obviously need more grants for direct, innovative science education that provide the support and recognition for this activity. But we also have to be careful, because there has been a large tendency to support innovative things and then not develop the mechanisms to institutionalize these.

Science education has an enormous sense of amnesia. We're very good at inventing wheels over and over again, and not very good at ever attaching them to the wagons.

So, I think it is not just to fund innovation. We have to develop institutional mechanisms to insure the things that went on before.

Our undergraduate research program is no different than one that has gone on in many, many years at all research universities. By codifying and expanding and spreading it around the campus, it's had a big effect. But we know how to do that. What we need are ways to institutionalize and support more of those.

Then, finally, of course, this committee and the fact that this panel is being held reflects the importance that our continuing attention to the education, both in public and in the legislature—the importance of science education—this cannot be overemphasized.

Thank you.

[The prepared statement of Dr. Ward follows:]

Research and Teaching in the Biological Sciences

Statement by

Samuel Ward, PhD
Professor and Department Head
Department of Molecular and Cellular Biology
Professor of Ecology and Evolutionary Biology

University of Arizona, Tucson, Arizona

Hearing on the Quality of
Undergraduate Science Education

Subcommittee on Science
U.S. House of Representatives
Committee on Science, Space and Technology

March 31, 1992

Research and Teaching in the Biological Sciences

Statement before the Subcommittee on Science of the U.S. House of Representatives
Committee on Science, Space and Technology

Samuel Ward, PhD
Professor and Head of the Department of Molecular and Cellular Biology and
Professor of Ecology and Evolutionary Biology
University of Arizona, Tucson, Arizona

> We share in the nationwide opinion that undergraduate education has not always received the priority that it deserves, and that the time has come to restore a better balance. Unfortunately, but inevitably, the discussion already has included suggestions that there is a choice between research and teaching. To my mind, nothing could be further from the truth. Research and teaching are two sides of the same coin. Research is a form of personal learning for the researcher, self-teaching if you like. More than that, in my experience active involvement in research represents one of the best possible guarantees of lively, up-to-date teaching. . . .Research versus teaching is a non-issue. Both must be done equally well and, in strengthening our research, we develop the ability to also strengthen our teaching programs.
>
> Dr. Manuel Pacheco, President of the University of Arizona

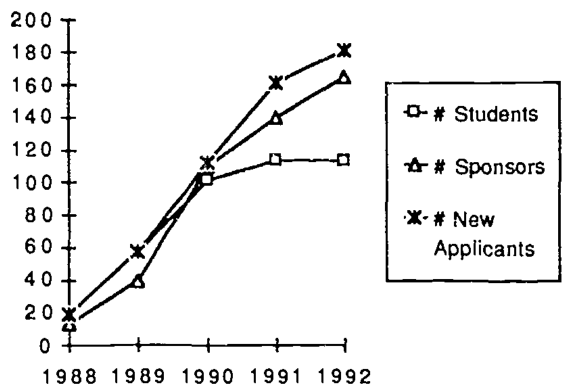
The proper balance between teaching and research at universities has been debated since the establishment of the first research universities in this country at the end of the last century. The issues are clearly laid out in the Committee's memorandum from Representative Boucher so I will not repeat them here. What I will do is describe some of the programs we have initiated at the University of Arizona to improve biology education at all educational levels by combining research and teaching.

Our philosophy is indicated by the quotation above from a speech Dr. Manuel Pacheco, President of the University of Arizona, delivered at our annual Undergraduate Biology Research Symposium this year. We believe that research and teaching are inseparable so that the discovery and dissemination of knowledge go hand in hand. At the University of Arizona, my colleagues and I have focused on attracting students into the biological sciences by providing opportunities for independent research in faculty laboratories. It is our conviction that actually doing science, rather than simply reading or listening about science, is the best way to learn science. A research university should enable as many undergraduate students as possible to work in research laboratories. Enterprising students have always found ways to get into research laboratories, and this has been encouraged at many universities. What we have done is establish a campus-wide program to facilitate participation by as many students as possible.

University of Arizona Undergraduate Biology Research Program

At the initiative of department head Michael Wells, the Department of Biochemistry began a formal undergraduate research program in the summer of 1988 with 19 students in 13 faculty labs. Under the energetic leadership of program coordinator Carol Bender, and aided partly by educational grants from the Howard Hughes Medical Institute, the National Science Foundation and others, and mostly from Federally funded faculty research grants, we have expanded this Undergraduate Biology Research Program (UBRP) to support 113 students during the summer and 75 during the school year (see figure).

Undergraduate Biology Research Program Growth
1988-1992



These students can choose sponsors from among 165 participating faculty. More than half these students are women and 18% are minorities. Both the faculty and student support for this program has been overwhelmingly enthusiastic, and many students have altered their career goals as a result of their experience.

Several distinctive features of our program contribute to its success. First, participation is restricted to University of Arizona undergraduates, except as described below. This provides program continuity and develops enthusiasm for the program on campus. Second, all students are paid for their work (currently $5.40-5.75/hour). This is essential for many of the students who must earn money for college expenses. Third, faculty sponsors must match program grant support by paying half the student's wages and all supply costs. This ensures that students are working in active labs with grant support, guarantees faculty commitment to the student, and leverages our educational grant money to support more students. Fourth, we recruit students early with a simple application process so that nearly a quarter of our students begin in the summer of their freshman year. This exposes students to the excitement of biology research early. We have found that with guidance, these inexperienced students can make significant contributions in the lab. Fifth, students take an active role in finding a lab by interviewing prospective faculty sponsors themselves. This ensures a match of interest and personalities and conveys a sense of responsibility to the students. Sixth, we define biology broadly so faculty from 26 different departments participate, including those from the Colleges of Arts and Science, Medicine, Agriculture, and Pharmacy, and the School of Health Related Professions. This gives students a wide array of research opportunities and gives us a large and growing pool of faculty sponsors.

Based on both student and faculty evaluations, we believe that one of the most important reasons for the impact of this program on the students involved is the intellectual and educational atmosphere of an effective research group. By being part of a team of faculty, graduate students, postdoctoral fellows, technicians and other students, undergraduates learn from a variety of individuals who share their own research experiences and serve as role models and mentors. This mentoring, particularly at a large, impersonal, state university, is important to their scientific success, particularly for minority students and women, who often lack the initial self confidence to succeed in science on their own.

In addition to the individual laboratory experience, UBRP sponsors informal seminars during the summer, a monthly newsletter, an undergraduate colloquium series with outside speakers, and an annual research conference with student posters. This conference generates great excitement among the students and outstanding participation. It would be difficult to distinguish the quality of their presentations from those at a professional scientific meeting. The program also provides travel funds for students to present their work at professional meetings. UBRP students have contributed posters or presentations at 51 professional meetings, and they have co-authored 37 scientific publications based on their own research.

Since the inception of this program, we have learned that students with a wide range of backgrounds can benefit. Therefore, we have expanded participation by including high school students, high school teachers and Native American students from other institutions, primarily Navajo Community College. Many of these students have been productive, and the teachers particularly have benefitted.

The UBRP has had several unexpected outcomes. When the undergraduates in the UBRP heard about our outreach programs to schools and teachers, they themselves formed *Science Connection*. This is a program for undergraduates to visit elementary and secondary schools to teach science. Their excitement has been infectious to younger students, and we now have an overwhelming demand from teachers for undergraduate student help. The undergraduates have learned the rewards and the challenges of teaching (they come back exhausted after only part of a day in an elementary school classroom), and some of them are thinking about teaching careers, an option most had not previously considered.

In addition to benefitting the students and faculty directly involved, the UBRP has had a significant impact on the University as a whole. It has created interest in undergraduate education among faculty who normally have no contact with undergraduates, such as faculty in the College of Medicine. It has served as a model for how research faculty should participate in undergraduate teaching, cooling the sometimes heated discussion on campus of research versus teaching. This program was highlighted as a "Science Role Model" in *Science* (24 January, 1992).

How can we foster more programs of this type and how else can we utilize the special resources of a research university to improve science education? To answer these questions, we must address the relationship between academic rewards and science teaching.

Academic Rewards and Science Teaching

Harvard University's former president, Derek Bok, entitled his 1989 report to Harvard's Board of Overseers "What's Wrong with Our Universities?" (*Harvard Magazine*, May-June 1990). In a section entitled "The Behavior of Faculty", he points out that:

> A serious attempt to balance the legitimate claims of teaching and research must begin by understanding something of the incentives that inspire each type of activity. Both pursuits hold great intrinsic interest, just as both can entail much drudgery and frustration. In contrast, the *extrinsic* incentives and rewards are almost always more powerful for research than they are for teaching.

President Bok goes on to describe the external rewards of financial support, recognition, and visibility outside the university that research conveys. In contrast, teaching is usually rewarded only internally. It follows from this analysis that to tip the balance toward the legitimate claims of teaching, a university must increase its internal rewards for teaching. But to truly redress the balance, the external rewards must be increased as well. How can this be accomplished?

Internal rewards

Internally, the university administration from the president to department heads must establish clear expectations for both quantity and quality of teaching, set good examples, and reward excellent teaching with promotion, salary increases and recognition. This requires an adequate system for teaching evaluation that includes student evaluations for presentation, clarity and student concern, peer evaluations of content and organization, and longer term evaluations of overall effectiveness from departmental assessment by graduating seniors and eventually alumni follow-up.

This evaluation is both difficult and time-consuming. The data are often hard to interpret and use fairly because there are multiple goals in science teaching. How do you evaluate a faculty member who presents a difficult, thought-provoking course that discourages half the students, but inspires a few to choose a career in biology? How do you compare the teacher who is effective in a large, introductory classroom with one who inspires a small number of students doing research in her laboratory? I believe the answer is flexibility in evaluation and recognition that faculty with different styles will reach different students. The department must be allowed to find the most effective teaching environment for each faculty. The late Richard Feynman, Nobel laureate physicist, taught freshman physics at Cal Tech for many years and stimulated a whole generation with his famous texts, *The Feynman Lectures in Physics*. Feynman varied his teaching style periodically from authoritative to exploratory. He observed that either way he taught he inspired a subset of his class, but it was a **different** subset each time.

I have found that there can be significant administrative barriers to promoting and rewarding a variety of teaching styles in a public research university. The legislature and Board of Regents evaluate teaching by the all important Student Credit Hour (SCH). Thus, giving an hour lecture to 500 freshman students is 500 times as valuable in SCHs as an hour spent instructing an individual undergraduate on how to run a DNA sequencing gel in your laboratory. This may make sense in some narrow concept of faculty efficiency, but it is the same hour out of a faculty member's day. As our Undergraduate Biology Research Program has shown, the laboratory experience has a major impact on students, but does involve a major investment of time and resources.

Extrinsic rewards

How can one increase the *extrinsic* rewards of undergraduate teaching? This is more difficult, but is being done in several ways. First, the significant increase in NSF funding for science education is having an immediate impact. The ability to obtain outside grants for teaching as well as research, besides directly supporting improved teaching, immediately elevates the prestige and reward of teaching and gets the attention of university administrators. For example, one of my department's tenured faculty recently decided to abandon his continuously funded research program to concentrate fully on teaching and developing multimedia instructional materials. I encouraged him to do so and pointed out that he could now attract even more grant funding than he could before. He is one of three tenured research faculty who revised our introductory biology course to make it serve all the biology programs on campus. They also created a new computer assisted Biology

Learning Center to support the students and introduced multimedia instruction. The enrollment in this course increased from 200 to 1100 in three years and together with UBRP has led to a nearly 20% increase in biology majors each year. They have given presentations at several of the growing number of national meetings on science teaching, thus achieving national recognition that had previously been largely confined to research.

Another significant impact on the extrinsic rewards of teaching in biology has been the Howard Hughes Medical Institute's investment in biology instruction. With the committed support of President Purnell Choppin, the Hughes Institute has invested $173 m 'on in biology instruction over the past four years. Their grants have gone to institution., of all kinds that have a record of preparing students for graduate or medical schools, including small private liberal arts schools, predominantly minority institutions, large urban commuter schools and research universities. The direct impact again has been immediate. The expansion of our UBRP at Arizona, as well as additional programs for schools and teachers, have been facilitated by a large Hughes grant, for which I am the principal investigator. But the indirect impact may be even greater. Because the Howard Hughes Medical Institute has such stature and prestige for its record of supporting outstanding research, the fact that this same Institute is now making a major investment in education immediately increases the prestige, hence extrinsic reward, for biology teaching. When the Howard Hughes Medical Institute says it is important to care about teaching, the best researchers listen and act.

A third source of increasing extrinsic recognition for teaching comes from the professional societies. Although all professional societies have education as one of their goals, in the biological sciences particularly those goals are receiving increased attention. The American Society for Cell Biology is now featuring symposia and workshops on teaching at its national meetings and is featuring the educational activities, particularly in secondary and elementary education, in its newsletters.

Another growing influence on the importance of teaching is the National Academy of Sciences through the National Research Council. They have prepared several outstanding reports on science education. In the biological sciences, the NRC report *Fulfilling the Promise: Biology Education in the Nation's Schools* has served as a call to arms for professional biologists to help fix the sorry state of biology education. The central message is that biologists have to take the leadership to improve education. I have circulated copies to all my fellow department heads at Arizona and keep a pile in my office to pass on to the unconverted, sometimes feeling like a trenchcoated street hawker selling gold watches. Following one of the recommendations of this report, I am now chairing a second NRC committee, the Committee on Biology Teacher Inservice Programs, to investigate and make direct recommendations to agencies, schools and universities for the best ways to help current biology teachers improve their teaching.

Personal Experiences

Finally, in response to the Science Subcommittee's request, I will describe some of my own experiences balancing teaching and research. My undergraduate education at Princeton, where every student has to do a senior thesis, certainly shaped my view of the importance of independent research to learning science. Since entering graduate school, I have always done both teaching and research because I love teaching and feel strongly that not only does research experience contribute to teaching, but teaching contributes to research. One of the dangers of the excitement of molecular biology and genetic engineering is that it is too easy. It is too easy to get lost in the minutia of the sequencing and cloning of your favorite gene and forget the organism that the gene helps build. Teaching makes you look up from your laboratory bench and see biology from a broader perspective to discover connectior   tween the details. I have also found teaching a good way to learn new subjects. I was greatly influenced at Cal Tech by the late Max Delbruck, Nobel laureate in Physiology and Medicine. Max had a course listed in the catalog as Biophysics, but we all knew the course was really "What Max wants to learn this year." It was an important educational experience to have a Nobel laureate stand up in class and reveal how he thinks, especially when he would begin a class with a complex derivation, look at the board then the class, and say "I don't understand this. Class is dismissed, I'll figure it out by next week." Some would fault him for being "unprepared" but this misses the point of science education: it is to learn how to think.

As an assistant professor at Harvard Medical School teaching first year medical students, one did not need any defined intrinsic or extrinsic rewards imposed for teaching. Just stand at the bottom of one of the steep amphitheater lecture halls looking up a class of demanding students and critical faculty twenty five feet above you, and see what happens when you give a bad lecture. I did that once and learned.

The Department of Embryology of the Carnegie Institution of Washington, where I moved from Harvard, is a research institute free of the university's schizophrenia between teaching and research. While there I held a joint appointment in the Department of Biology at Johns Hopkins and did substantial undergraduate and graduate teaching. Frankly, I was intrigued to discover when in their education the Harvard medical students I had taught had lost their curiosity and become mechanical learners. Unfortunately, I discovered it was while they were undergraduates.

That experience and the recognition of the dreadful state of science education in this country helped me decide after 11 years in an idyllic research environment that I had to do more for education. I accepted the position as head of a university-wide department at the University of Arizona because I wanted to see if we could provide an outstanding science education for a body of students that represents the diversity of our country. As I have described above, I believe we are making progress toward that goal.

I believe there are a number of actions that the Committee on Science and Technology can take to help improve science education.

Recommendations

• Support programs in the NSF, other Federal agencies, and particularly in industry that encourage the participation of undergraduate students, science teachers and selected high school students to do independent research in research laboratories. One effective mechanism to do this is to ensure that educational supplements for student support are available on all research grants as is being done at NSF and NIH.

• Increase the number of grant programs from all the Federal agencies that support innovative and effective science teaching. This will not only support good teaching but will provide external reward and recognition for teaching.

• Encourage mechanisms to institutionalize effective teaching programs. Science education suffers badly from amnesia; programs that have worked in the past are often forgotten in favor of innovations.

• Continue to recognize and publicize the importance of science education throughout our society.

Mr. THORNTON. I want to thank you for your splendid summary and for the paper. I was very impressed with your written testimony's anecdotal example of the influence that Max Delbrucok, now deceased, Nob:l laureate, had on you in a course which was labelled "Biophysics," but which you say was really what Max wants us to learn, or what Max wants to learn this year, himself, and that he'd put a complicated derivation on the wall, and step back and look at it and say, "I don't understand what this means. Class is dismissed, but next week, I'll have it figured out, so you all come back."

And the excitement of that, to me, is what it says to the student about the process of learning and about the discovery that's involved.

Your testimony is very good, Dr. Ward.

Dr. Lohmann, I'm looking forward to receiving your written paper, and including it in the record. We'd appreciate your summary of that paper.

STATEMENT OF DR. JACK R. LOHMANN, ASSOCIATE DEAN, COLLEGE OF ENGINEERING, AND PROFESSOR OF INDUSTRIAL AND SYSTEMS ENGINEERING, GEORGIA INSTITUTE OF TECHNOLOGY, ATLANTA, GEORGIA

Dr. LOHMANN. Thank you, Mr. Chairman.

It is a pleasure and indeed an honor to be here today to share with you my thoughts and experiences in undergraduate education.

All of us have heard the stories about the quality of undergraduate education in our universities, especially in our research universities.

We've all heard the stories of teaching assistants who can't speak English well, stories of junior faculty being told that teaching well won't get you tenure, stories that teaching awards are more a kiss of death than they are a mark of distinction, and stories that the epitome of academic success is not to have to teach undergraduates at all.

Although some of these stories are magnified beyond their real proportions, and others are believed to be more prevalent than they really are, they also cannot be dismissed as either without foundation or infrequent in their occurrence.

Nonetheless, I believe it is important for the committee to know that there are faculty out there, especially among the more junior faculty, who care deeply about the quality of their teaching, who care about the quality of undergraduate education, and who care about the quality of public education in this country.

Unfortunately, many of them also perceive themselves to be in an environment that is not as supportive of such concerns as they believe it should be.

For example, I recently had an opportunity to serve as a co-chair of a colloquium involving 53 Presidential Young Investigators that focused their attention on U.S. engineering, mathematics, and science education for the year 2010 and beyond. Without question, it was one of the most enjoyable experiences of my career.

These outstanding young faculty expressed uniformly a genuine concern for the quality of undergraduate and pre- college science education. Unfortunately, they also expressed serious reservations about the commitment of their institutions to teaching and about the wisdom of their own involvement in undergraduate and precollege initiatives in light of the current system of faculty rewards.

As one participant expressed in his written evaluation after the colloquium, "The process used for identifying the colloquium participants selected young faculty, mostly from research universities, probably a majority of them nontenured, with strong interests in teaching.

This is a somewhat lonely group in the sense that most return to environments where many of their colleagues ordinate their teaching to research interests and all are tempted to do so.

It is, therefore, strongly encouraging to spend two intense days with colleagues attempting to articulate a vision of the future which teaching shares with research a high priority."

A photocopy of the report from the colloquium entitled, "America's Academic Future" has been included as a part of my written testimony.

I believe you'll find much within this report that addresses directly the issue of the quality of undergraduate education, and the balance of teaching and research in our universities.

The report recommends, fundamentally, that the faculty, the leadership of our colleges and universities, and agencies that fund higher education reaffirm and recommit to what is the central mission of our institutions, namely, education.

To this end, the report recommends the need for reform in two critical areas: first, we must encourage and reward teaching excellence, instructional scholarship, and public service, as much as we do research.

Second, we must increase substantially the resources available for instructional innovation and curriculum renewal, especially for undergraduate education.

These are not independent issues. Inadequate resources and a lack of faculty incentives to engage in instructional innovation simply restricts the number of faculty regularly engaged in instructional scholarship, and it sustains an unfortunate and inaccurate impression in the minds of many that teaching well is not important and is without merit.

We must recognize that regularly budgeted programs for curriculum renewal to maintain the faculty's instructional excellence are as essential as programs for disciplinary renewal to maintain their technical currency.

This committee can help these young faculty and other faculty concerned about the quality of undergraduate education. I would like to highlight two of the five recommendations I have in my testimony.

First, I recommend a substantial increase in support for peer reviewed, regularly budgeted programs to improve the quality of undergraduate, engineering, mathematics and science instruction for all students, both majors and non-majors.

With respect to the National Science Foundation, support for programs to improve undergraduate instruction should be increased by at least $100 million immediately.

I believe that a thorough evaluation of the current NSF programmatic and budgetary commitment to undergraduate instruction, as compared to the programmatic and funding recommendations contained in the 1986 NSB report on undergraduate education, often called the Neal Report, would show a shortfall of at least one-half that amount.

Further, when coupled with very low success rates among many NSF undergraduate programs, such an increase would place the NSF support for improved undergraduate instruction more in line with the NSB's original intentions, and provide immediately the base of support needed to respond to the increasing proposal pressure in this area.

We cannot afford to continue to discourage those faculty willing to step forward and accept the challenge simply because of the lack of appropriate budget priorities.

We all know these are tight fiscal times. But it must be remembered that high quality undergraduate instruction is the key to improved instruction at all educational levels, and the key to improved scientific and technological literacy.

I emphasize regularly budgeted, peer reviewed programs for instructional innovation because they will enhance significantly the status of teaching in general, and faculty participation in instructional scholarship, in particular, by putting teaching excellence on par with regularly budgeted, peer-reviewed grants for disciplinary research.

Since World War II, this country has provided virtually unwavering support for regularly budgeted programs for academic research. That commitment has clearly paid off.

Unfortunately, similar support for instructional excellence and curriculum renewal has been much less consistent. Indeed, NSF's own budget priorities from the last decade or so have resulted in a generation of faculty who are largely unaware that NSF has had a mandate to support programs in both research and education since its creation in 1950.

This lack of awareness, in part, fuels the current misperception among many faculty that increases in education programs are either inconsistent with or at the expense of NSF's mission in research.

Second, I recommend that the membership of the National Science Board include a tenure-track assistant professor, a tenured associate professor, and a full professor with less than six years of service at that rank.

I believe we can all be proud of the leadership that has been provided by the National Science Board over the years.

Nonetheless, I also believe the Board's deliberations would be appropriately enriched with the advice of recent academic experience that could be provided by members of the junior to mid-career faculty.

In conclusion, I'm concerned that we are responding to the current crisis in science education too much that like that of a volunteer fire department, depending upon the good graces of a few brave volunteers with meager resources to come running to extinguish the emergency of the moment, and then we all go back to doing what we were doing before.

We must not be tempted to form yet another bucket brigade. Instead, we need to direct some major efforts at fire prevention that I believe can be provided by improving the quality of undergraduate educa ›n.

Thank you.

[The prepared statement of Dr. Lohmann follows:]

The Quality of Undergraduate Science Education: Achieving a Balance Between Teaching and Research

Testimony to the

Committee on Science, Space, and Technology
U S House of Representatives
Washington, D C

March 31 1992

by

Dr Jack R Lohmann
Associate Dean, College of Engineering, and
Professor of Industrial and Systems Engineering
Georgia Institute of Technology
Atlanta, Georgia

We have all heard stories about the quality of undergraduate education in our universities, especially in our research universities. We have all heard stories of teaching assistants who cannot speak English well, stories of junior faculty being told that "teaching well won't get you tenure," stories that teaching awards are more a "kiss of death" than a mark of distinction, and stories that the epitome of academic success is not to have to teach undergraduates at all. Although some of these stories are magnified beyond their real proportions and others are believed to be more prevalent than they really are, they also cannot be readily dismissed as either without foundation or infrequent in their occurrence. *Nonetheless I believe it is important for the Committee to know that there are faculty out there, especially among the more junior faculty, who care deeply about the quality of their teaching, who care about the quality of undergraduate education, and who care about the quality of public education in this country. Unfortunately, many of them also perceive themselves to be in an environment that is not as supportive of such concerns as they believe it should be.*

It is important for the Committee to know that there are faculty out there, especially among the more junior faculty, who care deeply about the quality of their teaching, who care about the quality of undergraduate education, and who care about the quality of public education in this country. Unfortunately, many of them also perceive themselves to be in an environment that is not as supportive of such concerns as they believe it should be.

For example, a little over a year ago I had the opportunity to serve as a Co-Chair of a Presidential Young Investigator Colloquium that focused on U S engineering, mathematics, and science education for the year 2010 and beyond. The colloquium was attended by 53 Presidential Young Investigators (PYIs) from a broad mix of academic institutions and disciplines of science, mathematics and engineering. Furthermore, most of the participants were either tenure-track assistant professors or tenured associate professors.

It was one of the most enjoyable and gratifying experiences of my career. These outstanding young faculty, many of whom will soon be among the leadership of higher education, expressed a genuine concern for the quality of undergraduate and precollege science education. They also expressed serious reservations about the commitment of their institutions to teaching and about the wisdom of their own involvement in undergraduate and precollege initiatives in light of the current system of faculty rewards. As one participant expressed in his written evaluation after the colloquium:

"The process used for identifying the colloquium participants selected young faculty, mostly from research universities, probably a majority of them non-tenured, with strong interests in teaching. This is a somewhat lonely group in the sense that most return to environments where many of their colleagues subordinate their teaching to research interests, and all are tempted to do so. It was, therefore, strongly encouraging to spend two intense days with colleagues attempting to articulate a vision of the future in which teaching shares with research a high priority."

The report from the colloquium, entitled America's Academic Future, was released by the National Science Foundation (NSF) a little over a month ago. A copy of the report has been included for the Committee's consideration as a part of my written testimony. I believe you will find much within this report that addresses directly the issue of the quality undergraduate education and the balance of teaching and research in our universities. It is through this report that I would like to share my thoughts on the future of undergraduate education.

As the title of the report suggests, America's Academic Future is as much a report about the future role of our institutions in the American educational system as it is a report offering some specific ideas and recommendations to address the current crisis in science education. This report is not unique in its concerns for educational reform, but it is unique in its focus on higher education in general, and undergraduate instruction in particular, as the key to a better future for all students at all educational levels. *The report recommends, fundamentally, that the faculty, the leadership of our colleges and universities, and agencies that fund higher education, reaffirm and recommit to what is the central mission of our institutions, namely, education.* We must not respond to the current crisis in science education like that of a volunteer fire department, depending upon the good graces of a few, brave volunteers, with meager resources, to come running to extinguish the emergency of the moment, and then we all go back to doing what we were doing before. This report is not a call to join the bucket brigade, it is a call for efforts directed at fire prevention.

To this end, the report recommends the need for reform in two areas that critically affect our institutions' capabilities to assure the long-term health of the American educational enterprise at all levels.

- *First, we must encourage and reward teaching excellence, instructional scholarship, and public service as much as we do research, and,*

- *Second, we must increase substantially the resources available for instructional innovation and curriculum renewal, especially for undergraduate education.*

These are not independent issues. Inadequate resources and a lack of faculty incentives to engage in instructional innovation simply restricts the number of faculty regularly engaged in instructional scholarship and it sustains an unfortunate and inaccurate impression in the minds of many that teaching well is not important and is without merit. After all, if teaching excellence is not rewarded and not supported as much as research, what else is one to conclude? *We must recognize that regularly-budgeted programs for curriculum renewal to maintain the faculty's instructional excellence are as essential as programs for disciplinary renewal to maintain their technical currency.*

If nothing else, I hope this report makes clear to the Committee that throughout our institutions there are talented young faculty who are more than ready, willing, and able to help improve the quality of instruction at all levels of the educational pipeline. They are ready to both respond to the emergency of the moment, and more importantly, to address the systemic issues affecting the long-term health of the American educational enterprise.

The report from the PYI colloquium, America's Academic Future, is not a call to join the bucket brigade, it is a call for efforts directed at fire prevention. It recommends, fundamentally, that the faculty, the leadership of our colleges and universities, and agencies that fund higher education, reaffirm and recommit to what is the central mission of our institutions, namely, education. To this end, the report recommends the need for reform in two areas that critically affect our institutions' capabilities to assure the long-term health of the American educational enterprise at all levels:

- *First, we must encourage and reward teaching excellence, instructional scholarship, and public service as much as we do research, and,*

- *Second, we must increase substantially the resources available for instructional innovation and curriculum renewal, especially for undergraduate education.*

These are not independent issues. We must recognize that regularly-budgeted programs for curriculum renewal to maintain the faculty's instructional excellence are as essential as programs for disciplinary renewal to maintain their technical currency.

This Committee can help these young faculty, and other faculty concerned about the quality of undergraduate education. I would like to offer five recommendations for the Committee's consideration

RECOMMENDATION

Increase substantially support for peer-reviewed, regularly-budgeted programs to improve the quality of undergraduate instruction for all students, both majors and non-majors.

With respect to the NSF, support for programs budgeted to improve undergraduate instruction in the classrooms and in the laboratories should be increased by at least $100 million immediately. I believe that a thorough, inflation-adjusted evaluation of the current NSF programmatic and budgetary commitment to undergraduate instruction as compared to the programmatic and funding recommendations contained in the 1986 National Science Board (NSB) report on undergraduate education, often called the "Neal Report," would likely show a short-fall of at least one-half that amount. Further, when coupled with the very low success rates among many NSF undergraduate programs, such an increase would place the NSF support for improved undergraduate instruction more in line with the NSB's original intentions and provide immediately the base of support needed to respond to NSF's increasing proposal pressure in this area. *We cannot afford to continue to discourage those faculty willing to step forward and accept the challenge simply because of a lack of appropriate budget priorities.* We all know these are tight fiscal times -- but it must be remembered that high-quality undergraduate instruction is the key to improved instruction at all educational levels and the key to improved scientific and technological literacy. Increased support for high-quality undergraduate instruction is also increased support for high-quality precollege instruction, too

I emphasize regularly-budgeted, peer-reviewed programs because they will enhance significantly the status of teaching in general and faculty participation in instructional innovation in particular. Regularly-budgeted, peer-reviewed grants for instructional scholarship will put teaching excellence on par with regularly-budgeted peer-reviewed grants for disciplinary research. Again, as I mentioned before regularly-budgeted programs for curriculum renewal to maintain the faculty's instructional excellence are as essential as programs for disciplinary renewal to maintain their technical currency. Since WWII, this country has provided virtually unwavering support for regularly-budgeted programs for academic research. And that commitment has clearly paid off. Our universities are the envy of the world in graduate education and research. Unfortunately, similar support for instructional excellence and curriculum renewal has been much less consistent. The National Science Foundation's budget for educational programs during this same period of time is a good example. Indeed, NSF's own budget priorities within the last decade or so have resulted in a generation of faculty who are largely unaware that NSF has had a mandate to support programs in both research and education since its creation in 1950. This lack of awareness, in part, fuels the current misperception among many faculty that increases in education programs are either inconsistent with or are at the expense of NSF's mission in research

With respect to the NSF, support for programs budgeted to improve undergraduate instruction in the classrooms and in the laboratories should be increased by at least $100 million immediately. We cannot afford to continue to discourage those faculty willing to step forward and accept the challenge simply because of a lack of appropriate budget priorities. Indeed, NSF's own budget priorities within the last decade or so have resulted in a generation of faculty who are largely unaware that NSF has had a mandate to support programs in both research and education since its creation in 1950. This lack of awareness, in part, fuels the current misinformed belief among many faculty that increases in education programs are either inconsistent with or are at the expense of NSF's mission in research.

RECOMMENDATION

Membership of the National Science Board should include a tenure-track assistant professor, a tenured associate professor, and a full professor with less than 6 years of service at that rank.

I believe we can all be proud of the leadership that has been provided by the National Science Board over the years Nonetheless, I also believe that the Board's deliberations would be appropriately enriched with the advice of recent academic experience that could be provided by members from the junior to mid-career faculty

RECOMMENDATION

Target special support to (1) improve the instructional preparation and qualifications of graduate students preparing for professorial careers and (2) engage, specifically, assistant and associate professors in instructional innovation.

It has been reported that nearly 40% of the professoriate is scheduled to retire by the end of this decade This represents both a challenge and an opportunity It is a challenge given the current statistics on Ph D. production, but it is also an opportunity in that those who enter academic life within the next decade may do so in large numbers If nothing else, the preparation and early academic experience of the next generation of young faculty will in large measure determine the culture of higher education well into the next century

RECOMMENDATION

Appoint a Blue Ribbon Commission on Norms in Scientific and Technological Literacy.

The purpose of this Commission would be to focus attention on the need for norms for literacy in science mathematics, and technology, for both students and teachers, and to identify promising strategies for defining, measuring, and implementing these norms.

RECOMMENDATION

The National Academy of Sciences should appoint a multi-disciplinary, standing committee of 100 junior to mid-career faculty to advise the Academy, Congress and the Nation periodically on matters of importance to the long-term health of higher education in general and undergraduate instruction in particular.

This committee would provide a natural complement to the Board on Mathematics and Science Education and the Board on Engineering Education within the Academy I recommend a multi-disciplinary committee because undergraduate education -- regardless of the degree program -- is, fundamentally, a multi-disciplinary education. We need to increase the opportunities for cross-disciplinary communication and collaboration, especially among the junior to mid-career faculty, to address some of the most pressing issues facing undergraduate education

Attachment:

America's Academic Future
A Report of the Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond
Directorate for Education and Human Resources
National Science Foundation
Washington, D C
January 1992
NSF Publication No 91-150

AMERICA'S ACADEMIC FUTURE

A Report of the Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond

Co-Chairs:

Jack R. Lohmann
Georgia Institute of Technology

Angelica M. Stacy
University of California, Berkeley

November 4–6, 1990
Washington, D.C.

Directorate for Education and Human Resources
National Science Foundation
January, 1992

NATIONAL SCIENCE FOUNDATION
1800 G STREET N.W.
WASHINGTON, D.C. 20550

nsf

OFFICE OF THE
ASSISTANT DIRECTOR
FOR EDUCATION AND
HUMAN RESOURCES

January 1992

Dr. Walter E. Massey
Director
National Science Foundation
Washington, D.C. 20550

Dear Walter:

I am pleased to submit to you the report from the faculty who participated in the Presidential Young Investigator (PYI) Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond. The participants, all PYIs, represent a broad array of fields within engineering, mathematics, and the sciences and a wide cross-section of our Nation's colleges and universities.

Their recommendations merit serious consideration. As outstanding young faculty today, they represent the future leadership of our academic institutions. Their visions of the future and recommendations for action yield considerable insight into the long term trends and directions for higher education well into the next century.

Sincerely,

Luther S. Williams

Luther S. Williams
Assistant Director

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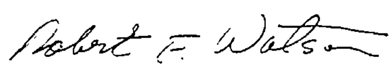
FOREWORD

The long-term success of the national efforts to revitalize engineering, mathematics, and science education depends critically on outstanding young faculty today who will increasingly shape and define all our educational institutions. It will be through their efforts and leadership that higher education will improve the quality of instruction in engineering, mathematics, and the sciences for all students at all educational levels into the next century. Their counsel and involvement now is vital to the national education agenda.

The National Science Foundation, through the Division of Undergraduate Science, Engineering and Mathematics Education (USEME), and in collaboration with the Division of Research Career Development and representatives from all the Foundation Directorates, convened a colloquium of fifty-three Presidential Young Investigators (PYIs) on November 4-6, 1990. The PYIs, all recipients from the class years 1984–1989, represented a broad distribution of institutions and disciplines. The participants were nominated by their institutions and selected by NSF for their demonstrable concern for precollege and undergraduate education and for their potential for future academic leadership.

The charge to the colloquium, broadly, was to prepare a report of their vision and recommendations of the role of U.S. higher education in the year 2010 and beyond to assure high quality precollege and undergraduate instruction in engineering, mathematics, and the sciences for everyone.

This report describes the principal conclusions of the Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond, including their vision of the future, key courses of action, and recommendations to U.S. higher education in general, and the National Science Foundation in particular. NSF expresses its appreciation to Dr. Jack R. Lohmann, from the Georgia Institute of Technology (on leave of absence from the University of Michigan, Ann Arbor to NSF/USEME from 1989–1991), and Dr. Angelica M. Stacy, from the University of California, Berkeley, who co-chaired the colloquium, and to the participants for their thoughtful counsel and contributions. The opinions expressed in this report are those of the participants and do not necessarily represent NSF policy. The findings of the participants are currently under review by NSF.



Robert F. Watson
Director, Division of Undergraduate Science,
Engineering and Mathematics Education

PARTICIPANTS AND SPECIAL GUESTS

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Assistant to the President
for Science and Technology
Washington, D.C.

Charles M. Vest
President
Massachusetts Institute of Technology
Cambridge, Massachusetts

Edward A. Knapp
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Colloquium Co-Chairs

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Georgia Institute of Technology

Angelica M. Stacy, '84
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EXECUTIVE SUMMARY

THE CONDITION OF U.S. EDUCATION

Numerous reports and studies have expressed serious concerns that the U.S. educational infrastructure is ill-prepared to meet the challenges and opportunities of the next century. The low level of scientific and technological literacy in our society is deplorable, and the trickle of talent flowing into careers in engineering, mathematics, and the sciences from all segments of society is deeply disturbing. The poor condition of our educational infrastructure is not the result of a few isolated, independent, or discipline-specific problems. Its condition mandates fundamental, comprehensive, and systemic changes in the way all of us go about the business of education.

VISION OF THE YEAR 2010

The success of the current national efforts to revitalize engineering, mathematics and science instruction depends on the commitment and collaboration of a number of communities, including industry, schools, colleges, universities, government at all levels, and the public. Mostly, however, it depends on the faculty in our Nation's schools, colleges, and universities. The faculty, be they elementary school teachers, community college instructors, or university professors, are the curriculum personified. The faculty, both individually and collectively, have considerable latitude in the curriculum content and in the instructional approaches used. Superior faculty motivate students to broaden and deepen their intellect, and aspire to higher achievements. Mediocre faculty dampen the enthusiasm of good students and stifle development of potential talents in learners.

"... let me begin with one simple statement: Professors should profess. It is hard to think of anything more illogical than to become a university professor if one does not want to teach. So if you do not want to teach, you should immediately look for another job."

Charles M. Vest
President, MIT
Colloquium Address
November 5, 1990

The faculty in higher education, however, have a special and critical responsibility. Higher education provides the professional preparation of many of our Nation's future business leaders, public officials, socially concerned citizens, and virtually all engineers, mathematicians, and scientists, including those who will become future faculty at all educational levels — elementary and secondary schools, community colleges, and colleges and universities themselves. Thus, the faculty in higher education and their commitment to teaching are absolutely critical to the quality of instruction in engineering, mathematics, and the sciences provided to both majors and non-majors on our college campuses and also to the quality of instruction in K-12 classrooms through the future teachers they prepare.

We believe strongly that higher education in general, and our institutions in particular, must be committed to assuring high quality instruction for all students in all segments of the American education pipeline. It is crucial that growth, change, and creativity that are so integral to research become equally integral to teaching. Thus, our vision of higher education in the year 2010 and beyond is that faculty in all our Nation's colleges and universities will be truly recognized for their individual leadership and achievements in support of broad institutional missions involving instructional scholarship, public service, and research excellence, and for their commitment to provide a quality education for all students at all educational levels.

FIVE PRINCIPAL POINTS

Many differing viewpoints, experiences, and ideas were expressed during the course of the colloquium. Six reports follow the Executive Summary that summarize the discussions of six individual panels, each of which focused on a different aspect of U.S. education. The reports include their visions of the future, major courses of action, and recommendations. Despite the diversity of the issues to be addressed by the panels and the diversity of the institutional, disciplinary, ethnic, and gender representation of the participants, five principal points emerged in common from the discussions.

To assure high quality precollege and undergraduate instruction in engineering, mathematics, and the sciences for all students and citizens in the year 2010 and beyond, U.S. higher education in general, and the National Science Foundation in particular, must:

Federal, state, and other agencies that fund and evaluate education must undergo as much of a change in culture as that of academe.

1. Encourage and reward teaching excellence, instructional scholarship, and public service as well as research.

Panel II
Encouraging Curriculum Renewal and the Development of New Learning Environments

The lack of support, indeed, occasional outright discouragement, of faculty achievements in teaching, instructional scholarship, and public service is among the most pressing problems in higher education. At the heart of it is an application of tenure and promotion criteria that does not encourage faculty to aspire to broad scholarly achievements, especially in instructional innovation, nor to contribute to public understanding and support of science and technology. The tenure and promotion criteria, and related faculty rewards that are based on such criteria, need to be applied with greater recognition of individual faculty ability and potential. Goals for faculty achievement tailored to match individual abilities and institutional missions should be defined and used for faculty evaluation. There are also needs for policies to provide leaves of absence that recognize the nature of contemporary faculty life, especially for younger faculty; significantly increased societal representation on engineering, mathematics, and science faculties; more balanced recognition of the interdependent roles of teaching and research; and more formal faculty career development initiatives.

"In short, there is a strong need to promote a higher quality of faculty life that more fully recognizes and develops the diverse talents and interests of all the faculty.

In our opinion, the single most effective contribution NSF can make to elevate the status of teaching on the university campus is to provide broad-based faculty-oriented programs to support high quality instructional experimentation and creative educational scholarship.

2. Increase substantially resources for instructional innovation and curriculum renewal, especially for undergraduate education.

Panel VI
Developing Young College Faculty During the Critical Years to Tenure

Support for disciplinary research may be increasingly inadequate but funds for instructional innovation are nearly nonexistent. Lack of adequate resources assures inadequate attention to long-term curriculum renewal, constricts the number of faculty engaged regularly in broad-based instructional scholarship, and sustains an unfortunate and inaccurate impression in the minds of many that teaching well is unimportant and without merit. The current condition of the American educational infrastructure should not be viewed as a problem to be fixed by a few, focused, temporary initiatives. All parties — education, industry, State and Federal agencies, and the public — must recognize that regularly budgeted, long-term programs for curriculum renewal to maintain the faculty's instructional excellence are as essential as funds for disciplinary renewal to maintain their technical currency.

There is a critical need for review of existing budget priorities to provide both new resources and expansion of current educational programs consistent with the equal importance of teaching and research.

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3. Assume primary responsibility for public understanding of science and technology, principally through high quality precollege teacher preparation and lower division undergraduate instruction.

Many Americans believe that knowledge of our fields has little to do with everyday life, and that coursework in our areas need only be taken by students preparing for careers in our fields. Whatever level of scientific and technological literacy we hope to attain in this country, indeed whatever basic level of common education, will be learned primarily in K-12 classrooms, and for those who go on to college, in the lower division curriculum in the Freshman and Sophomore years. Major, long-term improvement in scientific and technological literacy can be affected most by high quality, discovery-oriented learning, principally in precollege and lower division undergraduate curriculum. Especially critical, therefore, is the disciplinary preparation of those students aspiring to precollege teaching careers in mathematics and the sciences, and the instructional preparation of those graduate students aspiring to academic careers. Public understanding and appreciation of science and technology is important, not only for the preparation of an effective and competitive workforce, but also for broader concerns such as informed public choice and quality of life. To further these aims, faculty should: communicate their work to the public, not just among fellow professionals; be more encouraged and rewarded for activities that contribute significantly to public understanding and appreciation of science and technology; and be more involved in local, state, and national science policy.

We must assume a greater responsibility for public understanding of science and technology through high quality instructional offerings to all students and participation in science and technology education policy.

"There is a misconception in our universities that teaching and instructional innovation are less valuable, less difficult, less creative, and less scholarly than research. The Federal government, through its agencies and their past budget priorities, shares a principal responsibility for this misconception."

Panel I
Attaining and Maintaining Scientific and Technological Literacy for Everyone

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4. Assure adequate career participation in engineering, mathematics, and the sciences by all segments of society, particularly careers as precollege or college faculty.

Science, mathematics, and engineering careers, be they professional practice, teaching, or research, are viewed by many as rather unexciting, unrewarding, and non-inclusive careers. They are viewed as disciplines suitable for a select, gifted few. Career choice is primarily a product of experiences. Although individual experiences vary considerably, and we, as faculty, often have little influence on those experiences (e.g., parental nurturing, role models, job experiences), we do have considerable control over the educational environment in general, and the quality of instruction in particular. Students are not encouraged to pursue careers in fields in which they perceive instruction to be tedious and uninspired, coursework

"The engineering, mathematics, and science community cannot expect full support from society if large segments of that society perceive themselves as unwelcome and excluded."

Panel V
Assuring Career Participation by All Societal Groups

to be irrelevant or excessively demanding, and success to result from special talent or demographic similarity. We, the science and technical community, represent a small fraction of our society, yet it is society-at-large that determines the conditions under which we work, and provides the resources for what we do. We must be more inclusive. Broad collaboration among universities, professional societies, industry, and government at all levels, is needed, including: more engaging curricula motivated by societal relevance; attention to the transitions in the educational pipeline; improvements in entry-level college courses; programs for career paths such as science journalism or technology policy; and special attention to precollege teacher preparation.

In large measure, we must develop both an inviting educational environment and one that encourages all students to succeed.

The education of students in engineering, mathematics, and the sciences is crucial to the Nation's future. Equally crucial, therefore, is the need to foster an environment that, by our efforts and example, will make teaching careers an attractive option, and then to provide high quality programs to those aspiring to teaching careers.

Panel IV
Encouraging and Preparing Students for Careers as Precollege and College Faculty

5. **Encourage the development of discovery-oriented learning environments and technology-based instruction at all educational levels.**

The ubiquitous lecture is the bane of true learning, especially in observation-based, hands-on fields such as engineering, mathematics, and the sciences. Our lecture-dominated system of education encourages a passive learning environment, invites the development of a mass production-oriented, highly compartmentalized (lecture-sized) curriculum, and, worst of all, instills neither the motivation nor the skills for life-long learning. The overdependence on the standard lecture must be diminished with emphasis given instead to discovery-oriented learning in which disciplinary and geographic boundaries become less distinct through networked, technology-based instruction. Students must be active contributors in their own education and in the education of their fellow students, and faculty must be as creative in their teaching as they are in their research. The curriculum must emphasize laboratory and field experiences, and reflect an integrated approach to engineering, mathematics, and science education. New technologies, together with advances in the cognitive sciences, offer significant opportunities for individualized learning and teaching styles. They also offer important opportunities to interconnect all levels of the educational infrastructure to bring more cohesion to the educational pipeline. There are also needs for more concurrent learning opportunities involving simultaneous study and experimentation; an increase in information technology and computer literacy among faculty and students; and a change in the culture of academe, its funding agencies, and accreditation boards to better recognize the interdependence and coequal importance of teaching and research.

We must create discovery-oriented learning environments that capitalize on the full power of new communication, information, and visualization technologies.

University and college administrations must recognize that state-of-the-art instructional technology will be part of the physical plant needed for a twenty-first century education.

Panel III
Incorporating New and Evolving Technologies into the Curriculum

PANEL SUMMARIES

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PANEL I

ATTAINING AND MAINTAINING SCIENTIFIC AND TECHNOLOGICAL LITERACY FOR EVERYONE

PANEL MEMBERS: Robert Perry (Panel Chair), Gregory R. Baker, Barbara S. Beltz, A. Gordon Emslie, David E. Goldberg, William D. Hunt, Ian M. Kennedy, James V. Moroney, Marjorie A. Olmstead

In the year 2010, higher education will have assumed a leadership role and central responsibility for the scientific and technological literacy of all citizens.

VISION OF THE YEAR 2010 AND BEYOND

We envision a society in which the public regards science, mathematics, and technology as relevant to their personal lives. Engineers, mathematicians, and scientists are perceived by the public as vital to society, and scientific and technological literacy are well defined. Engineering, mathematics, and science concepts and contributions are communicated effectively to all segments of society, principally through formal instruction in our schools and universities but also through informal, out-of-classroom educational opportunities and programs. The public can apply the principles of science to the solution of their everyday problems.

KEY COURSES OF ACTION AND RECOMMENDATIONS

As engineers, mathematicians, and scientists, our vision of the future naturally recognizes the importance and contributions of engineering, mathematics, and science to our everyday lives. To most of society, however, our work is largely one of arcane subjects pursued in unseen laboratories and whose environmental and social impacts are often questionable, if not potentially disastrous. Mention our professions, and most do not think about their home, their neighborhood, or their jobs, nor do they picture themselves as capable and confident in applying even the most rudimentary principles of our disciplines. Science and technology are seldom portrayed as human endeavors.

Our vision for attaining and maintaining scientific and technological literacy is based on fundamental challenges in four areas: the relevance of science and technology in society, defining scientific and technological literacy, communication of science and technology to society, and public perception of science and technical professionals.

Relevance of Science and Technology in Society

The manner in which science and technology are taught in our schools and universities is our greatest barrier to scientific and technological literacy. Too many science and technology courses fail to stimulate and engage the students, much less educate them. Mostly, students learn to sit and listen, observe demonstrations, memorize facts and formulas, and, basically, work alone. From the outset of their education, they progressively spend less and less time applying their knowledge, performing experiments, participating in field trips, or working in groups. Is it any wonder that most of society finds science, mathematics, and technology dull, tedious, and not relevant to their daily lives?

We recommend —

To higher education and the NSF:

— *emphasize creative, discovery-oriented, collaborative student learning at all educational levels.* Integrate instruction in science, mathematics, and technology as much as possible, and de-emphasize separation and compartmentalization. Students should be encouraged to develop informed opinions about scientific, ethical, and political controversies involving important scientific and technical issues.

— *expand support for collaborative efforts among engineering, mathematics, science, and education faculties to provide high quality collegiate instruction in engineering, mathematics, and science for undergraduate students preparing for precollege teaching careers.* No one would hire a teacher who could not read; by the same token, there is no reason all teachers should not be scientifically literate.

— *create an NSF Discovery Program to expand support for discovery-oriented, instructional materials development for use in K-12 classrooms, and encourage all engineering, mathematics, and science faculty to participate in such programs.* Collaborative efforts between engineering, mathematics, and science faculty, and education faculty and precollege teachers should be especially encouraged. New texts and materials should: incorporate science history and philosophy both in history and science texts; include science and technology applications more frequently as part of mathematics education; emphasize scientific concepts and processes and de-emphasize the memorization of facts and formulas; and include supplements relating contemporary issues of the day with discoveries in science, mathematics, and technology. Workshops for precollege teachers to become familiar with the new materials should also be encouraged. Of special interest to *engineering* faculty is the development of precollege instructional materials directly related to engineering and technology. It is noteworthy that presently little engineering-oriented coursework is included in the precollege curriculum, and precollege teachers receive little, if any, preparation oriented to engineering. Activities should include plans for the manufacture and distribution of developed materials, and the involvement of industry in such dissemination should be strongly encouraged.

— *support curriculum development and in-service programs designed to assure a high level of scientific and technological literacy for practicing teachers at all educational levels.* Especially encouraged are collaborative efforts involving engineering, mathematics, science, education faculty, and precollege teachers.

Defining Scientific and Technological Literacy

We are concerned about the low level of American scientific literacy. If we are to attain and maintain scientific and technological literacy among all citizens, then we must first define it in measurable ways. We must have standards by which to judge student progress at all educational levels.

We recommend —

To the White House Office of Science and Technology Policy:

— *appoint a Presidential Commission on Norms in Literacy in Science, Mathematics, and Technology.* The White House Office of Science and Technology Policy should assume a leadership role and appoint a Commission to 1) focus attention on the need for norms for literacy in science, mathematics, and technology, for both students and teachers, and 2) identify promising strategies for defining, measuring, and implementing these norms.

To higher education and the NSF:

— *encourage more faculty scholarship in defining and measuring scientific and technological literacy.* Research in scientific and technological literacy will also have an ancillary effect on shedding light not only on the scientific and technical education of non-majors but also on majors as well. Indeed, research in science, mathematics, and engineering education in general is as much an opportunity for faculty scholarship as research in science, mathematics, and engineering itself.

Communication of Science and Technology to Society

Communication of science and technology to the public is woefully inadequate, if not often misleading.

We recommend —

To higher education

— *give greater consideration to popular forms of publication and dissemination of faculty work in tenure and promotion evaluations.* We, as engineers, mathematicians, and scientists, must communicate our work more frequently and effectively to the public, not just to our professional colleagues.

— *reduce the large communication barriers that exist in the classroom.* Effective communication begins in the classroom. Professors of engineering, mathematics, and science should be educated in effective teaching and communication, and their teaching effectiveness should be given more consideration in the tenure and promotion process.

— *encourage and support more faculty participation in local community organizations, public libraries, and schools to create discovery exploratoria to encourage hands-on involvement in science, mathematics, and engineering.* Especially encouraged are activities that provide more ready access to recent engineering, mathematics, or science achievements through contemporary information technologies and networks. Faculty should also be encouraged to serve in a variety of public forums, such as political office, school boards, museum advisory committees, and local, state, and national science policy organizations.

— *increase the number of professional science communicators.* Encourage more collaborative efforts among engineering, mathematics, science, and communication faculty. Engineering, mathematics, and science faculty on the one hand, and communications faculty on the other should seek to be more involved in each other's curriculum. We also suggest the creation of science/technology-oriented communication programs.

To the NSF

— *expand support for collaborative programs between science and non-science faculty to facilitate effective science and technology communication.* The recent joint agreement between the National Science Foundation, National Endowment for the Humanities, and the Department of Education for collaborative support of Leadership Projects in Science and the Humanities is an example of an initiative with significant potential to address effective science communication.

Public Perception of Science and Technical Professionals

While it is gratifying that the public perceives science and engineering professionals as intelligent, we regret being viewed as dull and not reflective of the full diversity of American society.

We recommend —

To higher education

— *expand extramural science and technology activities at schools and colleges.* Such events foster positive attitudes towards engineering, mathematics, and science through fun and competitive events. Similarly, we encourage efforts to highlight the true diversity among engineering, mathematics, and science professionals, including their involvement and participation in a wide variety of non-science activities.

— *create curricula and media presentations that demonstrate the social context within which engineering, mathematics, and the sciences are practiced.* Many persons have some idea about what lawyers and doctors do for a living, but little idea about what engineers, mathematicians, and scientists do.

To Federal funding agencies (including NSF)

— *re-evaluate budget priorities.* There is a misconception in our universities that teaching and instructional innovation are less valuable, less difficult, less creative, and less scholarly than research. The Federal government, through its agencies and their past budget priorities, shares a principal responsibility for this misconception.

— *create an NSF Ambassador Program.* Such a program would support outstanding engineers, mathematicians, and scientists to visit elementary and secondary schools, as well as participate in media, local, state, and national public forums. These individuals would serve as ambassadors to work with non-science professionals and students to improve their understanding of science, mathematics, and technology, and to appreciate the human endeavor associated with these disciplines. Participants in the program would be nominated by the president of their institution and would receive salary and travel support.

To the engineering community:

— *heighten the visibility of engineering.* Despite the fact that much of what the public encounters daily is as much an engineering and technological achievement as it is a scientific one, engineering is not often viewed as a principal contributor or originator. The engineering education community, industry, and engineering professional societies should: develop engineering and technology-oriented materials for the K-12 curriculum and for non-engineering college curriculum; promote visits by role models to schools; and include material describing the basic operating principles of technical products along with the operating/assembly instructions.

PANEL II

ENCOURAGING CURRICULUM RENEWAL AND THE DEVELOPMENT OF NEW LEARNING ENVIRONMENTS

PANEL MEMBERS. David L. Freyberg (Panel Chair), Steve Cramer, Solomon R. Eisenberg, Frank J. Feher, Nancy M. Haegel, Frank V. Kowalski, Peter D. Meyers, Brij M. Moudgil, Martha C. Zuniga

In the year 2010, growth, change, and creativity in higher education will be as integral to teaching as they are to research.

VISION OF THE YEAR 2010 AND BEYOND

We envision an academic environment in which faculty are as creative in their teaching as in their research. The culture of the academy views and rewards teaching and research equally, and cultivates individual achievements accordingly. Students are active and creative participants in their own education as well as in the education of their fellow students. Curricula emphasize numerous, high quality laboratory and field experiences, and reflect an integrated approach to engineering, mathematics, and the sciences. The lecture-driven, compartmentalization of knowledge into individual course-sized blocks is replaced by team-teaching and other integrating, discovery-oriented learning paradigms, particularly in the lower division. Students view their formal undergraduate education as the catalyst of life-long learning. Specialization plays a smaller part of undergraduate education, and science, mathematics, and technology are part of general education requirements of all students. Substantial resources are available for curriculum renewal and instructional scholarship. Higher education actively collaborates with precollege education to assure high-quality academic preparation and a smooth transition for college-bound students. New technologies are used at all educational levels to enhance the quality of the learning environment.

KEY COURSE OF ACTION AND RECOMMENDATIONS

Our vision of the future requires one principal, key course of action — a fundamental change in the culture of higher education, its funding agencies, and accreditation institutions. The culture of the university must be changed so that pedagogy and research become equal, dynamic partners in the mission of the university. The tenure, promotion, and reward system, the budgeting priorities, and the administrative organization of colleges and universities must be modified to foster and reward creativity and growth in teaching as well as in research. Federal, state, and other agencies that fund and evaluate education must undergo as much of a change in culture as that of academe. Resources for instructional experimentation must be equal to those for research. Accreditation organizations must value curriculum renewal and encourage innovation. We, therefore, recommend the following actions.

To higher education

— *apply tenure, promotion, and reward criteria in ways that value and encourage teaching and instructional scholarship.* A faculty member's time is a limited resource that must be divided among creation of knowledge (research), dissemination of knowledge and thinking skills (teaching), and administration (service). The most effective means to encourage greater faculty activity and creativity in curriculum renewal and the development of new learning environments is to truly encourage, recognize, and reward faculty participation in educational experimentation and innovation.

— *develop peer-based measures of teaching quality and instructional effectiveness.* Teaching presents challenges for evaluation that are, in many ways, unlike those for research. Nonetheless, we believe peer-based mechanisms, now readily accepted for research, hold the most promise. Among the possible mechanisms are: refereed publications and proceedings, peer-reviewed grants for educational experimentation and innovations, professional and public presentations, classroom visits by faculty colleagues, alumni evaluations, and external peer-review of teaching materials and other distributable educational products (e.g. textbooks and courseware).

— *establish permanent funding for curriculum development and renewal.* Universities in general, and individual departments in particular, must recognize that the development and maintenance of a quality curriculum is a continuous process requiring predictable long-term resources, including faculty release time.

— *encourage and reward faculty involvement in precollege education.* The sophistication and effectiveness of any undergraduate program is inherently limited by the motivation and abilities of its entering students. Clearly, it is in our national interest and our interest as faculty to be actively engaged in improving the quality of precollege instruction.

— *assume greater responsibility for and dissemination of innovative education developments beyond the institution.* Successful and innovative educational programs are products of considerable effort, yet information about these efforts often does not reach beyond the immediate campus environment. Support for workshops, conferences, etc., should be provided to facilitate educational dissemination.

— *eliminate barriers created by departmental boundaries.* There are many exciting opportunities and possibilities for interdisciplinary curriculum innovation. Unfortunately, many aspects of the current organizational structure — particularly the practice of allocating faculty, staff, and teaching assistant resources on the basis of departmental undergraduate enrollments — discourages exploration of interdisciplinary approaches to teaching. Universities should explore the development of organizational structures that encourage inter-departmental development of curriculum, particularly in the core curriculum.

— *encourage more creative pedagogical techniques and novel learning environments as alternatives to the standard lecture format.* Alternatives to the standard lecture format, such as "just-in-time" instruction, team teaching, and classroom environments with open-ended problems, would de-emphasize rote or result-oriented learning in favor of more dialectical approaches to solving problems.

— *infuse more computer and information technologies into the curriculum to enhance both the intellectual and the computational elements of science and engineering education, such as interactive computer simulations and artificial intelligence.* Furthermore, undergraduate laboratories should be continually upgraded to include open-ended experiments employing new and emerging technologies as well as traditional equipment.

To funding agencies (including NSF)

— *increase substantially support for faculty instructional innovation and educational experimentation, especially for undergraduate education.* Current support is seriously insufficient to meet the needs and demand for curriculum reform at all educational levels.

— *encourage undergraduate and precollege educational components in research grants.* Besides the obvious technological benefits, federally-funded research at colleges and universities has the potential of contributing to the education of large numbers of students, both majors and non-majors. Funding agencies should develop methods for assuring that *all* students benefit from research performed at their institutions.

To the national scientific leadership

— *The White House Office of Science and Technology Policy, the National Academies of Science and Engineering, the National Science Board, and similar* *institutions and organizations, should assume leadership in assessing and responding to the impact of Federal research funding policies on the educational mission of U S. universities* Since teaching programs compete with research programs for many of the same human resources, attention to the balance of the research and educational missions of colleges and universities is needed. Since Federal funding of research can have both positive and negative effects on the educational missions of colleges and universities, the national engineering and scientific leadership should assess the impact of such funding periodically and help assure the health and vitality of educational programs.

PANEL III

INCORPORATING NEW AND EVOLVING TECHNOLOGIES INTO THE CURRICULUM

PANEL MEMBERS: Sally Wood (Panel Chair), Robert L. Bryant, Robert M. Hanson, Anthony R. Ingraffea, John R. Kender, John J. Lewandowski, Sue McNeil, Helen L. Reed, Ronald J. Roedel

In the year 2010, a wide variety of technologies will interconnect all levels of the education pipeline and provide individualized, discovery-oriented learning opportunities that develop the intellectual, computational, and physical elements of engineering, mathematics, and science education.

A VISION OF THE YEAR 2010 AND BEYOND

We envision a future of technology-based, discovery-oriented learning in which disciplinary and geographic boundaries become less distinct through networked, real-time teaching and research. Electronic learning libraries, direct access electronic media, and the integration of laboratory and instrumentation facilities provide concurrent learning opportunities involving simultaneous study and experimentation, inquiry and verification. New technologies facilitate new forms of learning, networking, and interaction among students and faculty, and redefine their mutual roles in education. New technologies, together with advances in the cognitive sciences, provide the resources to address different learning and teaching styles. Technological and computer literacy is nearly universal, affording more and higher quality opportunities for design, open-ended problem solving, and other hands-on experiences in precollege and undergraduate curricula. A wide variety of communication, information, and visualization technologies interconnect all levels of the educational infrastructure bringing more cohesion and coherence to the education pipeline.

KEY COURSES OF ACTION AND RECOMMENDATIONS

University and college administrators must recognize that state-of-the-art instructional technology will be part of the physical plant needed for a twenty-first century education. Therefore, our vision is based on fundamental changes and initiatives in two basic areas: networking and infrastructure development, and curriculum renewal and learning environments.

Networking and Infrastructure Development

Computing and information technology on most precollege and college campuses, more often than not, resides in isolated rooms and laboratories as stand-alone resources responding passively to student commands. The full potential of contemporary technology must be unlocked through universal networking and imaginative, interactive courseware. Faculty must learn to use these resources effectively and to develop new teaching techniques that help students navigate the network.

Actions recommended —

To higher education

— *create a National Education Network (NEN), an information "super highway," that provides access to all colleges and universities, as well as elementary and secondary schools.* The NEN would afford uniform access (e.g., students, faculty, industry) and would support a broad array of information exchange activities, including informal communications, data transmission and manipulation, real-time experimentation, remote site interaction, recruiting, advertising, and so forth. The NEN would also require development of standards ("rules of the road") and programs for teaching users effective information navigation.

To the NSF

— *expand precollege and undergraduate programs that encourage bold uses of technology, especially those that support exploration of alternative teaching and learning approaches to address different cognitive styles.* New technologies together with advances in the cognitive sciences may soon provide opportunities to develop learning environments that are more tailored to individual teaching and learning styles. In essence, through technology we may reorient our mass production, lecture-driven curriculum to one focused on individualized, discovery-oriented learning. Especially important are initiatives that encourage innovations involving both networking technologies and their interface with state-of-the-art laboratory equipment and instrumentation.

To government legislators

— *provide incentives (legislation) for industry to 1) contribute new technology for universities, colleges, and K-12 classrooms, including maintenance and the regular upgrading of the information technology base and instrumentation, and 2) provide support for employee involvement in and contributions to educational programs.*

Curricula Renewal and Learning Environments

The use of technology in the curriculum should not be a substitute for hands-on, experiential learning; rather, new technologies should be used to leverage all aspects of the intellectual, computational, and physical elements of engineering, mathematics, and science education.

Actions recommended —

To higher education:

— *assure that tenure and promotion criteria are applied so as to recognize and reward faculty creativity in incorporating new technology into instruction.* Without adequate recognition and reward for instructional innovations of all kinds, it is unlikely that curricular renewal and the development of new learning environments will evolve as quickly or creatively as current technology already allows.

To higher education and the NSF

— *encourage curriculum innovations that focus on creativity and discovery-oriented learning through technology.* Create computer-oriented discovery laboratories that provide opportunities for both simulation and information manipulation and physical observation and experimentation, especially with remote site interaction. Instructional innovations tailored to different cognitive styles and the use of technology to foster group communication and problem solving are also encouraged.

— *create a National Design and Discovery Resource accessible through the NEN that provides a rich resource of design examples, problem sets, experimental data and results, and other instructional materials.* This electronic facility, a sort of "on line" exploratorium, will make special design and discovery resources available to all colleges and schools that might otherwise only be available at large research institutions or government laboratories. Encourage universities to provide release time for faculty to contribute "netware" to the NEN curricular database, and NSF to provide grant supplements for educational network software, data, video, etc.

— *promote and expand programs for undergraduate and secondary school research experiences and other in-depth learning experiences.*

— *develop programs to educate students and faculty in techniques to combat information overload, such as critical information navigation and information synthesis.*

To accreditation boards

- *develop standards that encourage instructional experimentation and technological innovation especially with respect to networking, group design experiences, interdisciplinary subjects, and nontraditional degree options*

Implications for Increased Participation

A National Educational Network, a National Design and Discovery Resource, and an emphasis on the development of alternative instructional methods all address issues of equal access. This access would be independent of geographic location or institution and would allow more individualized instruction to meet differences in cognitive styles. Consequently, we believe that a well-developed and well-maintained networked technology infrastructure would provide significant opportunities for targeted programs aimed at increasing participation by underrepresented groups.

PANEL IV

ENCOURAGING AND PREPARING STUDENTS FOR CAREERS AS PRECOLLEGE AND COLLEGE FACULTY

PANEL MEMBERS: Mark S. Mizruchi (Panel Chair), Linda M. Abriola, Charles R. Doering, Phillip D. Gould, Wendell T Hill, Carl R.F. Lund, Lynne Molter, Mamidala Ramulu, Peter Sarnak

In the year 2010, higher education will prepare outstanding students for *all* aspects of faculty careers at all educational levels.

A VISION OF THE YEAR 2010 AND BEYOND

We envision a future in which engineering, mathematics, and science faculty are actively involved in the preparation of future faculty at all educational levels. Teaching careers are viewed as open to all members of society because members from all major demographic groups are well represented at all levels and disciplines. Faculty are well-informed and well-prepared to assume all aspects of their academic challenges and responsibilities. There are adequate resources for effective teaching, including laboratory space and equipment, up-to-date teaching and research facilities, and funding for both research and teaching excellence. Good teaching is encouraged and rewarded at all institutions, including research universities. Extensive interaction among university, college, and precollege teachers facilitates the integration of teaching and research. Curricula encourage students to think critically, creatively, and independently at all levels. Pedagogy is important both in preparation of faculty as well as in their continuing professional development. Persons with experience in other areas, including industry and government, are encouraged and prepared to teach. Substantial efforts are made at all levels to identify, recruit, and retain potential teachers.

KEY COURSES OF ACTION AND RECOMMENDATIONS

The success of the current efforts to revitalize the U.S. educational infrastructure depends on the commitment and collaboration of a number of communities, but mostly it depends on the faculty. They, after all, teach the future leaders of our society and prepare those who, after them, will teach future generations. More importantly, long-term success will depend on those new faculty who enter the teaching profession within this decade because it is they who will shape and define our educational institutions well into the next century. It is they who, in large measure, will bring about the new paradigms needed in education.

This decade, however, is also a time of unique opportunity in the preparation of the next generation of new faculty. It is estimated that as many as half of the tenured college professoriate will retire within the decade. Further, only one qualified science and mathematics teacher graduates annually for every ten school districts in the country. Thus, with successful recruitment and retention strategies, the next generation of faculty who enter precollege or college teaching may do so in unprecedented numbers. Further, if adequate numbers of persons from all societal groups are to be encouraged to pursue teaching careers, then the demographic shifts in ethnicity and gender of the future workforce, and its consequent effect on societal expectations and demands of contemporary life, will need to be given special emphasis.

The education of students in engineering, mathematics, and the sciences is crucial to the Nation's future. Equally crucial, therefore, is the need to foster an environment that, by our efforts and example, will make teaching careers an attractive option, and then to provide high quality programs for those aspiring to teaching careers.

Our vision of the future requires fundamental changes in three major areas: faculty development, encouragement, and resources; desirability and perception of teaching careers; and curriculum development.

Faculty Development, Encouragement, and Resources

Highly-qualified, enthusiastic, and well-rewarded faculty as role models are probably the most effective means to attract students to pursue teaching careers.

We recommend —

To higher education

- *establish significantly more endowed chairs for teaching excellence and instructional scholarship, especially for tenured, associate professors.* The prospect of receiving such near-term support should induce some of our most talented assistant professors to aspire to broader accomplishments, and for those faculty who receive such chairs, to propel them to higher levels of academic leadership

- *encourage and support generously the best faculty to teach entry-level courses in engineering, mathematics, and the sciences* The quality of instruction during the freshman and sophomore years has a profound affect on student recruitment and retention in general, and, therefore, on the pipeline of potential future graduate students in particular, especially American-born students. Indeed, we encourage support for all engineering, mathematics, and science faculty to participate in programs and activities to improve the quality of their teaching and instruction at all levels

To the NSF

- *provide support for faculty development sabbaticals for K-12 teachers and community college instructors at local industries and universities to encourage them to maintain both their technical currency and their enthusiasm*

- *encourage faculty* exchange *programs between research universities and undergraduate colleges to cross-fertilize excellence in teaching and research among all institutions.*

Desirability and Perception of Teaching Careers

A recent survey of over 2,000 engineering graduate students revealed that nearly two-thirds had no desire to pursue an academic career. Indeed, since 1966 freshman interest in faculty and research careers has declined steadily by nearly 75%. While, undoubtedly, many factors affect career choice, one fact from these statistics is very clear — teaching careers are not perceived as very desirable to many students.

We recommend —

To higher education:

- *increase substantially the number of faculty from underrepresented groups* Such faculty serve as important role models for the fastest growing segment of our society from which to recruit future faculty. Further, we encourage support for continued study of fields of engineering, mathematics, and the sciences in which underrepresented groups already participate in significant numbers so as to better understand the issues and factors affecting their career choices.

- *develop prestigious teaching internships for engineering, mathematics, and science graduate students aspiring to faculty careers in higher education.* The internships would be to recruit and better prepare graduate students for their full responsibilities as future members of academe, and especially to improve their abilities in effective teaching and instructional scholarship.

To the NSF

— *expand programs of grants to precollege teachers and precollege students to participate in research projects at local universities to encourage students to consider academic careers*

— *increase support for informal science programs targeted to demystify and clarify science and technology in general, but especially those targeted to broaden public understanding of precollege and college faculty careers*

Curriculum Development

Career attraction is one issue, but formal academic preparation is another.

We recommend —

To higher education and the NSF

— *improve the quality of precollege and undergraduate instruction for all students, thereby encouraging more students to consider careers as precollege and college faculty.* Supportive, enthusiastic faculty set an example that students perceive favorably. There is no more convincing means of demonstrating that a teaching career is enjoyable, challenging, and rewarding.

— *encourage collaborative academic programs and curriculum development among engineering, mathematics, science, and education faculty to assure high quality disciplinary preparation of students interested in precollege teaching.* The collegiate preparation of students for precollege teaching is the most direct, effective, and long-term means in which higher education can affect the quality of precollege instruction for all students.

— *develop curricula to emphasize cross-disciplinary, philosophical, and historical discussions of engineering, mathematics, and the sciences.* Engineering, mathematics, and the sciences must be portrayed as more than a body of knowledge, but rather as a human endeavor rich in history, philosophical debates, and social implications.

To funding agencies (including the NSF) and industry:

— *expand the sources of support for classroom-quality precollege instructional materials and educational resources.* For example, we encourage local companies, colleges, or government laboratories to provide computer access to precollege students and teachers.

PANEL V

ASSURING CAREER PARTICIPATION BY ALL SOCIETAL GROUPS

PANEL MEMBERS: Susan L. Bramlev (Panel Chair), David T. Allen, Ilene Busch-Vishniac, Paul A. Cox, David E. Keyes, Diane Marshall, Carolyn W. Meyers, Daniel G. Nocera

In the year 2010, higher education will reflect the full range of societal diversity, and careers in engineering, mathematics, and the sciences will be viewed as accessible, challenging, and rewarding careers by all segments of society.

A VISION OF THE YEAR 2010 AND BEYOND

We envision in the year 2010 engineering, mathematics, and science professionals from all segments of American society, who are perceived as leading productive, interesting, and rewarding careers and lives. There is ready access to our disciplines regardless of ethnic, gender, physical, socioeconomic, or cultural background. Engineering, mathematics, and science curricula at all educational levels emphasize human processes, reinforce equal access in classroom techniques, and develop a sense of community among all students. Introductory-level undergraduate courses encourage, motivate, and invite students into our fields, and non-majors receive high quality instruction in the technical disciplines through an integrated curriculum. The educational infrastructure provides teachers with training and expertise to prepare students at an early age with the skills necessary for successful careers in engineering, mathematics, and science, including complementary technical careers such as technology policy and science journalism. The reward and compensation systems in academia and industry reward mentorship activities, community service, and political involvement. Professional advancement recognizes the career interests, social concerns, and personal needs of diverse groups within the faculty.

KEY COURSES OF ACTION AND RECOMMENDATIONS

The engineering, mathematics, and science community cannot expect full support from society if large segments of that society perceive themselves as unwelcome and excluded. Therefore, our vision of the year 2010 depends on systemic changes in three areas: enriching the pipeline, plugging the leaks, and career re-entry.

Enriching the Pipeline

The image and excitement of engineering, mathematics, and science must be enhanced, particularly in the early grades. We must encourage continued interest and study of science and mathematics at all educational levels, regardless of career participation, and especially to underrepresented groups.

We recommend —

To higher education and NSF

— *encourage more engineering, mathematics, and science faculty to work in partnership with education faculty and precollege teachers to (1) improve the quality of collegiate instruction in engineering, mathematics, and the sciences to undergraduate students preparing for precollege teaching careers* *especially in the early grades, and 2) prepare high quality materials and instructional aids for the K-12 curriculum* Helping to improve the overall quality of teacher preparation and educational materials for all K-12 students is the most direct, long-term action university faculty could ... to assure greater inclusion of all segments of society in careers in engineering, mathematics, and the sciences.

— *encourage more faculty to interact with the news media, to educate journalists and other public communicators in technical matters, and to ...minate the results and importance of their work more directly to the public* Encourage principal investigators of NSF grants to disseminate their results in public forums as well as in learned journals.

— *expand direct communications with precollege students through such means as weekly news reports (e.g. Scholastic Weekly Reader), television programs about science and technology, or computer networking with local universities and industries* Expand outreach programs or extension courses for parents and the local school community.

Plugging the Leaks

Recruitment is one issue, retention is another. Too many students are lost to careers in engineering, mathematics, and the sciences by unengaging curricula, isolation, and lack of guidance and mentoring.

We recommend —

To higher education

— *introduce more flexibility and individual career development in the application of tenure and promotion criteria, including, for example part-time tenure-track positions.* There is a signif...nt need to recognize dependent care, partner employment, and non-traditional career paths to encourage more persons from underrepresented groups into academic positions. Greater recognition must be given to the importance and demands of role models, to those who successfully recruit members of underrepresented groups into the disciplines, and especially to quality teaching - perhaps the one activity with the greatest impact on student interest, recruitment, and retention.

— *develop means beyond student evaluations to provide professional, peer-based feedback to the faculty on the quality and effectiveness of their teaching, especially with regard to their effectiveness in teaching members of underrepresented groups and non-traditional students* Most universities and colleges have faculty and staff on their campus who are skilled in such evaluations, but, sadly, they are an underutilized resource.

— *expand support programs, such as need-based graduate fellowships, undergraduate scholarships, formal mentoring, and tutoring programs involving faculty-student and student-student interaction, for members of underrepresented groups*

To higher education and NSF

— *reshape and revitalize the lower-division, undergraduate curriculum* Since the attrition of undergraduate students is greatest in lower division courses, this curriculum level most needs attention. In large measure, all faculty need to teach less, and uncover more. Introductory-level courses must emphasize scientific concepts more than isolated facts, including the development of courses that are more interdisciplinary, discovery-oriented, involve teamwork, and employ problems of interest and relevance to the students themselves.

— *encourage initiatives to foster interaction between faculty in education and in technical fields.* Collaborative educational research on the pedagogy of science and engineering should be strongly encouraged, and scholarly pedagogical experimentation should be an expectation of the faculty.

— *establish more flexible curricula for all students.* All students need to have more opportunity to flow into our disciplines apart from the traditional, highly sequenced, lock-step curriculum. Prerequisites should not necessarily impede a student's progress; for example, we suggest student tutoring teams be formed in classes with prerequisites in which students will help fellow team members with prerequisite ma...al they know best, and vice versa. Further, we encourage special attention to instructional innovations for non-traditional students; for example, computer graphics and display technologies developed for the hearing impaired not only assists this group of underrepresented students but may also lead to new learning environments of broad applicability to all students.

To NSF

— *consider institutional records of achievement in participation of underrepresented groups in science, mathematics, and engineering as part of the evaluation for funding for NSF research and education grants*

Career Re-entry

Faculty, students, and professionals who leave engineering, mathematics, and the sciences must be able to re-enter and enrich the profession with the diversity of their experiences.

We recommend —

To higher education and NSF

— *create fellowship and grant programs targeted at encouraging faculty and students to re-enter academic programs*

— *create more flexible degree-granting programs that accommodate students with non-traditional interests*

— *develop courses exclusively for non-majors that invite participation in science, mathematics and engineering.* Such courses can also serve the dual purpose of increasing scientific and technological literacy among non-majors in general.

— *provide encouragement and programs to prepare technical professionals in both academia and industry who wish to teach, even temporarily, in the K-12 system*

— *encourage more industrial role models to teach part-time or to take sabbaticals on college and university campuses*

PANEL VI

DEVELOPING YOUNG FACULTY DURING THE CRITICAL YEARS TO TENURE

PANEL MEMBERS: Denice D. Denton (Panel Chair), Jim Golden, Lisa-Noelle Hiellming, Kathleen C. Howell, R.J. Dwayne Miller, Mark A. Prelas, Deborah L. Thurston

In the year 2010, higher education will encourage and value a broad diversity of faculty scholarship, especially in instructional excellence and public service.

A VISION OF THE YEAR 2010 AND BEYOND

We envision an academe where young faculty develop their early academic talents in an environment supportive of individual faculty interests and abilities. The physical and fiscal infrastructure supporting higher education provides adequate support for both quality research and instruction. Students view their faculty as having jobs that are fun and rewarding. Senior faculty view junior faculty development as a primary responsibility. Tenure, promotion, and related reward criteria are applied with more regard to individual's contributions to an institution's overall academic mission. All aspects of scholarship in teaching, research, and service are truly recognized. The status of teaching in the university is elevated, and young persons entering the professoriate do so because they want to teach and inspire all students to higher achievements.

KEY COURSES OF ACTION AND RECOMMENDATIONS

Our vision is predicated on fundamental changes in five areas: the tenure and reward system, the status of teaching in the university, the availability of instructional and research funding, the professional development of the faculty, and the quality of faculty life.

The Tenure and Reward System

The tenure, promotion, and reward system is our greatest barrier to a better future. Tenure guidelines uniformly denote that teaching, research, and service are the criteria for tenure. It is our experience, however, that the road to tenure is marked research, research, research. It is common for young faculty who excel in teaching to be chided by their senior colleagues for "wasting too much time" on such an endeavor: "It won't get you tenure." *This must change!* The tenure system at present confines the faculty to a narrow spectrum of activity. Although individual research programs may differ dramatically, it is unlikely that an outside observer would view our faculties as diverse. This lack of diversity is exhibited in sex, race, and breadth of intellectual pursuits.

We recommend —

To higher education

— *adhere to the true spirit of tenure and promotion criteria.* Excellence and quality of performance in teaching, research, and service must be truly encouraged, valued, and rewarded. Further, we encourage inclusion of members of underrepresented groups on tenure and promotion committees for candidates from these groups.

— *establish faculty career development programs based on mutually defined institutional and individual faculty goals.* Such programs should incorporate formal evaluation procedures, periodic faculty review (at least annually), and require mutual institutional and individual accountability.

— *require internal and external peer-review of a candidate's instructional accomplishments.* In addition to student evaluations, we suggest classroom visits by fellow faculty, alumni evaluations, and internal and external peer-review of instructional materials and other disseminable educational products, and refereed pedagogical publications.

To the NSF

— *require Principal Investigators to adhere to the true spirit of the Importance of Education and Human Resources required on all NSF grant applications (per Important Notice No. 107 and GRESE NSF 90-77), to improve the quality, institutional distribution, or effectiveness of the Nation's scientific and engineering research, education, and workforce.* Principal investigators must truly seek innovative and effective ways to disseminate the results of their research to *all* students. *Undergraduate participation as research assistants on NSF grants is not enough.* Attention must also be directed to the large and important majority of students enrolled in the undergraduate curriculum. We encourage all NSF staff and reviewers to consider the educational merits of research in preliminary proposals, grant applications, site visits, and progress and final reports.

— *assure long-term, faculty-oriented support for instructional experimentation and educational innovations.* We believe it is imperative that the NSF adhere to the true spirit of its Statutory Authority*, "to initiate and support basic scientific research *and programs to strengthen scientific research potential and science education programs at all levels* in the mathematical, physical, medical, biological, social, and other sciences, and to initiate and support research fundamental to the engineering process *and programs to strengthen engineering research potential and engineering education programs at all levels* in the various fields of engineering, by making contracts or other arrangements (including grants, loans, and other forms of assistance) to support such scientific, engineering and *educational* activities." (NSF Act of 1950; 42 U.S.C. §1861) *Emphasis added.*

* For complete excerpts of Statutory Authority, see p. 26

The Status of Teaching in the University

According to MIT President Charles M. Vest: "...there is one overriding constant that is absolutely critical to the future, and that is the creation and dissemination of knowledge to new generations of young men and women." Creation and dissemination of knowledge - research and teaching. These two complementary and central endeavors of academe must be given equal weight. Sadly, it is our belief that the preferential status of research over teaching in the university has degraded the quality of instruction for generations of young people. We believe that the status of teaching in the university must be elevated to equal that of research.

We recommend —

To higher education

— *regard teaching as both a privilege and a responsibility of the faculty.* Faculty who can not teach, should not teach. It is the responsibility of university administrations to assure that academic programs are staffed by well-qualified faculty and to provide guidance and assistance to those in need of improving their pedagogical skills. We encourage the creation of incentives that provide rewards and resources for use either in instructional or research innovation for those who excel in teaching.

To the National Science Foundation

— *increase the NSF budget for undergraduate education substantially.* In our opinion, the most important contribution NSF can make to elevate the status of teaching on the university campus is to provide broad-based, faculty-oriented programs for high quality instructional experimentation and creative educational scholarship.

— *modify the Presidential Young Investigator award to become the Presidential Young Scholar award to recognize young faculty who excel in both teaching and research.* In its present form, the PYI program, unfortunately, reinforces the lesser status of teaching.

Availability of Instructional and Research Funding

Research and teaching are mutually supportive activities. They are also, jointly, the primary responsibilities of young faculty. However, the inadequacy of funds for research and instructional scholarship, especially the latter, has resulted in an inordinate effort to secure adequate funding. This has particularly degraded the quality of teaching. The decline in support for higher education has added an additional criterion for tenure: grantsmanship and fund raising. This state of affairs neither supports nor encourages quality undergraduate education.

We recommend —

To higher education and the NSF

— *establish dependable, long-term, budgeted support for faculty initiated research and instructional innovation.* Higher education must assume a greater responsibility for support of its research and instructional programs beyond normal teaching activities and facilities maintenance. Similarly, NSF must fulfill its statutory obligation to support research and education in science and engineering consistent with their coequal importance.

— *provide adequate start-up resources to young faculty to initiate their research and teaching programs.* Young faculty must be encouraged to attract both undergraduate and graduate students into research as well as infuse new perspectives into both the undergraduate and graduate curricula.

To higher education

— *value and reward peer-reviewed funding for educational innovation equally with funding for disciplinary research.*

Professional Development of the Faculty

Young faculty today are poorly prepared and lack adequate support to assume the full responsibilities of academic life. In large measure, young faculty are left to their own devices and therefore doomed to repeat the mistakes of their predecessors due to inadequate instructional preparation, lack of senior faculty guidance, and insufficient financial support.

We recommend —

To higher education and the NSF

— *support instructional internships to better prepare graduate students for faculty careers in higher education, and especially to enhance their future teaching effectiveness and instructional scholarship.*

To higher education

— *establish formal senior-junior faculty mentoring programs, ones that begin with the hiring process and are guided by the mutual pairing of the interests and abilities of individual faculty to the broad mission of the institution.*

— *provide special attention to the mentoring of underrepresented groups.* Their lack of participation in our fields and their growing prominence in the future workforce of our society mandates special attention to insure that they flourish in an academic environment.

Quality of Faculty Life

The quality of faculty life profoundly affects the productivity and career longevity of young faculty. Central to the quality of faculty life is an academic environment that provides an adequate capital and human resource infrastructure to support high quality faculty instructional and research initiatives.

We recommend —

To higher education:

— *recruit and retain faculty more aggressively from all societal groups.* This is probably the single most important action to promote greater diversity in professorial contributions to the broad academic mission and to enhance wider student and public interest in science and engineering.

— *stop and start tenure clocks more flexibly through leaves of absence that recognize the reality of contemporary faculty life, including parental and personal obligations, and special opportunities for teaching, research, and professional enhancement.*

— *increase substantially capital expenditures to assure an adequate educational and research infrastructure and overall quality learning environment*

— *establish faculty committees to evaluate and monitor the quality of faculty life.* Such committees could focus on issues related to flexible tenure clocks and formal leave policies for such issues as parental leave, "bridging" research fellowships, and personal, professional, and teaching leaves of absence.

Special Recommendation

In addition, the panel offers a suggestion aimed at one central and important concern about the health and vitality of our profession - attracting outstanding students to the professoriate to insure a quality educational and research infrastructure of the future.

To encourage young persons to enter academia, the panel recommends to higher education

— *improve substantially the quality of instruction and quality of life of undergraduate students, and, by our efforts and example, encourage them to pursue graduate studies and faculty careers.* This is probably the most effective action we could take to the betterment and health of our profession.

NSF's Statutory Authority to Initiate and Support Programs in Engineering, Mathematics, and Science Education

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NATIONAL SCIENCE FOUNDATION ACT OF 1950, AS AMENDED (P.L. 81-507; 64 Stat. 149)

An Act

To promote the progress of science; to advan ne national health, prosperity, and welfare; to secure the national defe . and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Science Foundation Act of 1950."

Functions of the Foundation (42 U.S.C. §1861)

SEC. 3 (a) (1) The Foundation is authorized and directed to initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels in the mathematical, physical, medical, biological, social, and other sciences, and to initiate and support research fundamental to the engineering process and programs to strengthen engineering research potential and engineering education programs at all levels in the various fields of engineering, by making contracts or other arrangements (including grants, loans, and other forms of assistance) to support such scientific, engineering and educational activities.

NSF STATUTORY AUTHORITY AS AMENDED (P.L. 99-159, 99 Stat. 893)

Policy (20 U.S.C. §3911)

SEC. 101. (a) The Congress declares that the science and engineering education responsibilities of the National Science Foundation are —

(1) to improve the quality of instruction in the fields of mathematics, sciences, and engineering;

(2) to support research, fellowships, teacher-faculty-business exchange programs in mathematics, science, and engineering;

(3) to improve the quality and availability of instrumentation for mathematics, science, and engineering instruction;

(4) to encourage partnerships in education between local and State education agencies, business and industry, colleges and universities, and cultural and professional institutions and societies; and

(5) to improve the quality of education at all levels in the fields of mathematics, science, and engineering.

NATIONAL SCIENCE FOUNDATION
Directorate for Education and Human Resources
Division of Undergraduate Science, Engineering, and Mathematics Education

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PRESIDENTIAL YOUNG INVESTIGATOR COLLOQUIUM ON U.S. ENGINEERING, MATHEMATICS, AND SCIENCE EDUCATION FOR THE YEAR 2010 AND BEYOND

Washington, D.C.
November 4–6, 1990

Colloquium Address by

Dr. Charles M. Vest
President
Massachusetts Institute of Technology

Good evening. I am delighted to offer my greetings this evening to such a remarkably talented group. In so doing, I am reminded of John F. Kennedy's famous greeting to an assemblage of Nobel prize winners at the White House. He looked out over the illustrious guests and commented that the room had never contained such a vast array of talent and accomplishment in so many fields - with the exception of those evenings when Thomas Jefferson used to dine alone.

I have something of the same feeling as I see all of you here, knowing that you represent the best that this nation has to offer You have every reason to be very proud of your accomplishments and to look to your professional futures with confidence and excitement. It is about that future that I want to speak this evening.

The Academic Life

I am pleased and comforted by the fact that you have chosen to pursue academic careers. Our nation and world cry out for leadership, and faculty members can, by definition, provide a very critical component of leadership.

I have observed and studied the nature of academic life for many years. My own father was a professor of mathematics and my great uncle - a sort of surrogate grandfather to me - was an engineering professor and president of a small college. I, too, chose the academic life and I have a hard time envisioning any other calling for myself.

I must say, though, that during the last half of this century the life of professors has changed dramatically. The complexity of this life, the expectations of us, the pace and politics of the academy, and our connections beyond its boundaries have all changed greatly. On the home front, many of you are in dual career families, juggling competing responsibilities of family and work, and I know that this creates burdens that few of us in my academic generation had to bear This fact is but one reflection of the changing face of America, which is represented in our universities in the increasingly diverse gender, racial, and ethnic makeup of our family and students.

The increasing richness and complexity of university life is a far cry from the traditional view of the academy. Sometimes we are called upon by both critics and colleagues to return to the golden age of universities, but I don't believe that the golden age ever really existed. And I don't believe we would really take that option if it were presented to us. Life in the academy today is filled with renewal, increased and varied opportunity, access to sophisticated laboratories and computers, greater productivity, better monetary rewards, a more diverse set of colleagues, and more opportunities for travel.

In short, I believe that the academic life is still the best life there is. In spite of all the changes, there is one overriding constant that is absolutely critical to the future, and that is the creation and dissemination of knowledge to new generations of young men and women. You will look back a few years hence and observe that your relations with students, your influence upon them, and your pride in their accomplishments will have been the most rewarding aspect of your professional lives.

I will have more to say about teaching and the balance between teaching and research later, but let me begin with one simple statement. *Professors should profess.* It is hard to think of anything more illogical than to become a university professor if one does not want to teach. So if you do not want to teach, you should immediately look for another job. If you don't get a thrill out of seeing a student's eyes light up with understanding, and if the thought of always having junior partners around — young men and women to inspire you as well as to draw sustenance from you — doesn't hold strong appeal for you, then perhaps you should reconsider your commitment to academia.

Now let me continue under the assumption that not too many of you are left with an uneasy feeling by this statement.

Opportunity and Service

Although it may be increasingly difficult to discern, I believe that being a university professor is a calling. It is a calling to service to our society. One of its pleasures comes in recognizing that what we do is terribly important — that the future depends in large measure on how well we do it. I hope that you share this belief, because it can sustain you through some of the difficult and lonely times of your lives.

Defining the Future

What you do as engineering and science educators has far-reaching consequences. What you do will affect the quality of the lives of your students. And from your laboratories and studies will come the ideas that will shape the intellectual fabric of the future and can greatly affect the strength and vitality of our economy.

Wherever your individual careers take you, I hope that you will be bold and that you will tackle the problems that appear to be of fundamental importance to you. The quality of your accomplishments will in large measure derive from the depth of your belief in their importance. Similarly, your ability to play a catalytic role in the research and studies of your students will depend on the depth of your scholarly commitment and belief in its importance.

The Research University

I would like to spend a few moments talking about the setting in which many of you will spend your careers — the research university — and the question of the balance of teaching and research.

Many of you are faculty members at research universities. Those of you who are not are probably products of research universities. I cannot speak about science and engineering education without offering a few comments about the U.S. research university. This is a uniquely American invention. And in my view this invention is the secret of the success of our higher education system. Indeed, I believe that our university system is the envy of the rest of the world. Here are the primary reasons:

1. For many decades Americans believed that higher education was singularly important for the betterment of their children's lives and they were willing to invest public, private and personal funds to create, sustain and enhance our public and private systems of universities.

2. The wonderful and unique blending of graduate education, undergraduate education and research that occurs in our leading research universities creates an unparalleled opportunity for learning and expanding one's horizons.

3. Our system, unlike that in most other parts of the world, provides great opportunity for young faculty members to quickly involve themselves in all levels of educational and research activities as full partners in the academic enterprise.

4. We have a decentralized system of autonomous public and private universities that allows for experimentation, variation and change.

5. Finally, although it is the bane of my existence as an academic administrator, I believe that competition - the competition of universities for faculty, and the

competition of faculty members for research support on the basis of peer review — is the yeast that keeps our system strong.

Our system of higher education, and our research universities in particular are under a lot of criticism these days. Some of our critics are sensational and strident. Others are thoughtful. We should listen to them and think about what they have to say. We must be willing to better explain to them and to the public what we do and why it is important. We must also be willing to make changes where our critics are correct.

Balancing One's Career

There is much discussion today both within and outside of the academy about the balance between teaching and research. Some may regard my view on this matter to be hopelessly old fashioned or unrealistic. Nonetheless, I will share it with you. As I do so, you might remember my earlier statement that if you don't want to teach, you shouldn't be professors.

However, having said this, I believe that research is fundamental to our activities. Following World War II this nation made a basic decision that its university system would become its research infrastructure. This remains true today, and I believe that it is in our best interest that it remain true. I further believe that the primary reason that we should do research in universities is that it is a form of teaching. It certainly is a form of learning for each of us, but it also should be an integral part of how we teach graduate students, and undergraduates as well.

I believe that over the long run, it requires the discipline, joy and continual renewal of original research, scholarship or other creative intellectual activity to keep lively and successful teachers. One may start out as an effective and even brilliant teacher, but without the kind of continuous renewal that research and scholarship provide, one will not grow in wisdom and breadth, and over time may lose rather than gain in effectiveness as a teacher.

Now how do we balance teaching and research? Must one be equally adept at both? Should you put the development of your teaching skills on hold until you receive tenure? Does teaching count?

My honest answers are: I don't know. Probably not. No. Yes.

Questions about the balance between teaching (whether in the classroom or the laboratory) and research must be answered both institutionally and personally. Each institution must decide for itself what the overall balance of activities should be, and then whether this balance should be met within each faculty member, or whether it is met by an appropriate mix of talents and activities across its entire faculty. Similarly, each individual must decide what his or her balance should be and whether this should be accomplished by a constant balance throughout each year of one's career, or simply as integral in one's activities over an entire career.

I won't answer this for you, but I will state my own personal preference to maintain a strong commitment to both teaching and research at each stage throughout one's career. I would also warn that if one prefers to emphasize research more in the early years of his or her career, it must not come at the expense of teaching poorly. That is an abrogation of responsibility. The quality of one's thinking and work are affected by habits and approaches developed very early on. It is a terrible mistake to think in terms of postponing the development of teaching skills until later, for example after tenure is earned. Given my view of what professors should do and the interrelation between teaching and research, that is a little like saying "I'll go out and write a wonderful computer program, and after it is completed I'll learn the programming language." Don't do it. Rather, devote yourself to excellence in all that you undertake.

Does teaching count for tenure? That is probably the question most frequently asked by assistant professors. The most likely answer to that question in each of your universities is that, yes, it definitely counts — probably more than you and many of your departmental colleagues think — and probably less than it ideally should. Furthermore, I would guess that its role in the evaluation of candidates for promotion and tenure will increase during the years ahead. We need to do a much better job in assessing contributions to teaching - that is, to the effective learning of students in our own institutions and, beyond that, to students in this country's educational system in general.

The Challenges

This brings me to my next point — the problems in public education and in social divisiveness that set the context for higher education in the United States today.

Our educational system is in deep trouble. We all know that within the international context our students on the whole are consistently at or near the bottom of the heap in objective tests of mathematics and science at the high school level. But this is only one manifestation of the underlying problems. Let me give you a specific example: it is one that would be roughly duplicated in most of our large cities.

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In 1987 in the Detroit Public School System, 23,000 students started into the ninth grade. Four years later 6 700 of them graduated from high school. Of these, 2,800 took the ACT examination. And just over 500 of them scored 19 or higher. Hence, from an input of almost 23,000 students in the ninth grade, only about 500 emerged with any hope of advanced education of any sort.

A leading Japanese businessman recently was asked what were the most positive and the most negative factors affecting the ability of the U.S. to compete in the world marketplace. He answered that our greatest strength is our universities, and that our greatest weakness is our primary and secondary school systems. I agree. But how can it be that our higher education is the envy of the rest of the world, and our K-12 system is considered to be inferior? I have already spoken of the strengths of this country's university system. I will leave it up to you as citizens to determine why our K-12 system is failing. The point I wish to make is that this situation is not stable. The continued degeneration of our K-12 system, if unchecked, will eventually destroy our higher education system as well, or at least render it increasingly irrelevant and ineffective.

This has to be our common concern. In our professional lives and in our lives as citizens, we must recognize that there is a single spectrum of education starting at kindergarten (if not earlier still) and extending through postdoctoral education. Until this nation wakes up to the fact that it must increase its investment in human capital — in people and ideas — our education system will spiral downward, pulling our economy and way of life with it. This is a danger of the first magnitude and we must all work for its solution.

An even more fundamental danger, in my view, is the increasing bifurcation of our society into rich and poor, and the increasingly contentious splits along racial and ethnic lines. The first steps toward resolving these issues are to really understand how the face of this nation is changing and to ask how we can best respond to this in our personal and professional lives.

Let me review a few statistics that I assume you are already familiar with:

— Today's school population is 74% white, 14% African-American and 9% Hispanic-American. By the year 2020, when you will be ensconced in various leadership positions, this profile will have changed greatly. The school population will be 52% white, 20% African-American, and 24% Hispanic-American.

— Sixty-five percent of the entrants to the U.S. labor force before the year 2000 (just ten years hence) will be women; only 15% will be white males.

— In 1950 there were 17 active workers in the U.S. for each retired person. By the year 2020 there will be just 3 active workers to support each retiree.

These are quite dramatic changes and our educational and enterprise systems must recognize them. We are beginning to do so, but much of the burden will fall upon your generation.

Now I would like to consider specifically the so-called pipeline of students into science and engineering. You have probably seen these statistics many times, and have undoubtedly addressed them at this meeting. However, a little redundancy won't hurt when the message is this important. And the message is that it is absolutely essential to our economy and our society that we produce engineers and scientists.

— The NSF predicts a shortfall of around 700,000 scientists and engineers by 2010. In 1977 there were 4,000,000 high school sophomores in the U.S.. 730,000 of these students expressed interest in science and engineering careers. In 1980, when this cohort entered college, 340,000 retained this interest. By 1984, 206,000 had actually graduated in scientific or engineering disciplines. Only 61 ''0 of these men and women entered graduate school in science or engineering. By 1992, just 9,700 will graduate with Ph.D.s.

I know that we are a selective bunch, but to have only 0.2% of these students end up with doctoral degrees in science and engineering does not bode well.

• • •

I have taken my personal enthusiastic and altruistic view of the academic life, added to it a sense of urgency and finally spread some doom and gloom statistics. What is my message?

It is that we need you, that what you do is very important, and that you had better do it well and in a manner that reflects the realities of the world around us, but that you can look forward to enjoyment and fulfillment as you take on the challenges.

Education in the 1990s

Why do we need you? What are the challenges of education in the 1990s?

The world is changing rapidly and in ways that are so fundamental as to be without precedent. We have already discussed the changing racial, ethnic, and gender mixes of U.S. students and of our workforce. But we must also look to even greater forces of change. The world political and economic order of the 1990s will be different than any we have experienced in our history. We are connected economically, physically and politically in ways that have never before been the case. At the same time, the nature of jobs and the qualifications and skills they require is also changing rapidly. Manufacturing processes are increasingly sophisticated, the acquisition and utilization of new knowledge is becoming the primary basis of commerce, and emerging working modes require mental agility, flexibility of approach and judgment skills, often quantitatively based. Yet, as we have discussed above, our populace is headed in the opposite direction.

We must work together to correct this growing disparity between the education of our populace and the realities of the changing nature of work that will be required in the years ahead. This is a task that will increasingly fall on us as engineering, science, and mathematics faculties. We must work to assure that our stewardship of the undergraduate education of our populace is a wise and effective one. But further, I believe that we are going to have to play some role in the reform of primary and secondary education — by speaking out, by working on the local level, by developing inspirational new curricula, by developing new educational technologies, by fostering interaction with industry and with retired scientists and engineers, by exposing school students to our laboratories, by demystifying what we do, and by opening discussions with students and faculty in other parts of our own campuses.

We at MIT are very concerned about the problems of scientific illiteracy and lack of numeracy. We have over 50 ad hoc programs to work with primary and secondary schools, and our alumni and alumnae associations are beginning to work on the problems in various localities around the country. Yet we are still searching for a way of making some really fundamental and far-reaching contribution to the betterment of scientific knowledge and understanding among young people. I can assure you that we will look with great interest at the results of your workshop.

Closure

Paul Krugman, a noted MIT economist has just published a very interesting book describing the nature of the current U.S. economy and what possible future directions it may take. He titled his book *The Age of Diminishing Expectations*. His exposition is straightforward and non-ideological, but throughout it he asks the haunting question "Why are we so satisfied with the way things are?"

If we are satisfied with "the way things are", then we will be the victims of a number of unpleasant self-fulfilling prophesies. I have faith that you will not be thus satisfied, and that we can count on you to apply your talents and abilities wisely in the service of your fellow men and women.

I wish you well on your journey.

CHARGE TO THE COLLOQUIUM

The charge to the colloquium is to prepare a report focusing on six major, interrelated issues of special significance to U.S. higher education to assure high quality *precollege* and *undergraduate* instruction in engineering, mathematics, and the sciences for all students. The issues are:

1) attaining and maintaining scientific and technological literacy for everyone.

2) encouraging curriculum renewal and the development of new learning environments, including laboratories and field experiences.

3) incorporating new and evolving technologies into the curriculum, especially information and computer technologies.

4) encouraging and preparing students for careers as precollege and college faculty.

5) assuring career participation by all societal groups, especially women, minorities, and persons with disabilities, and

6) developing young college faculty during the critical years to tenure.

For each issue, we would like you to 1) develop a vision of what the role of U.S. higher education should be in the *year 2010 and beyond* to meet the challenges and opportunities of each issue, 2) identify the key courses of action needed to achieve that vision, and 3) make specific recommendations to higher education, in general, and faculty, in particular, the National Science Foundation, and others as identified by the colloquium

I encourage you to approach your discussions from a broad and visionary perspective. We are interested in your thoughts about the fundamental, long-term, and systemic factors affecting the quality of precollege and undergraduate instruction in engineering, mathematics, and the sciences well into the next century. You should consider all human resources, including persons pursuing careers in the disciplines, the scientific and technological literacy of all citizens, and especially underrepresented groups who will make up most of our society of the future.

Luther S. Williams

Luther S. Williams
Assistant Director
Directorate for Education
and Human Resources

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AGENDA

Presidential Young Investigator Colloquium
on
U.S. Engineering, Mathematics, and Science Education
for the Year 2010 and Beyond

Holiday Inn Crowne Plaza
Arlington, Virginia
November 4-6, 1990

SUNDAY, NOVEMBER 4, 1990

7:00 p.m. **Registration**

7:30 p.m. **Welcome and Overview**

Dr. Luther S. Williams, Assistant Director
Directorate for Education and Human Resources, National Science Foundation

Dr. Robert F. Watson, Division Director
Division of Undergraduate Science, Engineering and Mathematics Education,
National Science Foundation

8:00 p.m. **Colloquium Agenda and Goals**

Dr. Jack R. Lohmann
National Science Foundation
(and the University of Michigan, Ann Arbor)

Dr. Angelica M. Stacy
University of California, Berkeley

MONDAY, NOVEMBER 5, 1990

8:00 a.m. Panel Sessions: A Vision for the Year 2010

AREA A. EDUCATION

Panel I - Attaining and maintaining scientific and technological literacy for everyone.

Chair: Dr. Robert Perry, Ohio State University

Panel II - Encouraging curriculum renewal and the development of new learning environments including laboratories and field experiences.

Chair: Dr. David L. Freyberg, Stanford University

Panel III - Incorporating new and evolving technologies into the curriculum, especially information and computer technologies.

Chair: Dr. Sally Wood, Santa Clara University

AREA B HUMAN RESOURCES

Panel IV - Encouraging and preparing students for careers as precollege and college faculty

Chair: Dr. Mark S. Mizruchi, Columbia University

Panel V - Assuring career participation by all societal groups, especially women, minorities, and persons with disabilities.

Chair: Dr. Susan L. Brantley, Pennsylvania State University

Panel VI - Developing young faculty during the critical years to tenure.

Chair: Dr. Denice D. Denton, University of Wisconsin, Madison

10:00 a.m. Break

10:15 a.m. Area Sessions

Area A (Panels I-III) and Area B (Panels IV-VI) meet in separate sessions to exchange ideas and develop a composite vision for each area.

11:30 a.m. Plenary Session

Both Areas meet together to present their composite visions.

12:00 p.m. Lunch

Speaker: *Dr. Edward A. Knapp, Director*
Los Alamos Meson Physics Facility
Los Alamos National Laboratory

1:15 p.m. Panel Sessions: Key Courses of Action

The six panels meet separately to identify the key courses of action to achieve the composite vision developed in the morning sessions

3:15 p m **Break**

3.30 p.m. **Panel Sessions: Specific Recommendations**

The six groups continue to meet separately and draft specific recommendations to: 1) higher education, in general, and faculty, in particular, 2) NSF, and 3) others as identified by the panels.

5:30 p.m. **Reception**

6 30 p m. **Banquet**

Speaker: Dr. Charles M. Vest, President
Massachusetts Institute of Technology

8:30 p.m. **Summary/Integration Session**

One person from each panel and the colloquium co-chairs will meet to summarize and integrate the highlights of the visions, courses of action, and recommendations in preparation for developing a draft of the report for Tuesday morning.

TUESDAY, NOVEMBER 6, 1990

8 00 a.m. **Panel Sessions: Report Drafts**

Each panel meets separately to review the highlights from the Summary/Integration session of Monday evening, develop a draft of the panel's contributions to the colloquium report, and prepare remarks for the next two sessions.

9 45 a m **Break**

10:00 a.m. **Plenary Session: Review of Report Drafts**

All panels meet to present their key courses of action and specific recommendations and to share their report drafts. The session will conclude with a general discussion of any other related issues, ideas, etc.

12:00 p.m. **Lunch**

1 30 p m. **PRESENTATION AND DISCUSSION WITH THE SCIENCE ADVISOR TO THE PRESIDENT, NSF DIRECTOR AND ASSISTANT DIRECTORS**

Special Guest. Dr. D Allan Bromley
Assistant to the President for Science and Technology

3:00 p.m. **Adjournment**

EPILOGUE

The USEME-sponsored *Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics, and Science Education for the Year 2010 and Beyond*, will, all hope, lead to a report which is useful to readers in academia and government with educational policy making responsibilities. However, its major benefits may already have been delivered in the lives of its participants.

The process used for identifying the colloquium participants selected young faculty, mostly from research universities, probably a majority of them non-tenured, with strong interests in teaching. This is a somewhat lonely group in the sense that most return to environments where many of their colleagues subordinate their teaching to research interests, and all are tempted to do so. It was, therefore, strongly encouraging to spend two intense days with colleagues attempting to articulate a vision of the future in which teaching shares with research a high priority. It was also useful to participants to be introduced to a directorate of the NSF with which most were previously not well acquainted, and which currently accounts for the most rapid funding growth within the Foundation. It was an honor, furthermore, to obtain the ear of the President's Science Advisor for an hour-and-a-half at the concluding presentation of the meeting. In short, the report outlined and drafted at the colloquium was as much a mechanism for creating valuable career links and reinforcing commitments to teaching among participants as it was a product of intrinsic value."

A Participant's
Post Colloquium Evaluation

Mr. THORNTON. Thank you, Dr. Lohmann, for a fine written document. The recommendations you highlighted will be considered along with the several recommendations you made, which are included in your written report.

Dr. Denton, we'd be pleased to enter your prepared testimony in the record, and ask you to summarize it.

STATEMENT OF DR. DENICE D. DENTON, ASSOCIATE PROFESSOR, DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, UNIVERSITY OF WISCONSIN AT MADISON, MADISON, WISCONSIN

Dr. DENTON. Thank you.

I would like to begin by thanking the House of Representatives for promoting me to the rank of Associate Professor, prior to the University of Wisconsin's taking that action.

Mr. THORNTON. It's merely a forecast.

Dr. DENTON. Yes. I am, in fact, an Assistant Professor of Electrical Engineering at the University of Wisconsin, and I also participated in the PYI Colloquium on America's academic future.

I am from Texas, originally, and I attended MIT, where I received the Bachelors, Masters, and Ph.D. degrees in electrical engineering.

In my freshman year at MIT, I took the introductory circuits course. The instructor was highly theoretical, and refused to draw circuit component symbols on the blackboard. Instead, they were represented as boxes.

This complicated greatly the assimilation of the material and, consequently, the class average on the first exam was very low.

The professor was so disappointed in our performance that he mailed out form letters to all of us receiving a grade below a certain cutoff, informing us that we are not cut out for a career in electrical engineering, and should seriously consider transferring to another major.

This was disheartening and discouraging, and I came very close to transferring to Harvard to major in humanities.

I believe it never occurred to this faculty member that there may have been something amiss with his instruction, rather than with our intellects. I believe this example illustrates, in a concise way, a serious problem in undergraduate engineering education.

The tenure guidelines across the country uniformly denote excellence in teaching, research, and service. This sounds great but, unfortunately, at many research universities, it is made clear to junior faculty that only one of the three areas is recognized at tenure time—research.

Young faculty have two career interests—teaching and research. They have boundless energy and enthusiasm for teaching and education, which the current tenure process extinguishes almost immediately.

Senior faculty pull their young colleagues aside and admonish them for spending too much time on teaching. This has happened to me and to many of my colleagues.

On this point, the PYI report states, "The tenure system at present confines the faculty to a narrow spectrum of activity. Although individual research programs may differ dramatically, it is unlikely that an outside observer would view our faculties as diverse. This lack of diversity is exhibited in sex, race, and breadth of intellectual pursuits."

In essence, the tenure process tends to leave out women and people of color. Given the demographic realities of the 21st Century, this state of affairs is intolerable. Until women and minorities occupy tenured positions on the faculties of America's universities, we will not be able to provide quality undergraduate science and engineering education to all of the women and men on campus.

I have worked to increase the participation of women and minorities in science and engineering. I'm the faculty advisor for the Society of Women Engineers, and I frequently visit K-12 classrooms.

I am deeply committed to the enhancement of diversity among scientists and engineers. I am, however, reluctant to discuss these activities with my colleagues, since they question why I pursue them.

Recently, I traveled around the state to encourage high school girls to study engineering. One of my colleagues asked me if we could get together, and I informed him that I would be off on this recruiting trip. His response was, "Wow, we sure have different value systems."

His value systems were in large part molded by the tenure process, and it is not surprising to find that he did not revert to a broader and more flexible outlook after his promotion.

So what can be done to improve this state of affairs? The recommendations of the PYI group include: first, young faculty must have the resources available to pursue innovations in education. We've all alluded to this.

In particular, I would recommend increases in the level of funding for the instrumentation in the laboratory improvement program, and the undergraduate curriculum and course development in engineering, math, and the sciences program.

It is essential, however, that the funding of these programs is not enhanced at the expense of research. There is a perception among faculty at research universities that the NSF budget is zero sum in that monies allocated to education are taken away from research.

This leads to great acrimony and drives major researchers even farther away from active participation in the education enterprise. The hope is that researchers can be encouraged to become engaged in education, and this will not be possible if the advocates for education are viewed as villains and Robin Hoods.

Quality education and research in academia are both essential to U.S. competitiveness, and should both be supported at the greatest possible levels.

Second, performance in teaching, research, and service must be truly encouraged and rewarded. When this point is raised in the university, a common refrain is, that it is so difficult to evaluate excellence in teaching.

This was, in fact, indicated in the background report for this hearing. I would argue that this statement is completely unfounded, as was alluded to earlier by Dr. Pister.

In addition to student evaluations, we can use classroom visits by fellow faculty, alumni evaluations, and internal and external peer review of instructional materials.

The Academy puts much time and effort into peer review of a faculty member's research. It can and should do the same for teaching achievements.

Finally, there are 3,500 institutions of higher education in the country, and only about 100 of these are research universities. It is important to ensure quality education at all of these institutions.

One may argue that the PYI report is focused on the 100 research universities. However, many of the teachers at the remaining 3,400 institutions and a large fraction of the K-12 teachers are trained at the research universities.

Success in elevating the status of teaching in research universities will have an impact across the educational spectrum in that future teachers at all levels will not only learn science and engineering, but they will also learn how to teach by example, if teaching excellence becomes the norm at the 100 research institutions.

I believe we can achieve this goal of teaching excellence with alacrity if the recommendations presented today are put in place.

I hope I speak for all the panelists in saying we look forward to working with the Subcommittee on Science to ensure their implementation.

Thank you for your attention.

[The prepared statement of Dr. Denton follows:]

THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION: ACHIEVING A BALANCE BETWEEN TEACHING AND RESEARCH

Denice D. Denton
Assistant Professor
Department of Electrical and Computer Engineering
University of Wisconsin-Madison
Madison, WI 53706

I received the BS, MS and Ph. D. degrees in Electrical Engineering from MIT. I began my studies there in 1977. In my freshman year, I chose to take the introductory level circuits course normally taken in the sophomore year. This was a difficult course and the difficulty was compounded by the fact that the instructor was highly theoretical and refused to draw actual circuit components on the blackboard. All resistors, capacitors and inductors were represented as boxes. This complicated greatly the assimilation of the material, especially for the more practically minded students. As a result, the class average on the first exam was very low. The professor was clearly disappointed in our performance. He even went so far as to mail out form letters to all of us receiving a grade below a certain cutoff level chosen by him. This letter informed us that based on our performance on the first exam, we were obviously not cut out for a career in electrical engineering and we should seriously consider transferring to another major. Needless to say, receiving this letter was most disheartening and discouraging. One of my peers took the professor's advice and transferred to the Sloan School of Management. I came very close to transferring up the Charles River to Harvard to major in humanities. I believe now that it never occurred to this faculty member that perhaps there may have been something amiss with his instruction rather than with our intellects. Furthermore, in retrospect and speaking as an electrical engineering faculty member, it was incredibly inappropriate to suggest to an entire cadre of students that they should seek alternative career paths based on the performance on a single exam. I believe this example illustrates in a concise way some of the problems endemic in undergraduate science and engineering education.

Since joining the ranks of the engineering faculty, I am beginning to understand the reasons for the deterioration in undergraduate science and engineering education. The tenure guidelines in universities across the country uniformly denote excellence in teaching, research and service as requisite. On the surface, this sounds good. One would expect that faculty members about to be given job security for life should be teachers and researchers of very high quality and outstanding citizens. Unfortunately, at many research universities it is made clear to junior faculty members very early that only one of the three areas is truly evaluated and recognized at tenure time: RESEARCH. Of course, the desire to do state-of-the-art research is a primary reason for junior faculty to join such institutions. But, young faculty arrive on campus with two major career interests: teaching and research. These young people have great contributions to make. They have boundless energy and enthusiasm for teaching which the current tenure process successfully extinguishes nearly immediately. It is not uncommon for senior faculty to pull their young colleagues aside and admonish them for spending too much time on teaching. This has happened to me and to many of my peers. This lack of recognition of teaching in the tenure and reward system MUST CHANGE.

What is wrong with the tenure process? At research universities, the tenure process is an effective mechanism for churning out hundreds of nearly identical faculty members. It allows minimal breadth in intellectual pursuits and it recognizes only one contribution-research narrowly defined. In essence, young people enter this pipeline at one end and six years later, the ones who are left standing look very similar to one another. As the National Science Foundation Presidential Young Investigator report America's Academic Future states: "The tenure system at present confines the faculty to a narrow spectrum of activity. Although individual research programs may differ dramatically, it is unlikely that an outside observer would view our faculties as diverse. This lack of diversity is exhibited in sex, race, and breadth of intellectual pursuits." A key point here is that not only does the tenure process yield researchers with little enthusiasm left for teaching, it also tends to leave out women and people of color because it is an inherently narrow filter. Given the demographic realities of the 21st century, this state of affairs is intolerable.

As a faculty member in Electrical and Computer Engineering at the University of Wisconsin-Madison, I have worked extensively to increase the participation of women and underrepresented minorities in science and engineering. In particular, I am the faculty advisor for the Society of Women Engineers (SWE) and I frequently visit K-12 classrooms around the state to encourage kids to consider technical careers. I am reluctant, however, to discuss my precollege and outreach activities with many of my colleagues. They cannot understand why I would participate in activities that take time away from my research program. Recently, I travelled around the state with some students from SWE to encourage high school girls to study engineering. One of my colleagues asked me if we could get together and I informed him that I would be off on this recruiting trip. His response was: "Wow, we sure have different value systems." His value systems were in large part molded by the tenure process. It is important to understand that junior faculty spend five to six years working toward a single goal: tenure. If the road to this goal is inflexible and narrow, it is not surprising to find that tenured faculty members are often inflexible and narrow in their outlooks. Most people cannot spend five years fully engaged in one mode of operation and then after tenure, suddenly revert to a broader and more flexible outlook. This lack of flexibility and allowance for breadth in the tenure process is perhaps the most responsible for the deterioration of undergraduate science and engineering education.

I participated recently in a National Science Foundation colloquium for Presidential Young Investigators (PYI). The charge to the group was to consider engineering, math and science education in the year 2010 and beyond. The result was the report America's Academic Future. The group consisted of about 60 young and well established researchers from a broad variety of disciplines at primarily research universities. There was an overwhelming consensus among the participants that major changes must be made in the academic infrastructure to insure a quality education for all students, especially women and underrepresented minorities. One of the key notions is that the academic culture must change. The participants believed strongly that the academy must accommodate the demands and desires of young faculty members to engage themselves actively in the business of educating the next generation while also enthusiastically pursuing their research programs. At present, the belief is that this is nearly impossible given the constraints of the tenure and rewards process.

RECOMMENDATIONS

There are a number of recommendations made by the PYI group to enhance the quality of science and engineering undergraduate education. Foremost among these are two:

1. Young faculty must have the resources available to pursue innovations in education. It is recommended that NSF "...assure long-term, faculty-oriented support for instructional experimentation and educational innovations." In particular, I would recommend increases in the level of funding for the Instrumentation and Laboratory

Improvement Program and the Undergraduate Curriculum and Course Development in Engineering, Mathematics and the Sciences Program. These are programs where individual faculty members can make a substantive contribution, and the tenure process requires that faculty show an ability to independently succeed in securing funding for programs and achieving the desired objectives. In addition, an increase in the education budget will encourage faculty to propose innovative programs. As the PYI report states: "There is a misconception in our universities that teaching and instructional innovation are less valuable, less difficult, less creative, and less scholarly than research. The Federal government, through its agencies and their past budget priorities, shares a principal responsibility for this misconception." This situation should not be perpetuated.

It is essential, however, that the funding of these programs is not enhanced at the expense of research programs. There is a perception among faculty at research universities that the NSF budget is zero sum in that any monies allocated to education are taken away from research. This leads to great acrimony among the faculty and drives major researchers even farther away from active participation in the education enterprise. The hope is that the senior researchers can be encouraged to become engaged in education and this will not be possible if the advocates for funding of education programs are viewed as villains and Robin Hoods. Quality education and research efforts in academia are both essential to the competitiveness of the country. We must insure that both are supported at the greatest possible levels.

2. The academy must "..adhere to the true spirit of tenure and promotion criteria. Excellence and quality of performance in teaching, research, and service must be truly encouraged, valued and rewarded." When this point is raised in the university, a common refrain is: "But it is so difficult to evaluate excellence in teaching." In fact, the background statement for this hearing declares "In contrast to research, where the academic acumen of faculty can be readily assessed and rewarded on the basis of publications and research grants, the metric to assess and reward excellence in teaching is far more complex." I would argue that this statement is completely unfounded. The simple way to evaluate research is to count the number of papers published and the number of research dollars brought in and then to equate large numbers with excellence. One could just as easily count the number of students taught and the number of education dollars brought in. Of course, neither of these metrics yields a true indication of quality in research or teaching. To truly evaluate excellence in either endeavor is difficult and complex. It requires a combination of internal and external peer-review. The PYI report states that the academy should "...require internal and external peer-review of a candidate's instructional accomplishments. In addition to student evaluations, we suggest classroom visits by fellow faculty, alumni evaluations, and internal and external peer-review of instructional materials and other disseminable educational products, and refereed pedagogical publications." The academy puts much time and effort into internal and external peer-review of a junior faculty member's research. It can and should do the same for teaching achievements. This would accomplish the dual goals of including teaching performance in the tenure review process and making clear to faculty at all levels that the contribution to education is as essential and highly rewarded as that to research. Finally, in assessing teaching in the tenure process, teaching should be broadly defined. It is important to consider contributions to education made over a large spectrum. These can and should go well beyond classroom teaching.

In addition to the two recommendations above, I believe it is important to consider several more possibilities. First, I recommend that the National Science Foundation sponsor a meeting of junior faculty, senior faculty and administrators from research universities. The charge to this group should be to develop strategies and tactics for the elevation of the status of teaching in universities with science and engineering programs.

There are a number of groups beginning to address the issues being discussed in this hearing and it is essential to consolidate their efforts to insure that the desired ends are achieved as rapidly as possible.

Second, we must recall that there are 3500 institutions of higher education in the country and only about 100 of these are research universities. It is important to insure quality undergraduate science education at all of these institutions. One may argue that the PYI report is focussed on the 100 research universities. However, many of the teachers at the remaining 3400 institutions are trained at the research universities. In addition, a large fraction of the K-12 teachers are also educated there. Clearly, success in elevating the status of teaching in research universities will have an impact across the educational spectrum. Future teachers at all levels will not only learn science and engineering, but they will also learn how to teach by example if teaching excellence becomes the norm at the 100 research institutions. In addition, elevating the status of teaching at the research universities will enhance the prestige of teaching at all levels. Congressional committees with oversight responsibilities for the tax payers' money should endeavor to insure that the tenure and reward system guarantees a quality education for students at all 3500 institutions of higher learning.

I would like to conclude by re-emphasizing the clear and present need to insure the participation of women and minorities in science and engineering at all levels. This is particularly important given the context of the rapidly changing demographics of the US work force and the need to insure international competitiveness. The barriers to participation of underrepresented groups are many and varied and will not be adequately lowered until there is a critical mass of underrepresentented groups in senior positions. Such individuals are the only ones who can truly understand all of the biases and patterns of discrimination and therefore help remove the barriers, empathize with the young students and faculty members struggling to surmount them, and in the long run help to remove the barriers entirely. This illustrates the urgent need for role models at all levels. This need is particularly important in the faculty ranks where tenured women and minorities in the sciences and engineering are few and far between. The lack of faculty role models is due in large part to the narrowness, inflexibility and time scale inherent in the tenure process. Women and minorities in academia hit the glass ceiling much sooner than do their counterparts in industry due to the compressed time scale of the tenure process. It is very unlikely that an entry level employee at IBM will be bucking for a top management job in five years. But that is the time frame in which a young faculty member comes up for the ultimate promotion to membership in The Club. The PYI report recommends that "...we encourage inclusion of underrepresented groups on tenure and promotion committees for candidates from these groups." This is an essential first step. Until women and other underrepresented groups occupy tenured positions on the faculties of America's universities, we will not be able to provide quality undergraduate science and engineering education to all of the women and men on campus.

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REDEFINING THE ACADEMIC ETHOS

Syracuse Seeks a Balance Between Teaching and Research

By CAROLYN J. MOONEY

SYRACUSE, N.Y.

Syracuse University is staging a quiet assault against one of academe's most sacrosanct traditions.

Simply put, it is trying to change the "publish or perish" culture that has dominated life at research universities for decades.

For the last three years, a group of professors and administrators here has been scrutinizing the way teaching is evaluated and rewarded. Though new policies aimed at giving teaching a higher priority, they hope to strike a balance between professors' responsibilities to teach and conduct research.

Already there have been small changes—better-organized courses and syllabi, more-vigorous teaching eval-

Syracuse Wants to Change Academic Ethos to Place Greater Emphasis on Teaching

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uation policies, and more money to provide strong teachers with merit raises and grants. The hope is that more-ambitious changes will follow—broader definitions of what counts as scholarship, tenure decisions that favor strong teachers the way they traditionally have favored strong scholars, and an emphasis on the quality rather than quantity of research.

A Mushrooming Effort

Those who support the eff[illegible]—and not everybody here does—never expected it to grow as it has. But through a combination of chance, design, and good timing, what began as a modest year-long project has mushroomed into what is thought to be the most comprehensive effort yet to redefine academic culture.

Can Syracuse pull it off?

Some professors here are deeply skeptical. They question whether Syracuse can change in a few years an academic ethos that began more than a century ago, when some American institutions, notably the Johns Hopkins University, began adopting the German model for research universities. Syracuse is taking on powerful academic disciplines, administrators with big appetites for research grants, and most of all, widely held notions of prestige. When universities raid each other's faculties, the skeptics note, they don't do it because they want cutting-edge teachers.

"I think they're making a valiant effort," says William D. Coplin, a public-affairs professor who advises a student group called Undergraduates for a Better Education. "But I don't think the faculty believes it will happen."

Jack E. Graver, a mathematics professor, says: "We're old-fashioned—we believe in the teacher-scholar system. We've been doing that for years, and I must say with a little bitterness, to our disadvantage."

Others here are more optimistic. They say Syracuse is slowly chipping away at an ethos that prizes research most.

"I think there's now a cohort of deans and adm[illegible]strators who think the momentum has [illegible]," says David M. Rubin, dean of the communications school.

The motivations behind Syracuse's efforts are both idealistic and pragmatic. Mr. Rubin and others say the private 15,000-student university has no choice but to do what it is doing. It's in a financial crunch, faced with a potential $38-million deficit and steep competition for students who can afford its rising tuition. Administrators

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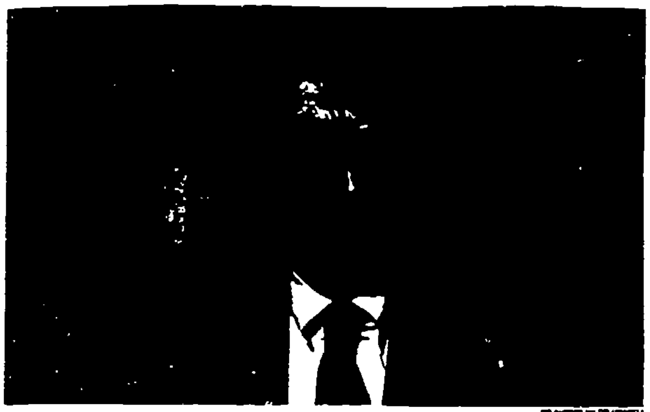

Robert M. Diamond, assistant vice-chancellor for instructional development: "Our timing happened to be perfect," he says of the new restructuring plan.

frankly admit that a reputation as a "student-centered research institution"—that's the term used to describe Syracuse's new restructuring plan—will better position the university for the future. "For that reason, our timing happened to be perfect," says Robert M. Diamond, assistant vice-chancellor for instructional development and a co-director of the teaching project.

Misplaced Emphasis on Research?

The project also coincides with a growing interest—at Syracuse and nationally—in improving undergraduate education. In the past year, many research universities, blistered by criticism from students, legislators, and other critics, have announced plans to examine their faculty-reward systems. In addition, some comprehensive campuses—those whose research and graduate programs are more limited but which have adopted the same values as more elite research universities—are now asking whether their growing emphasis on research is misplaced.

A special committee at the University of California system recently issued a report calling for major changes in the way teaching is evaluated and rewarded. Rutgers University is using federal grant money to raise awareness among new professors about the need to balance teaching and research. And last month, Arizona State University's "Commission on the Place of Teaching at the University" released a draft report urging the campus to adopt a broader definition of faculty scholarship, as recommended in a 1990 report issued by the Carnegie Foundation for the Advancement of Teaching.

The Carnegie report, "Scholarship Reconsidered: Priorities of the Professoriate," is credited with putting the teaching-versus-research issue on the table nationally. It called for a broader definition of research that would reward professors for activities related to teaching, and not just the discovery of new knowledge, traditionally the only kind of scholarship that counts for promotion.

Carnegie's president, Ernest L. Boyer, says the report has been one of his organization's best-sellers. More than 25 institutions, including Syracuse, have invited him to their campuses to discuss it.

"The issue of the role of the faculty and the reward system is being discussed more openly now than at any time since World War II," he contends. "The exciting news is not that everything's changing overnight, but that it's a legitimate topic to discuss."

At Syracuse, the discussion began in the spring of 1989, when the university received a one-year, $25,000 grant from the Sears-Roebuck Foundation.

Syracuse, which in the mid-1980's had been harshly criticized by student groups upset over teaching assistants who spoke poor English and over a lack of contact with professors, already had numerous programs under way to improve undergraduate education. The grant's purpose was to improve the perceived importance of teaching on the campus. The project's directors were—and still are—Mr. Diamond and Ronald R. Cavanagh, vice-president for undergraduate studies. Mr. Diamond is also director of the university's Center for Instructional Development. Its staff helps professors improve their curricula and teaching and works closely with Mr. Cavanagh, who considers the center his "academic green-beret unit."

Ammunition From Survey

Once a campuswide advisory board was set up, the first step was a survey to examine how professors, department heads, and deans viewed the relative importance of teaching and research. The results provided plenty of ammunition. They showed that while all three groups saw themselves as favoring a balance between teaching and research, they saw others—particularly the central administration—as favoring research.

Some saw the results as evidence that Syracuse had a large corps of "closet teachers." Comments made by those surveyed left little doubt about what the campus valued most. Wrote one professor: "I think that lip service is paid to undergraduate teaching, but rewards (salary, promotion, leaves, etc.) are given for research." And another: "I could point to a dozen examples of how we honor 'good' research (on a weekly basis even). We don't always know or care if it's good. We care that it is publicized and funded."

In the summer of 1989 a two-day conference drew more than 100 deans and department heads from Syracuse's 14 autonomous schools. Participants were asked to develop plans to improve teaching and suggest ways the administration could help. In the fall, many units held faculty discussions on those issues, and the administration announced a new grant program that would finance 58 innovative-teaching proposals—at a cost of $50,000—in its first year.

By the time the Sears grant ran out in early 1990, Syracuse had decided to continue the effort on its own. But as a project report notes, the initial $25,000 grant was "the key, because it enabled Syracuse to implement some activities that would have had far less chance of being supported by the academic community if sponsored internally."

In the project's second year, the advisory board asked all academic units to develop better standards for evaluating and rewarding teaching, and to develop a definition of scholarly activities for faculty in their disciplines. That summer, 36 people attended a workshop on evaluating teaching.

For years, the lack of national standards for judging teaching has been seen as a major obstacle in rewarding strong teachers. A proposal from the communications school, though, listed 27 possible criteria ranging from surveying alumni to examining any textbooks or new courses designed by candidates to looking at student attrition rates. While professors will have flexibility in choosing which criteria are used, the long list showed that student reviews weren't the only way to evaluate teaching.

The project's third year saw more concrete change. Many departments and schools completed teaching-improvement plans, and some modified their tenure and promotion policies to make explicit their expectations. The heads of the foreign-language and religion departments, for example, say they now encourage professors to use a teaching portfolio—a collection of materials that document a professor's teaching ability. And many units, including the architecture school, now require student evaluations of every course.

In a memo outlining its response to the teaching project, the economics department provided an economist's perspective, complete with a discussion of incentives and a cost-benefit analysis. Cooperating on the project, the memo said, would help both the department at budget time and the "primary client," the students. But it also noted that "the market emphasizes scholarly output" and that the department "has a tradition of playing hard ball" during salary reviews.

Since the project began, the department has started to evaluate teaching more thoroughly and to tie merit raises to teaching evaluations. It has also established the post of undergraduate director.

Plenty of Obstacles

The teaching project is being watched with interest outside Syracuse. The university is currently involved in several spinoff projects aimed at expanding its efforts to other campuses and encouraging learned societies to develop broader standards for research.

But the project still faces plenty of obstacles here. Some professors worry that it will subject junior professors, already under enormous pressure, to even tougher standards. Some worry that the university will lose ground in scientific research. And some say that until students take learning seriously, the initiatives will be meaningless.

Syracuse's new chancellor, Kenneth A. Shaw, addressed that point last month when he outlined the new restructuring plan. He called for a "student-centered culture" that would make Syracuse a national model, but also called upon students to change their culture, which he said "values social activities more than our prime reason for existence." In Decem-

"We're old-fashioned—we believe in the teacher-scholar system. We've been doing that for years, and, I must say with a little bitterness, to our disadvantage."

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Syracuse Wants to Place More Emphasis on Teaching

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ber one professor here who was fed up with that culture abruptly ended a large lecture class—after most students said they hadn't done the required reading—and bought a $111 newspaper advertisement to express his disgust.

Perhaps the biggest question is whether the efforts here will make a difference at promotion time.

Almost everyone interviewed agreed that an outstanding teacher with a poor publishing record should not receive tenure. But there was far less consensus about an outstanding teacher who is an average or fair scholar.

Some here contend that the project has already resulted in at least one live body—a scholar who received tenure last year but might not have done so several years ago.

A Close Call

That scholar is Jerry Evensky, now an associate professor of economics. Even with the teaching initiatives outlined by his department, Mr. Evensky knew his case would be close. He had a reputation as an excellent teacher who had published highly readable textbooks. The issue was not even whether he was an active scholar; it was whether the *type* of scholarship he did—on the history of economic thought and on ethics and economics—was valued by a department that stressed applied research.

In the end, Mr. Evensky did get tenure—by a one-vote majority.

James Follain, the department chairman, says it would be unfair to portray the case as a "litmus test" on the teaching-versus-research issue. But to others, a decision not to grant tenure to Mr. Evensky would have been disastrous for a university that was preaching teaching. Among them was Christopher M. LaVallee, a senior economics major who says Mr. Evensky's reputation was the main reason he first took an economics course. He recalls how Mr. Evensky stood before a large class one day, popping M&M's into his mouth and later explaining that he had actually been illustrating the concept of diminishing marginal utility.

"To have lost the Evensky case," says Robert D. McClure, associate dean of the school of public affairs, "would have meant losing nearly everything."

As for Mr. Evensky, now the department's undergraduate director, he says: "My teaching helped, and it wouldn't have helped enough three years ago.

"I think they're buying into the teaching business." ■

Critics Say Faculty-Reward System Discounts the Importance of Service

Just as a movement to provide more rewards for college teaching is building up steam, some observers are pointing to another deficiency in the faculty-reward system—its failure to recognize professors' so-called service activities.

Such activities might include serving in the faculty senate or on a curriculum-review panel, or organizing an academic conference.

In January, the National Association of State Universities and Land-Grant Colleges invited representatives of more than a dozen learned societies to discuss the issue at a conference in Racine, Wis.

Three Criteria

In a statement released at the conference, participants acknowledged that, although the disciplines and institutions expect such activities, they often fail to encourage and recognize them. They agreed to have their societies discuss ways to better evaluate and reward service activities.

Traditionally, service to the campus and community has been one of three criteria used to evaluate faculty members for promotion and raises. The others are teaching and research.

Institutions that expect their professors to conduct research might weight those three areas—in theory, at least—like this: Teaching and scholarship would each count 40 per cent, and service would count 20 per cent. In fact, junior professors at research universities are routinely told to forget about service activities if they want to achieve tenure, and to distinguish themselves through their scholarship. One consequence has been that service activities have generally been left to more senior professors.

Among those working on the project is Nevin C. Brown, director of the national conference on school-college collaboration at the American Association for Higher Education.

Mr. Brown thinks the time is right to provide better rewards for service activities. "Universities and their faculties," he says, "are increasingly being looked at as resources for helping society deal with lots of external problems."

Participants in the project plan to meet again in June.

—CAROLYN J. MOONEY

Syracuse Tries to Involve Others in Teaching-vs.-Research Debate

By CAROLYN J. MOONEY

SYRACUSE

Syracuse University recognizes that if it's going to change its faculty-reward system, it can't do it alone.

Since 1989, when it began a project to provide more rewards for teaching, Syracuse has become involved in several related projects that are bringing the teaching-versus-research debate to other campuses and to learned societies.

Broader View of Scholarship

One project involves a national survey on how teaching and research are valued by different campus groups. Another is encouraging six research universities to examine the role of teaching in their faculty-reward systems, much as Syracuse is doing. A third is asking learned societies to consider a broader view of what counts as scholarship.

The projects are being conducted by Syracuse's Center for Instructional Development. Following is a summary of each.

The national survey. In 1989, as part of its teaching project, Syracuse conducted a survey to examine how its professors, department heads, and deans viewed the relative importance of teaching and research. The results showed that while each group saw itself as favoring a balance between teaching and research, each saw the others—especially the central administration—as favoring research.

The following year, the instructional center received a Lilly Endowment grant to extend the survey to 47 research universities—33 public and 14 private institutions. Results of that survey provide additional evidence of a major perception gap. The results show that while many faculty members, department heads, deans, and administrators agreed on the need to balance teaching and research, they also agreed that the emphasis was shifting more toward research than they would like.

"The differences in the way respondents perceive the way the university *is going* and the way it *should go* suggest that there is a serious conflict between the culture of the university and the values of individuals," concludes a report of the survey, "A National Study of Research Universities: On the Balance Between Research and Undergraduate Teaching."

Professors also perceived central administrators as favoring research, while administrators saw themselves as favoring teaching.

Efforts on other campuses. As part of a project financed by the Fund for the Improvement of Postsecondary Education, six universities are examining ways to emphasize teaching on their campuses. They are Carnegie Mellon, Northwestern, and Ohio State Universities and the Universities of California at Berkeley, Massachusetts at Amherst, and Michigan.

The six, which participated in the survey described above, have begun discussions of ways to improve and better reward teaching.

Another part of the project will identify the intrinsic rewards that professors receive from teaching in an effort to provide a better context in which to examine "extrinsic" rewards.

The role of learned societies. Because the academic disciplines determine what kind of scholarship is most valued, directors of Syracuse's teaching project decided it was crucial to involve the learned societies in any discussion about redefining scholarship.

More than 20 groups representing disciplines ranging from business to history have agreed to participate in a project aimed at doing exactly that. The project is being sponsored both by the Fund for the Improvement of Postsecondary Education and the Lilly Endowment.

In 1990 the Carnegie Foundation for the Advancement of Teaching issued a report that recommended that scholarship be defined as having four components: the discovery of knowledge, the integration of knowledge, the application of knowledge, and the teaching of knowledge. Traditionally, the discovery of new knowledge has been the only type that counts at promotion and raise time.

The Carnegie recommendation has since been widely discussed in academe. Organizers of the project hope the learned societies will adopt broader definitions of scholarship that will lead to changes in the way decisions about tenure, promotion, and raises are made.

Some of the early letters from the societies expressed strong interest. The American Sociological Association, for example, noted that many of its members felt teaching was "soft" and therefore hard to measure. But sociologists could give it a try, the letter said, noting that "we measure alienation, urban decay, marital happiness, and the underclass."

Some observers have noted the irony of asking the very groups that set the current standards for scholarship to lead in reform efforts.

At a conference held last fall, the participating learned societies agreed to appoint special panels to examine ways to redefine scholarship in each discipline. A panel representing the American Historical Association has since developed a draft document that used the definitions proposed in the Carnegie report. It lists textbooks and newsletters, papers given at conferences, and museum exhibitions as scholarly activities related to the *synthesis* of knowledge. Activities related to the *application* of knowledge include historic preservation, journal editing, and participation in state humanities councils. Activities related to *teaching* include student advising, development of course materials, and projects with elementary and secondary schools.

Some observers have noted the irony of asking the very groups that set the current standards for scholarship to lead in reform efforts. But change cannot take place without them, project organizers say.

For more information on the projects, contact the Center for Instructional Development, Syracuse University, 111 Waverly Avenue, Suite 220, Syracuse, New York 13244; (315) 443-4571.

Mr. THORNTON. Thank you, Dr. Denton, for your fine summary of your excellent testimony.

I must recognize that we have once again been called to vote on a measure over in the House of Representatives. I want to make this vote, so I am going to declare a 10 minute recess, at which time I will be back, and we will have an opportunity to explore with some questions.

Thank you. We'll be recessed for ten minutes.

[Recess.]

Mr. THORNTON. The hearing will resume.

I must tell you that we will have another vote or series of votes in a few minutes, so I may have to abbreviate the questioning to some degree.

I was very impressed with all of your analyses of the distinction between research and teaching as being at opposite ends of a balance beam, and considering that the two were a coin—opposite sides of a coin—or connected intricately with each other, and I accept that. I think that teaching and research are part of the process of developing the creative part of a human mind and then sharing that with others.

Still, two elements of the tricameral troika of education — research, teaching, and service—two are generally not considered as much as the research. The research is easily gradable. It's something that you can—and I thought your comments that there were ways to grade the others were important.

But one thing that has troubled me as we talked about teaching and research is that very little attention has been given to service.

I'd like to ask each of you to give me an illustration of some element of service that you have provided in your own career, something quantifiable or appropriate to that function. I heard some examples as I listened, but I'd like to get a specific case from each of you.

Dr. Neal, would you begin.

Dr. NEAL. Yes, Mr. Chairman.

Service, as I'm sure you are quite well aware, is a very broadly defined term, and many departments use it. Many universities use it to refer to national service, all the way down to service in one's own department. I'll just give you two examples at the two extremes of that for me.

I participated in mentoring of graduate students and undergraduate students at our university, meeting with them regularly, dealing with issues that they have, ranging from academic to personal ones. So, that's one extreme of that spectrum.

The other for me was, for example, service on the National Science Board.

Mr. THORNTON. Right, right. Dr. Ward.

Dr. WARD. Yes, I could site a number of examples. Certainly, servicing as Chair of the National Research Council Committee on Biology in Service Education is a really important service activity that I'm directly involved in.

But many of our outreach activities, at least in our university, are classed as service. I think that that's one of the things that we put a large emphasis on and use resources from our Howard

Hughes Grant to develop programs for elementary school teachers, for high school teachers, and so on.

Now, I'm arguing with the university that I want them to change the definition of teaching to where that becomes called teaching. The reason for that is that if you think P&T committees don't pay attention to teaching, you ought to see how little attention they pay to service.

Mr. THORNTON. This is the point that I'm trying to bring up.

Dr. WARD. I think, you know, we all say it's in our mission and, particularly, at the land grant university, it really is in our mission, and that is our task.

Now, we have faculty that—since I span the college of medicine and the college of agriculture, we have faculty in those colleges which have a direct, more mission orientation that certainly are performing service, and are connected to the agriculture extension service, for example.

Mr. THORNTON. Well, of course the agriculture extension service is a text book example of that mission being carried forward.

Dr. WARD. Yes, and I think there are many more opportunities to expand that and, I think, like teaching, it's inhibited by the fact that, in fact, it's not.

It is not recognized and rewarded in a way that it could be. But that's an issue that maybe you might want to take up with a separate hearing.

Mr. THORNTON. Well, in any event, the National Science Foundation's charge is to provide support for both teaching and research.

I'm not sure that the NSF's charge contains a commitment to service. Is my understanding of that correct?

Dr. WARD. I'm sorry that I don't know the answer to that. I think you are, but again—

Mr. THORNTON. I believe that that is in the language of the statute that the NSF, since its formation, dealt with both research and teaching, but not with service.

So, perhaps it's inappropriate to this hearing to be discussing this, and yet, as a former academician, I'm deeply concerned that little emphasis has been given.

Dr. WARD. I think that's an issue that you ought to address.

Mr. THORNTON. Dr. Lohmann.

Dr. LOHMANN. Yes. I'm very proud to say that I recently served at the National Science Foundation as Program Officer in the Division for Undergraduate Science, Mathematics, and Engineering Education.

Without question, it was probably the best two and a half years of my professional career, and indeed of my professorial career.

I would go on to mention, though, that it was a decision to serve that was very difficult to make. It was at a time in my career when I was an associate professor, and I was very concerned about how my colleagues might view such service.

I can tell you with great pride that the leadership at the institution that I was with at that time was very supportive of my going to the National Science Foundation. But with respect to my colleagues, the perspective was quite different.

One of the things that I think we've got to start thinking about in our institutions—and this mirrors off of my colleagues' comments—we've got to start broadening what is the definition of "scholarship" in our institutions.

We've got to stop thinking that if you can't get a grant to do it, get a Ph.D. thesis on it, or write a paper about it, it's not worth doing. Public service falls into that category.

We have some very critical national priorities, like the increased participation from women, minorities, and others who are not traditionally, at the present time, in our programs.

That's not an instructional issue. That's not a research issue. That's a social issue. It's something that we need to start paying more attention to.

Mr. THORNTON. Thank you, Dr. Lohmann.

Dr. Denton.

Dr. DENTON. Yes, thank you.

In terms of more traditional service, I've served in the National Science Foundation Advisory Committee for the Division of Electrical and Communications Systems.

I'm now a member of the National Research Council Board on Engineering Education, which is chaired by Dr. Pister, and on campus, I'm on a variety of college and department committees.

With respect to what Dr. Lohmann was just saying, I'd like to comment on the fact that in this period of trying to bring more women and under-represented groups into the science and engineering enterprise, women and minorities are called on with great frequency to take on responsibilities and engage in activities that our white male counterparts are not asked to do.

I think it is very important to recognize that during this transition period, while we are trying to integrate everyone into the system, it's important to pay attention to that issue, and it's exacerbated by the fact that as we've all said, service doesn't count at all.

So then you have the very people that you're trying to really integrate into the system being left behind because they did participate so much in those service activities, and then received no credit for it.

Mr. THORNTON. Thank you, Dr. Denton.

Dr. Neal, you have cited that numerous projects exist to improve undergraduate education. Could you pick an exemplary case from the University of Michigan and share it with us?

Dr. NEAL. Yes. One example is that the university started its own research experience for the undergraduate program, even before the NSF program was underway. That's a program where one aspect of it was directed to minority students.

Mr. THORNTON. With what effect? Has it begun to show an effect?

Dr. NEAL. Well, it's hard to tell. You have to follow these for many years, but there is the sense that there is nothing more important in undergraduate education than to provide students with an opportunity to work closely with faculty.

So they provided that for our students to work with our faculty in the summer. That's one example of an initiative under way at the university, and there are several others. Many departments are coming forward with their own proposals. Some departments are proposing—

Mr. THORNTON. Is there a way to share these successes across the university?

Dr. NEAL. Across the university? There is a mechanism. The science chairs at the University of Michigan do meet regularly as a group.

When there are activities in one of our departments that seem to be successful, information about that is shared with the other chairs.

Mr. THORNTON. Thank you, Dr. Neal.

Dr. Ward, you mentioned the undergraduate biology research program, which was cited in "Science Magazine" in January of this year. Did you encounter any failures in implementing the program or any lessons learned that might be helpful to other people?

Dr. WARD. Yes. We learned quite a lot of some sort of silly technical details and some were more significant. We started off early on—and we're actually preparing a publication on this.

To our surprise, we have found very few examples in the literature of people who have really developed a program and analyzed it in some detail as to what actually works.

For example, when we started off, we had students start in the middle of the school year. We discovered that didn't work, because undergraduates have a lot of demands on them

Mr. THORNTON. Yes.

Dr. WARD. So now, all students have to start in the summer where they can work full-time.

Mr. THORNTON. Yes.

Dr. WARD. Then, by the time they've worked in a lab ten or twelve weeks during the summer, they then know enough that they actually can continue part-time and do something. That's a small advance.

Again, many of these things are rediscovered wheels. Other people, if we knew who they were and where to find them, we could have gathered some of that information.

Mr. THORNTON. That, again, addresses this question of the dissemination sharing of information.

Dr. WARD. Absolutely. I mean, I'm looking forward to reading these reports.

One of the enormous sources of dissemination in biology is through these Howard Hugh programs, which are now supporting almost 200 programs. When the program directors meet, and they prepare reports you get to find out what other people are doing in the rest of the country.

We've put a lot of investment into multi-media technology in our introductory biology courses and it really increased the number of students enrolled.

Again, by the same mechanism that Dr. Neal has said, when we meet and discuss with the other faculty of science department heads, this undergraduate program, which is now in biology, other people are beginning to develop in other disciplines, and they are using the same tools.

So, as long as the disciplines communicate, I think we need to do that.

Mr. THORNTON. Thank you, Dr. Ward.

Dr. Lohmann, you have co-chaired a colloquium, which produced the report "America's Academic Future". It had a number of specific recommendations regarding the crisis in science education.

How's that been received back in Georgia Tech?

Dr. LOHMANN. So far, I would say it's been received fairly favorably. The president of our institution, Dr. Crecine, is going to distribute a copy of the report with a very positive letter of support to every Georgia Tech faculty member. It's just now reaching, if you will, circulation among the faculty.

As you can well guess, there are those who are enthusiastic supporters, and others who are less enthusiastic supporters. Nonetheless, I'd say on the balance, it's being fairly favorably received.

Mr. THORNTON. Do you know whether the National Science Foundation is taking steps to implement any of these recommendations?

Dr. LOHMANN. I believe, at the present time, that the report is so new that we are at the stage—

Mr. THORNTON. So you can not make that determination right now?

Dr. LOHMANN. No. I can say this, I'm going to be speaking to the National Science Board at one of their upcoming meetings. I think it is in June—I can't remember the exact date—to provide them with a summary of the report.

I'm also going to be speaking to the Education and Human Resource National Advisory Committee within that directorate, also, to again summarize that report.

So, there's clearly opportunities there for the National Science Foundation to begin taking steps.

Mr. THORNTON. Dr. Denton, you made a strong assertion that it was possible to evaluate teaching and that the excuse that you simply can't measure it is not really an appropriate excuse.

Could you expand on that some? How do we go about addressing that question of evaluation of teaching?

Dr. DENTON. Well, as a preface, I would comment that if you look at what the Academy does now carried to an extreme, the evaluation of research can degenerate to a counting exercise—counting research publications and counting dollars.

Given that sort of an approach to assessing quality, one could certainly count numbers of students taught and count or average the teaching evaluations. Obviously, neither of these is acceptable.

Mr. THORNTON. Yes.

Dr. DENTON. So, I think, the preface has to be that it's an overstatement to say that we evaluate research very well—that we assess quality in research very well. But we can't do that in teaching. I think that is really wrong.

So, to go on from there, though, I think it's easy to start listing some ways to really evaluate both of those.

Mr. THORNTON. So there may be problems in evaluating both.

Dr. DENTON. Yes.

Mr. THORNTON. And, of course, Dr. Ward mentioned his difficulty with the per credit hour number of hours taught, and that does strike me as being not the best way of evaluating teaching, just by multiplying the number of classes you have times the average number of students in each class.

Dr. DENTON. Right, and the proper evaluation of both, I believe, is complex.

Mr. THORNTON. Yes.

Dr. DENTON. And, I think that what we've done is, because research is the part of the spectrum that's rewarded financially, we spend more time worrying about evaluating that.

Mr. THORNTON. Dr. Ward, if you can give me just a few quick comments.

Dr. WARD. Can I comment quickly on that issue.

I think we can do it. I agree, very much, with what Denice has said. I think we commonly evaluate research fairly superficially.

But we can collect student evaluations, that's one kind of thing. It's not hard to have your faculty go over the curricula and syllabus of a course to see what the content is. One thing students can't evaluate is content. They have no idea whether what you are teaching them is what you ought to be teaching them.

Mr. THORNTON. Yes.

Dr. WARD. Your faculty can do that. Then you can interview students when they graduate, because one of the problems is, you are educating people, not for what they think when they took your final exam on that day. You care what they thought about your course. Where you really care about it is when they start their career.

Now, that gets really expensive and hard to follow alumni, but at least you can interview your seniors when they graduate and collect their opinion. Well, which courses did you take that really made an impact? Well, I hated that course when I took it. But boy, you know, it turns out, I really learned that biochemistry, and I needed it later on.

Those are the kinds of things which you can do, but it's a lot of work.

Mr. THORNTON. Yes.

Dr. WARD. But it's something we have to do.

Mr. THORNTON. I agree. It's something we have to do

On that note, and under the pressure of having to go to the floor of the House to make another vote, I ask if each of you would agree to respond to such additional questions as the staff may address to you in writing.

Thank you very much for your excellent testimony. I apologize, again, because I'm just getting warmed up. I'd like to continue this dialogue, but rather than have you wait here while I go to the floor, and then return, I will declare that this hearing is adjourned, and thank you.

[Whereupon, at 4:44 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

[The prepared statement of Mr. Costello follows:]

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STATEMENT OF U.S. REPRESENTATIVE JERRY F. COSTELLO (D-IL)
SCIENCE, SPACE, AND TECHNOLOGY SUBCOMMITTEE ON SCIENCE
"QUALITY OF UNDERGRADUATE SCIENCE EDUCATION"
MARCH 31, 1992

MR. CHAIRMAN, THANK YOU FOR CALLING THIS HEARING. I AM PLEASED TO BE HERE AS WE ADDRESS THE PERCEPTION THAT THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION HAS DETERIORATED. I WOULD LIKE TO TAKE THIS OPPORTUNITY TO WELCOME OUR EXPERT PANEL. I AM LOOKING FORWARD TO HEARING THE WITNESSES' TESTIMONY.

MR. CHAIRMAN, OUR NATION HAS LONG ENJOYED AN INTERNATIONAL REPUTATION AS A WORLD LEADER IN SCIENCE. RECENTLY, HOWEVER, WE HAVE BECOME AWARE OF ALARMING STATISTICS WHICH POINT TOWARD A DEFICIENCY IN SCIENCE LITERACY IN OUR COUNTRY. A RECENT REPORT FOUND THAT U.S. STUDENTS IN ELEMENTARY AND SECONDARY SCHOOLS PALE IN COMPARISON WITH THEIR PEERS FROM MANY OTHER NATIONS WHEN TESTED ON THEIR ABILITIES IN MATH AND SCIENCE.

ADDITIONALLY, DURING THE 1980'S THE NUMBER OF UNDERGRADUATE DEGREES IN SCIENCE AND ENGINEERING CONTINUED TO DECLINE. IN LIGHT OF THESE TRENDS, I AM COMPELLED TO WONDER IF THE QUALITY OF UNDERGRADUATE SCIENCE EDUCATION MAY BE A CONTRIBUTING FACTOR.

I HOPE THAT TODAY'S HEARING WILL OPEN DISCUSSION ABOUT HOW TO ENHANCE OUR NATION'S COMMITMENT TO PROVIDING QUALITY SCIENCE EDUCATION TO OUR STUDENTS. I ANTICIPATE FRANK DISCUSSION ABOUT HOW TO STIMULATE CULTURAL CHANGE WITHIN UNIVERSITIES TO BALANCE THE STATUS OF TEACHING WITH RESEARCH TO ENSURE THAT UNDERGRADUATE STUDENTS RECEIVE A QUALITY SCIENCE EDUCATION. I AM ALSO LOOKING FORWARD TO HEARING THE PANEL'S PROPOSED OPTIONS AND RECOMMENDATIONS FOR MOTIVATING UNDERGRADUATE SCIENCE EDUCATION IN COLLEGES AND UNIVERSITIES.

AGAIN, THANK YOU MR. CHAIRMAN FOR CALLING THIS HEARING AND FOR YOUR CONTINUED LEADERSHIP OF THIS SUBCOMMITTEE.

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