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AUTHOR Bell, Jerry A., Ed.; Buccino, Alphonse, Ed.
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ABSTRACT

This report is divided into four main parts. (1) "Overview" summarizes the plenary presentations and discussions that set the agenda for the small group discussions by participants, the focus of which are on the formation of a good teacher--what teachers must know and be able to do, and how collaborative programs based in universities must be designed to prepare them. (2) "Responses for Action" is a synthesis of the small group discussions throughout the forum as well as the final reporting session. (3) "Small Group Reports" is an abbreviated version of the final reporting session and discussion. (4) "Text of Presentations" consists of edited versions of the plenary presentations and discussant responses. Appendices providing references to reports, books, documents, and other resources mentioned in this report, and listings of the forum participants and institutions represented are also included. (CCM)

Seizing Opportunities

Collaborating for Excellence in Teacher Preparation

JERRY A. BELL AND ALPHONSE BUCCINO

RECOMMENDATIONS

- Design and implement strategies addressing the fundamentals of values, rewards, and incentives, along with the rebalance of the university mission to teach, inquire, and serve.
- Place the emphasis on learning rather than teaching. This shift is essential to the reform of teaching and the enhanced effectiveness of teaching. It includes the college teacher's willingness to serve as a model for the prospective school teacher.
- Be sensitive to context. Designing programs for the preparation of science and mathematics teachers is important in itself, but it is embedded in movements for reform in many parts of the educational system.
- There are significant curriculum issues associated with the reform of undergraduate education and the teacher preparation programs, but curriculum issues should not be confused with issues of teaching and learning.
- Define and develop standards for the scholarship of teaching. Implementation of these standards is essential for rebalancing the mission that the movement for higher education reform is endeavoring to effect.
- Build collaborations based on strengths and mutual benefits. Collaborations within the university (especially between the college of education and the college of science), among the university, schools, and community, and across institutions are necessary, but involve sensitivities that must be understood and accounted for.
- Have a sense of role and the distribution of responsibilities. Faculty design academic programs; deans facilitate. Teacher education and undergraduate education, moreover, are institutional responsibilities and must involve provosts and presidents in their re-design.
- Use all available leverage for reform. Fresh resources are always desirable, but their absence is no reason to be discouraged. Employ all institutional incentives creatively and, for ideas and information, examine other projects such as NSF Education and Human Resources projects and programs at other institutions that were discussed at the forum.
- Develop a resource of expertise and expert assistance on best practice which institutions seeking to rebalance their mission could call upon to help faculty and administration to recognize that teaching is subject to analysis, to understand the results of research on teaching and learning, and to apply them in the local context.

Seizing Opportunities

Collaborating *for* Excellence *in* Teacher Preparation

EDITED BY JERRY A. BELL AND ALPHONSE BUCCINO

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AAAS
Education and Human Resources Directorate
1200 New York Avenue, NW
Washington, DC 20005-3290
(202) 326-6670
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Preface

The teacher is the single most important factor affecting student learning at all classroom levels. (See *What Matters Most: Teaching for America's Future*, the 1996 report from the National Commission on Teaching & America's Future.)

Teacher effectiveness can be judged by what students have understood and are able to do with their understanding when they leave the classroom. All future teachers gain their knowledge of content in colleges and universities. The vast majority also begin there the acquisition of pedagogical content knowledge, both through course work and by observation of their teachers (virtually the only source of such knowledge for future college teachers). Elementary and secondary teachers later hone, reinforce, and deepen their pedagogical content knowledge by classroom experience. Thus, if the changes in the teaching of science, mathematics, and technology advocated by the American Association for the Advancement of Science (AAAS), the National Academy of Sciences, the National Science Teachers Association, the National Council of Teachers of Mathematics, and the National Science Foundation are to be realized, colleges and universities must prepare teachers to teach differently and provide continuing professional development.

The need to restructure programs for teacher preparation was the reason for the forum, "Seizing Opportunities: Collaborating for Excellence in Teacher Preparation." The underlying assumption for restructuring is that no isolated department, school, or institution can provide the breadth of preparation science and mathematics teachers need; a variety of players must collaborate. These include departments and schools in such fields as natural and social sciences, mathematics, and engineering, departments and schools of education, school systems, and community organizations, including business and industry, science and technology centers, and parent groups that encourage and support innovative and effective teaching. Strong collaborations potentially have the staying power necessary to nurture and sustain the long-term systemic changes envisioned by science education reformers.

College and university faculty should be contributors to a forum like this one. Since there are so many faculty who would be involved, even from a small selection of universities, it seemed reasonable to begin the conversation with deans of science and of education, each of whom represents a large number of the relevant faculty. Deans generally understand and reflect the concerns of faculty with regard to new programs and are also attuned to institutional priorities and resources that provide opportunities for and will affect a revamped teacher preparation program. Long-term university collaborations with schools and the community, moreover, necessarily involve administration as well as faculty. Therefore, for both pragmatic and programmatic reasons, the participants in this forum on teacher preparation were teams of deans of science and of education from each university represented. We expect that follow-up from the forum will involve faculty, administrators, and many others in activities designed to prepare excellent science and mathematics teachers for the nation's schools.

Jerry A. Bell
Program Director
Science, Mathematics, and Technology Education Programs
Education and Human Resources Directorate
American Association for the Advancement of Science
eMail: *jbell@aaas.org*

Acknowledgments

Support from the National Science Foundation (NSF), Division of Undergraduate Education, Directorate for Education and Human Resources was essential to the success of this forum. From NSF came not only financial support (Grant DUE 96-22600), but the participation of several Program Officers and other staff (Appendix B) in the forum planning and implementation. This report, however, reflects the views of the participating deans and invited presenters, not necessarily the NSF. As both a mathematics educator and a dean, Alphonse Buccino lent his experience and expertise to the development, implementation, and reporting of the forum. Many of the participating deans were drafted to serve as facilitators and recorders for the small group discussions, accepted these roles with good humor, and carried them out superbly. Several deans, identified in Appendix B, served on an *ad hoc* program development advisory group for the forum. The facilitators, discussants, and plenary presenters provided timely responses to requests for input and emendations to the edited transcripts and thematic syntheses. Shirley Malcom, Director, Education and Human Resources Directorate, AAAS (AAAS-EHR) and moderator for the final reporting-out session, drew out from the reporters and discussants generalizations and recognition of the many connections among the various agencies, institutions, and other parts of the educational system in which teacher preparation is embedded. As copy editor, Tom West, The Catholic University of America, smoothed and improved the clarity of the manuscript. AAAS-EHR staff Virginia Van Horne, Jane Privé, Elizabeth Spring, and Tracy Gath did the final editing, formatting, and production of this report. Finally, Mary Beth Lennon, AAAS-EHR Project Director for the forum, played the central role in developing the request for support from NSF, constructing the forum program and gathering the participants and presenters, taking care of the myriad arrangements and details that made the participants comfortable and the forum run without problems, and gathering all the pieces for this report.

Introduction

One hundred and two deans, the dean of education and the dean of science from each of fifty-one institutions, convened on 10-12 March 1996, in Crystal City, Virginia to participate in the forum, "Seizing Opportunities: Collaborating for Excellence in Teacher Preparation." The forum was organized by the AAAS and supported by the Collaboratives for Excellence in Teacher Preparation (CETP) program in the Division of Undergraduate Education (DUE) of the National Science Foundation.

The topic of the forum was preparing science and mathematics teachers. The structure of the forum was to introduce a theme related to teacher preparation in a plenary session with a keynote address, a panel of discussants, and brief general discussion and follow up with a longer time for discussions in five small groups that retained the same participants and facilitator throughout the forum.

The objective of the first session, "What Is a Good Teacher?" was to define the attitudes, aptitudes, and skills that should result from the preparation of science and mathematics teachers. The theme of the second forum session, "Teacher Knowledge: A Principal Arena for Collaboration in Teacher Preparation," addressed the kinds of intra-institutional collaborations necessary for parallel and reinforcing development of subject and pedagogical content knowledge. The third session, "University, School, and Community Collaboration," expanded the discussion to consider collaborations outside the institutions of higher education, collaborations that will provide a practical base for prospective teachers and, in turn, help create a system that will support new initiatives and provide excellent opportunities for all students to learn science and mathematics. Extending this theme, the luncheon address introduced the *National Science Education Standards* developed by the National Research Council and published by the National Academy of Sciences. This gave the deans further insight into the K-12 science education reforms that are underway.

The forum's fourth session, "Lessons from Current Collaborative Teacher Preparation Efforts," provided the participants reports from three of the projects supported by the NSF-CETP program. These accounts of the strengths and weaknesses informed the succeeding small group discussions, bringing together and sharpening previous ideas on seizing opportunities (and barriers to doing so) as well as some discussion of the most appropriate forms of external programmatic support; for example, from the NSF-CETP program or a modified form. The final plenary session of the forum consisted of reporting out and subsequently discussing the major themes developed from the small groups.

This report from the forum has four main parts. The Overview summarizes the plenary presentations and discussions designed to set the agenda for the small group discussions by the participants. The focus is on the formation of a good teacher — what teachers must know and be able to do, and how collaborative programs based in universities must be designed to prepare them. Responses for Action is a synthesis of the small group discussions throughout the forum as well as the final reporting session. Small Group Reports is an abbreviated version of the final reporting session and discussion and Text of Presentations consists of edited versions of plenary presentations and discussant responses . There are also Appendices providing references to reports, books, documents, and other resources mentioned in this report and listing the forum participants and institutions represented.

The forum was the third event in a series of meetings on teacher preparation supported by NSF-DUE. The first was a workshop (November 1992) reported as *The Role of Faculty from the Science Disciplines in the Undergraduate Preparation of Future Science and Mathematics Teachers*

[National Science Foundation]. The second workshop (November 1994) was reported as *Science, Mathematics, and Technology Preparation of Future Teachers* [National Institute for Science Education].

This report (and the others) will be of no value if they are simply read and put on your shelf. The main title, *Seizing Opportunities*, is action-oriented. Throughout the text you will find ideas for actions others are taking to enhance undergraduate learning and the preparation of science and mathematics teachers; one or more of them can surely be adapted to your institution. Seize the opportunity to do so. And, as another form of collaboration, please let us know what you have done and what the results have been, so we might let others know as well.

Overview

What is a Good Teacher?

Keynote: *Charles W. (Andy) Anderson*, Professor, Department of Teacher Education, Michigan State University

Discussants: *Rachel Wood*, Secondary Science Teacher on assignment with the Delaware Department of Public Instruction
William Badders, Science Resource Teacher, Cleveland Public Schools
Susan A. Henry, Dean, Mellon College of Science, Carnegie Mellon University

Focus on Outcomes: Student Understanding

Anderson's keynote appropriately turned the emphasis of the forum discussions from inputs, good teachers and good teaching, to outputs, student learning and understanding, and there the emphasis remained throughout the forum. His main point is that monitoring students' conceptual understandings so that teaching can be adjusted to help them achieve those understandings is an essential element of teaching. He used case studies to exemplify his point. Among a number of second semester students who had been "taught" the molecular model of matter and chemical bonding, fewer than twenty percent could draw something that approximated the way chemists picture hydrogen bonding among three water molecules or that illustrated a sample of polluted air. But when asked questions about a passage, "The Montillation of Traxoline" (which appears to describe the processing of one substance to yield another, but is totally without meaning or substance), students could produce formally correct answers to questions of what, where, how, and even why. That, Anderson observed, demonstrates that students can have procedural knowledge (e.g., how to apply an algorithm) without conceptual knowledge.

Monitoring students' conceptual understandings so that teaching can be adjusted to help them achieve those understandings is an essential element of teaching.

Scholarship of Teaching

Anderson defined goals for student learning, teaching strategies and materials, and assessment of student understanding as the three elements of a dynamic system of "diagnosis and treatment" among which professional teachers at all levels work. To raise the process to a level that can be called the *scholarship* of teaching, requires the addition of underlying *tools* and *principles* for each of the three. As in the rest of scholarship, interaction with and review by peers who are trying to do similar work in other places are also

The scholarship of teaching, requires interaction with and review by peers who are trying to do similar work in other places.

needed. Important resources to help develop the tools and principles are the AAAS Project 2061 publications *Science for All Americans* [AAAS], which addresses goals for student learning, and *Benchmarks for Science Literacy* [AAAS], which lays out steps and milestones for reaching these goals, the National Council of Teachers of Mathematics *Standards* [NCTM] for Curriculum, Teaching, and Assessment, and *National Science Education Standards* [National Academy of Sciences].

Some faculty view alternatives that concentrate on alleviating student conceptual misunderstanding as a threat to rigorous standards.

In goals for student learning, the important issue is to formulate them in a way that clarifies what it means for the students to *understand* what is expected, as opposed to memorizing by rote in order to get through the test. The resources Anderson listed, which are aimed at the elementary and secondary levels, approach the goals in this way and can be taken as models for college instruction as well as for what teachers need to be prepared to do.

For example, Bybee pointed out in his presentation that the content standards in the *National Science Education Standards* address the questions: What should the scientifically literate person know, understand, and be able to do after thirteen years of school science? The core subjects contain more specific statements: As a result of their activities in grades 9–12, all students should develop understanding of the cell. "Should develop understanding of" is significant; the words "know" or "knowledge" are purposely avoided. The level of understanding is not addressed; teachers, the professionals in the field, have to make decisions about how they interpret that and what the level is in their context. It is a way of recognizing, for example, that not all students in introductory biology are going to be molecular geneticists.

Some tools and principles related to teaching strategies and materials are also embodied in the *Standards*. Understanding is to be based on activities, not only on reading or teaching. Anderson described discourse between teacher and students and among students as an important form of assessment. Even in large lecture classes, there are ways to promote discourse that enhances student understanding and provides the teacher with a continuous means of deciding whether the teaching strategy needs modification.

Barriers to Change

Budget constraints and competing demands, Anderson warned, comprise formidable difficulties to implementing a program for improved teaching and the scholarship of teaching. Other barriers include a reward system that values faculty identification with disciplinary communities rather than with teaching, and the quickness of faculty to blame the students. Some faculty view alternatives that concentrate on alleviating student conceptual misunderstanding as a threat to rigorous standards, coddling with "soft and mushy stuff," that will replace the "hard stuff," like the results from multiple choice achievement tests.

But drawing on data samples, Anderson argued that while some might interpret student attitudes toward science as evidence of laziness, they are really evidence of *alienation*. In particular, scientists and prospective elementary school teachers are alienated from each other and end up tacitly agreeing to do this "traxoline-like stuff" that allows one side to pretend to teach and the other to pretend to learn. Thus faculty and students each fulfill their requirements as quickly as possible with no productive interaction that could potentially enhance learning and teaching for both.

Recommendations

Anderson concluded with the observation that while quite a bit is now known about how to improve science teaching and learning, effort is required to translate this knowledge into action. His principal recommendations challenge administrators to strengthen value and reward systems that support good performance and scholarly work in teaching, bolstered by programs that provide access to new teaching methods, materials, and technologies and incentives for worthwhile educational research and develop scholarship of teaching communities within and across institutions that include colloquia, seminars, and discussions for faculty and graduate students, time or work-load credit for discussion, debate, empirical work, and contact and communication with those who are teaching similar courses in other places, and opportunities to share work and ideas through publication and travel.

[Administrators were challenged] to strengthen value and reward systems that support good performance and scholarly work in teaching and develop scholarship of teaching communities within and across institutions.

Discussion

Both Badders and Wood spoke of their personal experiences and professional development as teachers and leaders in science education. Their narratives underscored the significance of a *community* for teaching and learning. Crucial to the professional development of both were professional efforts outside of the work in their schools. Wood extended the concept of community to include faculty in education who provide the pedagogical content portion of teacher preparation, interaction through planning and policy with other teachers and school administrators in system- and state-level science education endeavors, as well as local school effort, and involvement with business and industry leaders in science and mathematics education matters of mutual interest.

A context is required for [elementary and secondary] teacher professionalism to develop, a context that includes significant professional activity in a larger community that involves colleges and universities.

Badders argued forcefully for NSF teacher institutes as a force in building the kinds of communities that he agrees are needed. He suggested that relatively modest resources can empower teacher initiatives in developing communities. Wood and Badders proposed in effect that a context is required for teacher professionalism to develop, a context that includes external influences on the individual and significant professional activity in a larger community that involves colleges and universities.

Henry reiterated the importance of developing a collegial environment and partnerships for science education that span all levels, elementary through graduate school. The concept of a community for learning applies in her interpretation to all institutions, including those that may not have formal programs for the education of teachers. These institutions have, for a number of reasons, a vested interest in becoming part of the discussion about teaching and the issues this forum is addressing. At the very least, they need to know what background their entering students have.

Henry endorsed Anderson's analysis of university science faculty attitudes and values. Administrators are much concerned about high attrition rates in mathematics and science courses, especially because they affect an institution's position in rankings of higher education institutions and programs. Faculty, as Henry perceives them, tend to see attrition problems as belonging to someone else, for example, the admissions office, for not bringing in better students who would reduce failure rates, even though the failure rate of any given class is more accurately predicted by who is teaching the class.

[A]ssessment should not only determine the grade a student receives, but also gauge what the student has learned and thereby estimate how effective the teaching has been.

She also made the point that college and university faculty must begin to understand that assessment should not only determine the grade a student receives, but also gauge what the student has learned and thereby estimate how effective the teaching has been. She judged the problem to be much worse at the college and university level than in elementary and secondary schools because it has not yet even been recognized as a problem.

Teacher Knowledge: A Principal Arena for Collaboration in Teacher Preparation

Keynote: *Jerome D. Odom*, Dean, College of Science and Mathematics, University of South Carolina, Columbia

Discussants: *Jo Ellen Roseman*, Curriculum Director, Project 2061, AAAS
Frank B. Murray, Professor, College of Education, University of Delaware

Promoting Collaboration

This session was to establish the framework for discussion of issues of collaboration within a college or university, especially among faculty members from the school or college of education and the school or college of science. Odom described a new program at his institution, the Masters in Teaching program. It is a five-year program the successful completion of which results in two degrees: a B.S. degree in a major in the arts and sciences college and a master's degree in a professional education program. Development involved collaboration between education and science faculty. Although the extent of the collaboration among these faculties is relatively small to date, Odom hopes that the new program will provide a framework for greater collaboration in the future.

Odom presented seven suggestions for collaboration:

- undergraduate research, a means of providing prospective teachers experience in the process of inquiry,
- appointment of science education researchers to science departments,
- joint appointments between colleges,
- departments of science education in the college of arts and sciences,
- team teaching,

- in-service education for science teachers, and
- making primary and secondary schools an essential third partner to the collaboration between the college of education and the college of arts and sciences.

A suggestion for collaboration: undergraduate research [as] a means of providing prospective teachers experience in the process of inquiry.

Barriers

Odom identified three barriers to collaboration for improving the preparation of teachers:

- "war-weary" faculty who, within the last few years, have experienced increasing demands while the capacity to address them has been reduced,
- the value system that, in research universities, clearly favors research over teaching, and
- resource limitations that reduce or eliminate additional funds for new, exciting, and challenging things. Although internal reallocation is possible, it is difficult and unpopular.

Discussion

Demonstrating misconceptions among students about basic science, Roseman presented video segments from the *Private Universe* project that depict graduates receiving baccalaureates from prestigious universities giving astonishingly incorrect accounts of the cause of the seasons and the origin of the mass of material that makes up a tree. She also identified tools, especially some being produced by Project 2061, for advancing science literacy and science teaching at the college and university level.

Frank Murray described the Project 30 Alliance as aimed at collaboration between education and arts and science. He briefly described the four basic issues that the Alliance is addressing:

- making provision for general or liberal study in teacher education programs; this is material the students probably will not teach directly, but provides the basis in values and shared culture that will underpin their approach to subject matter and teaching,
- preparing students in the subject they will be teaching,
- preparing students with appropriate pedagogical content knowledge and stressing the interplay between pedagogy and subject content, and
- preparing a more diverse student body and students more aware of the benefits of diversity.

University, School, and Community Collaboration

Keynote: *Rodney Reed*, Dean, College of Education, Pennsylvania State University

Discussants: *Dennis Sorge*, Director, Academic Services and Coordinator, Mathematics Outreach, School of Science, Purdue University

Leonard Solo, Principal, Graham & Parks Alternative Public School, Cambridge, MA

Linda L. Slakey, Dean, College of Natural Sciences and Mathematics, University of Massachusetts, Amherst

The Context for Collaboration

Once upon a time, collaboration between schools and universities was a simple matter. Teacher education programs traditionally required student teaching (also called field experience or internship) for final credentialling and the collaboration required only developing agreements between school sites and university teacher education programs. Now, however, such relationships are being approached in a new way. One central concern is that teachers being educated in the climate of reform ought to experience the field component of their preparation in an appropriate setting. It does not make sense to place reform-minded student teachers in schools that are considered regressive or, worse, failures. Set in this context, Reed presented stimulating ideas and current thinking about collaboration between university, school, and community.

> *Teachers being educated in the climate of reform ought to experience the field component of their preparation in an appropriate setting [not] in schools that are considered regressive or, worse, failures.*

He began with a discussion of society on the eve of the new millennium: changing demographics — the near future age, racial, and ethnic distributions in the population; poverty, especially youth poverty; hazards such as AIDS, now the number one killer of young adults, and the correlation between high school drop-out rates and incarceration. He related these conditions to the kind of educational reform they necessitate. Turning to the National Education Goals (now numbering eight), Reed argued that they imply rethinking of teaching and learning. He also discussed issues of collaboration in the past, the lessons learned, and their applicability today to various kinds of collaboration, including academic alliances and other educational linkages.

Professional Development Schools

A special instance of the collaboration Reed considered is the Professional Development Schools (PDSs) that were advocated initially by the Holmes Group and the Carnegie Forum on Education and the Economy. Probably the closest precursor of the PDS is the university laboratory school, developed in the late nineteenth century. Typically, these laboratory schools served a select group of students, many of whom were children of university faculty members. As conceived by the Holmes Group, the PDS is not just a laboratory school for university research, or a demonstration school, or a clinical setting for preparing student and intern teachers. It is all of these together: a school for the development of novice professionals, for continuing development of experienced professionals, and for research into the teaching profession along with initiatives for its improvement.

Reed discussed the principles of the PDS and some of the problems involved in trying to establish one, including the thorny issues of dedicated funding to cover such costs as release time for the school teachers and university faculty associated with them. He argued that education reform in general and the PDS concept in particular present significant challenges for the university culture. One is to modify the value system that favors research. Reed cited Ernest Boyer's *Scholarship Reconsidered*, which gives explicit weighting to four overlapping categories of scholarship: discovery, integration, application, and teaching.

Discussion

Sorge spoke of the lessons learned from his outreach program. It is impressive in employing six people as outreach coordinators around the state of Indiana in addition to utilizing Purdue science faculty in various activities. Eighty-five percent of its effort goes to teacher enhancement; the remainder is for demonstrations and efforts at motivating students. The program actively engages school superintendents and business and industry. It is budgeted currently at about $800K annually and has expended about $2.5M over the five years it has been in operation. One indicator of its success is that demand for service is outstripping capacity and additional personnel resources are needed.

A Professional Development School [is] a school for the development of novice professionals, for continuing development of experienced professionals, and for research into the teaching profession along with initiatives for its improvement.

Solo, principal of an award-winning school and member of the Board of the Harvard Principals' Center, began his remarks with the provocative statement, "In twenty-five years of running K–8 schools, I have never hired a teacher new out of college, because they do not know enough." But he has entered now into a Professional Development School arrangement with MIT and University of Massachusetts-Boston in conjunction with an NSF-funded collaborative of five colleges and universities, four high schools, and five elementary or middle schools. He said this is an opportunity to address the problems he has had in the past with newly prepared teachers. Solo described some of the programs and activities in which his school is participating and outlined features of the school that many other schools are reforming towards: conditions that convince students that school and learning are important; more substantial parental involvement, including shared decision-making; a staff that is committed, cooperative, constantly alive to their own learning, and dedicated to seeing that each child is learning well.

Slakey began by describing one of the oldest higher education collaboratives in the country, the Five Colleges: University of Massachusetts, Smith, Mt. Holyoke, Amherst, and Hampshire. A funded office manages the Five-Colleges cooperation and for some years there has been a Five-Colleges cooperative with the local schools. She considered it quite useful that the university reviews annually the individual activities it has with the K–12 sector in the state. At last count, most come from the College of Education, but twenty-five percent of the activities have involved the College of Natural Science and Mathematics. Funding is an important issue in successful and highly significant programs. The science enrichment programs for students from disadvantaged schools is a case in point. Complicating the issue of finding funds for educational projects and compounding the difficulty for faculty is the pressure on them to obtain research funding.

In spite of the constraints, Slakey said there are some things a dean can do. One is to give moral support to innovation and commitment to teaching — and that is not trivial. Working with the personnel committee to recognize teaching excellence in the promotion and tenure process is another. A dean can keep the question on the agenda by continuing to ask whether we are rewarding people for innovation in teaching, and paying attention to the quality of the education provided. While resource constraints present a limitation, they have also stimulated creativity at the University of Massachusetts in dealing with large introductory courses through an initiative in computer-based instructional technology.

A dean can keep the question [of commitment to teaching] on the agenda by continuing to ask whether we are rewarding people for innovation in teaching, and paying attention to the quality of the education provided.

The University of Massachusetts has recently acquired Research I status, but Slakey said that a sense of the fragility of the enterprise is very strong. In the present competition for ever more limited funds, it is simply not going to be possible for all of the faculty, at Massachusetts and elsewhere, to continue to stay funded in the way that they have been in the past. At the very least, people are going to seek funding for collaborative work and reduce the emphasis on the individual high-profile success. Slakey said that collaboration is going to allow a gentle and graceful return to differentiation in departments between people who focus on teaching and its associated scholarship and others who are expected to be highly visible and highly funded in traditional research.

Lessons from Current Collaborative Teacher Preparation Efforts

Presider: ***Barbara Burch***, Dean, School of Education and Human Development, California State University-Fresno and President, American Association of Colleges for Teacher Education

Presenters: ***Genevieve Knight***, Professor, Mathematics Department, Coppin State College, Maryland Collaborative for Teacher Preparation

Fredrick Stein, Director, Center for Science, Mathematics, and Technology Education, Colorado State University and Principal Investigator, Rocky Mountain Teacher Education Collaborative

John Bristol, Dean of Science, University of Texas at El Paso and Co-Principal Investigator, El Paso CETP

Arturo Pacheco, Dean, College of Education, University of Texas at El Paso and Co-Principal Investigator, El Paso CETP

Burch presided over a panel presentation of what can be learned from three projects funded by the NSF-CETP program, the sponsor of this forum. The projects were chosen as models of what had been done, what had been learned, and what challenges posed and met (or not met) could be applicable to the opportunities each forum participant faces on her or his campus. These are multi-faceted projects that could be outlined only very generally in the presentations synopsized here. Readers who wish to learn more about a particular project should contact the presenter(s) directly.

Maryland Collaborative for Teacher Preparation (MCTP)

Knight introduced the MCTP, a state-wide project for which she said Maryland was ready. The Chancellor of the state system of four-year colleges and universities had initiated a K–16 initiative intended to promote collaboration between higher education and elementary and secondary education. A commission was established that charged all of the colleges and universities in the state system to improve undergraduate mathematics and science education for all students. This stimulated a great deal of activity in the state and led to development of a proposal to the NSF-CETP program. The partners include classroom teachers, research and teaching faculty from community colleges, colleges and universities, the Maryland State Department of Education, and school districts, as well as museums, zoos, and other community resources.

The elements the MCTP considers in restructuring or redesigning teacher education, Knight reported, are active learning, alternative assessment, use of technology, a conceptual framework for learning, internship and field experiences, and induction to teaching. The project has taken a constructivist approach to learning and teaching that also models the MCTP vision. Prospective teachers have to prepare for a performance-based assessment system using technology. They have to learn that *less is more*, that thorough examination of a few topics is better than a quick glance at many. Another important component of the project addresses the matter of attracting students. Maryland has very few high school magnet schools for teaching. Scholarships funded by the project have been especially important for minority students who have the ability to become teachers, but not the means.

The elements the MCTP considers in restructuring teacher education are active learning, alternative assessment, use of technology, a conceptual framework for learning, internship and field experiences, and induction to teaching.

Knight remarked that, because the project is state-wide, technology plays an important practical role in the MCTP. Communication is by interactive television and e-mail. All of the teaching colleagues from the public school systems have some e-mail connection and lessons and evaluations are presented through this network. What will happen after five years when NSF funding is gone? What will remain of this project? Knight expresssed her optimism for continuation, but no specific plans were presented.

Rocky Mountain Teacher Education Collaborative (RMTEC)

Stein defined the RMTEC, a consortium of institutions led by Colorado State University (CSU) and Metropolitan State College of Denver, which, in turn, are developing partnerships with community colleges and school districts to share the content and pedagogical outreach across the state. The project centers on secondary school teachers, although pre-service elementary teachers at Metropolitan and the University of Northern Colorado, benefit from the revised courses that have been developed.

The RMTEC is administered from the Center for Science, Mathematics, and Technology Education at CSU. This outreach center was created in 1991 with budget contributions from the Deans of Natural Science and of Education. This has been the core of collaboration between the school of education and schools of arts and science.

The focus of the [RMTEC] program is the revision of courses. Various things are being done to revise large sections in regular courses for majors and in some cases to combine lecture and laboratory.

The focus of the program is the revision of courses. Various things are being done to revise large sections in regular courses for majors and in some cases to combine lecture and laboratory. Several challenges have been encountered. Especially difficult were dealing with three different offices for sponsored programs and talking with department heads regarding faculty release time and revisions of course descriptions in catalogs. But Stein said the project is operating well, there are good communications supported by e-mail, and participants are optimistic about meeting their goals.

Partnership for Excellence in Teacher Education (PETE)

Pacheco and Bristol shared in describing PETE, the collaborative project in El Paso, which, in contrast with the others, involves a relatively closed system. The collaborative partners are the University of Texas at El Paso (UTEP), El Paso Community College, and the El Paso public schools. There are no other large institutions in that part of Texas within a couple of hundred miles and no other large urban centers until you get to Albuquerque to the north or Tucson to the west. All the students and all the teachers come from and are educated in the system.

Other UTEP grant support from NSF comes from the Urban Systemic Initiative and a Collaborative for Academic Excellence. The combination provides enough energy and funds to overcome difficulties in getting science and mathematics faculty to participate. The project aims to recruit the best and brightest into science teaching, revise and enhance curricula, and support a two-year induction process for new teachers.

One of the biggest efforts of the [PETE] project has been to try to change the university culture to encourage science faculty involved in the education of teachers to be more receptive to enhancing their own teaching skills.

One of the biggest efforts of the project has been to try to change the university culture to encourage science faculty involved in the education of teachers to be more receptive to enhancing their own teaching skills. The university has helped the project to this end by the university using its own funds to hire a mathematics, a physics, and a life science educator who are faculty in the mathematics and science departments. How they fare at UTEP depends on the other faculty of those departments. Pacheco believes that underway in El Paso are deep structural changes that are not going to disappear when the grants are spent, but this remains to be seen.

The National Science Education Standards

Presenter: *Rodger Bybee*, Director, Center for Science, Mathematics, and Engineering Education, National Research Council

Science Education Reform: Staying the Course

Bybee gave an overview of the *National Science Education Standards* [National Academy of Sciences] and noted that they include standards for teaching, professional development, assessment, content, program, and the system. His emphasis was on the content standards, but he did provide comments on the others. He said the overall task of reforming and improving science education is to gain a consensus on the general direction we need to take, establish a steady course, look in one direction, and stay with that direction for a period of time. Standards documents published by the National Council of Teachers of Mathematics that aim at establishing a steady course for mathematics education were received so well at the time of their publication that they became the model and incentive for developing standards in all the fields mentioned in the National Education Goals that emerged from the 1989 Conference of Governors.

The overall task of reforming and improving science education is to gain a consensus on the general direction we need to take, establish a steady course, look in one direction, and stay with that direction for a period of time.

Three documents aim at establishing a steady course for science education, the *National Science Education Standards*, and AAAS Project 2061's *Science for All Americans* and *Benchmarks for Science Literacy*. The differences between the *Benchmarks* and the *Standards* for content are insignificant, so there is, in fact, a single direction defined by these documents that the nation needs to stay with for some time. Bybee said that the immediate task is to explain to the public why that direction is best for the nation. The explanation can vary. If you are talking to Congress, your explanation has to address issues of economic benefit and global competitiveness. Congress probably also wants to hear about how the *Standards* address equity issues. The *Standards* address both.

Standard for Scientific Inquiry

Bybee's summary of the first part of the content standards, what students should know, was presented earlier in the opening section on teaching and learning (page 10). The second part of the content standards, on what students should be able to *do*, is addressed through *scientific inquiry:* what students should understand about inquiry and what abilities of inquiry they should develop. Bybee provided examples to show the kinds of abilities associated with formulating and revising alternative explanations and models by use of logic and evidence, recognizing and analyzing alternative explanations and models, and communicating and defending a scientific argument.

The *Standards* endeavor to raise the level of inquiry above the idea of process as it was developed in the 1960s and 1970s, to go beyond simply having students classify, infer, observe, form a hypothesis, and so on. The *Standards* seek critical thinking; students should be able to use evidence to form explanation and make the association between the evidence, the explanation, and the logic of a position.

Standards Beyond Content

Bybee emphasized that the standards for teaching and for professional development, which were distributed to the participants in preparation for the forum, clearly call for change on the part of teachers which we hope teacher preparation programs will address. Standards for program, he observed, are directed at classrooms and are intended to help school districts present a more consistent and coherent school science program across all grades. Standards for the system apply to the kind of environment and support principals and teachers need for hands-on science or to teach by inquiry.

What students should be able to do, *is addressed through* scientific inquiry: *formulating and revising alternative explanations and models by use of logic and evidence, recognizing and analyzing alternative explanations and models, and communicating and defending a scientific argument.*

Bybee described the purpose of the National Research Council's new Center for Science, Mathematics, and Engineering Education to support disseminating and implementing the *Standards*. For example, the Center is working with the Council of Chief State School Officers to help states revise or change teacher licensing and credentialling. Bybee is trying to find ways to work with 15,000 school districts, 100,000 schools. The Center is collaborating with the National Science Teachers Association (NSTA) on a project that aims to place copies of the *Standards* in every school in the nation and to have an NSTA member in each school organize a faculty meeting or seminar to acquaint all the teachers with them. An introduction to the *Standards* and practice in using them should also be an important part of every college and university teacher preparation program in the country.

Responses for Action

This chapter is a summary and synthesis of discussions by the forum participants. It is taken mainly from the reporting session that was the concluding forum event, the edited version of which is included in the Small Group Reports chapter of this report for additional detail. This summary and synthesis also reflects discussions that occurred throughout the forum. It is organized by theme rather than chronology or group.

An Emerging Movement: Rebalancing the Mission

It is noteworthy that the forum participants were looking beyond concern for their own institutions. Implicitly and explicitly, the forum discussions were defining a *movement* for the reform of higher education. After fifty years of growth, accomplishment, and success unprecedented anywhere in the world, American higher education needs to rebalance its mission comprised of teaching, research, and public service. The participants have sensed that a major shift is beginning to affect higher education, and they welcomed the opportunity to engage in a forum that reflected upon it.

The forum discussions were defining a movement *for the reform of higher education. American higher education needs to rebalance its mission comprised of teaching, research, and public service.*

The role of the dean in the reform movement was acknowledged as significant, but limited in various ways. Faculty are responsible for program design; deans can facilitate and support their efforts. At the university level, provosts and presidents have a substantial role, as well. And the university has a tradition of shared authority, with faculty as enablers as well as implementers of reform. Reform must engage the commitment of all the players.

In science and mathematics, the need is to improve learning and teaching in order to reduce student attrition in these subjects and insure that undergraduate science and mathematics study at the introductory level should be "a pump, not a filter": should encourage further exploration, not discourage it. The reform movement in elementary and secondary science and mathematics education, reinforced by the recent publication of the *National Science Education Standards* [National Academy of Sciences] which joins the earlier National Council of Teachers of Mathematics' *Standards* for curriculum, teaching, and assessment, and AAAS Project 2061's *Science for All Americans* and *Benchmarks for Science Literacy*, creates consequences for higher education in general. Reform of K–12 teacher preparation programs can lead to change in undergraduate and graduate education.

Learning and Teaching

A change of perspective from teaching (teacher inputs) to learning (student outcomes) represented a significant transformation for the forum participants. The discussion of student *understanding* of science, as expressed by keynoters and in all the K–12 standards documents, signaled the consensus that the current discussion of teaching is deeper than routine and perennial discussions have been. There is recognition that students coming out of courses they have passed fail to understand what they have just been "taught."

Participants agreed that many faculty, confronted with the issue of faulty learning, shift to discussing the difficulties of curricula that demand brief exposure to many topics. Or they blame the students for being lazy or dull. If the admissions office would do a better job of recruiting a higher grade of student, they argue, problems of attrition and lack of understanding would disappear. Forum participants themselves put some of the blame on the students. Some students, they observed, are narrow in their expectations and willingness to participate in learning. Some prefer clear-cut rote learning to any method that makes them responsible for their learning. In the shift from passive reception to active learning, student attitudes and expectations must be part of the change. Participants agreed that, if the concentration is now on learning, a learning compact between teacher and student needs to be forged that supersedes the current preoccupation with credentialing.

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There was discussion of the evidence that one teaches as one is taught. Science faculty have had little inclination or incentive to practice the kind of teaching expected of their students who are prospective teachers and this lack should be a subject for reform. Introductory undergraduate courses, especially, should be reexamined in the light of the *Standards* and *Benchmarks*.

Scholarship of Teaching

How to define and implement the scholarship of teaching was an issue of special interest. Boyer's *Scholarship Reconsidered* gave impetus to the discussion, which addressed criteria for the scholarship of teaching and how these should be incorporated into reward systems and guidelines for appointment, promotion, and tenure. A common conviction was that faculty will have to be reoriented to what for many might be new and unfamiliar territory. Already used at some institutions are campus teaching academies and portfolios that document teaching.

Preparation in teaching and in the scholarship of teaching, participants in the forum agreed, should be part of the doctoral education of students headed for academic careers. It was pointed out that giving doctoral students opportunities to study pedagogy in the context of their scientific, engineering, and mathematics work could give them an advantage in the tight academic job market. The apprenticeship and coaching methods of teaching, believed to be so effective in doctoral training for research, can be modified and extended for undergraduate teaching and learning purposes as well. Undergraduate students who are prospective teachers should have an active engagement in authentic science, undergraduate research that will promote an understanding of science and its procedures.

There were admonitions that good teaching in itself should be encouraged and rewarded. Effective and reflective teaching, substantiated by student outcomes, is in itself a scholarly activity and we must find ways to recognize such scholarship other than through traditional publication. The study of teaching, asking questions about the effects, impact, and nature of our teaching in an integrated

Effective and reflective teaching, substantiated by student outcomes, is in itself a scholarly activity and we must find ways to recognize such scholarship.

way, is an important role for faculty and can be part of the promotion and tenure process. In this vein, the use of technology in teaching was recommended, not only as intrinsically desirable, but also as having the potential to sharpen the analyses of teaching and learning issues. Moreover, given the evidence that teachers teach as they are taught, the need for college and university faculty to, themselves, model good teaching is apparent.

Curriculum

Faculty discussions of teaching frequently become discussions of curriculum, fixing on the material to be covered that we hope students will learn, rather than on the teacher's role in helping that learning to occur. This complicates questions of learning and teaching, because problems of teaching appear to be more acute than curriculum issues. Nevertheless, a number of genuine curriculum problems need to be addressed.

One problem that came up frequently was the pursuit of "coverage" and "exposure," the practice of including short discussions, perhaps just snippets, of many different topics of varying relevance and significance. Some participants looked to the "less is more" principle of Project 2061, reflected also in the *National Science Education Standards*, that developing a deeper *understanding* of a limited number of integrated concepts is more valuable than promoting a superficial grasp of many disconnected topics.

The reexamination of the curriculum that is needed must be done with intelligent sensitivity that there is simply a lot to learn and that preparation for a lifetime of learning is essential.

The consideration on the other side was that the advancement of knowledge and technique has created a need, generally, for everyone to learn more and to "learn how to learn." Answering this need might be the work of the curriculum in science literacy. No longer referring to the notion of general education in science or science for poets that prevailed in the 1950s and 1960s, science literacy now assumes the urgency of universal schooling in science. Some faculty members do not accept the idea of science for all, and continue to hold the belief that science is indeed only for the few. The reexamination of the curriculum that is needed must be done with intelligent sensitivity that there is simply a lot to learn and that preparation for a lifetime of learning is essential.

Related to this is the idea of differentiation, for example, a separate introductory course tailored to prospective science teachers in contrast to a single course for all students. Among a number of responses to this issue were the ideas of a basic course for all students with laboratories with differing emphases and of a basic course with an added seminar for prospective teachers that specifically addresses issues of pedagogy associated with the course.

Resources

A condition of diminishing resources was a dominant factor in the background at the forum that often made its way to the forefront. The prospect of reduced federal funding for research and a generally reduced federal role in research and education, coupled with equally tight conditions at the state level, came up frequently. Change has a cost. Most of the resources of an organization like a university are consumed by its doing what it already does. An organizational form of one of Newton's laws of motion is that change requires an external force in the form of new resources addressed to bringing about the change. The cachet of membership in the Association of American Universities (AAU) is still the ambition of many university presidents who want to be identified with this elite group. The participants saw this kind of quest as reinforcing the emphasis on research and making it difficult to direct attention to teaching issues and other proposals to rebalance the mission.

The deans were uneasy about the difficulty of bringing about change amidst diminishing resources. A number of interesting ideas were discussed for what might be done without added funding, some of which are discussed below under "Strategies for Change."

Federal Program Design

Complex and comprehensive projects for the education of teachers must be adapted to a great many local factors and variables. [T]he ability of any given project, no matter how innovative, to serve as a model is likely to be quite limited.

One specific issue associated with designing a program for federal funding concerns the meaning of "models." Referring to the three CETP projects that were presented as models at the forum, participants pointed out that each project was unique and adapted to the particular context in which it operated. It is unlikely that a project developed in one place can be transported to another, no matter how wonderful it may be in its local context. Complex and comprehensive projects for the education of teachers must be adapted to a great many local factors and variables. Proposal guidelines and evaluation criteria can certainly emphasize intrinsic quality and merit, but the ability of any given project, no matter how innovative, to serve as a model is likely to be quite limited. The strategy, then, is to tone down the rhetoric of transportable models and focus more on intrinsic quality and merit. Note that the impact of a proposed project on the infrastructure of the scientific enterprise is one of the four criteria NSF and its reviewers are supposed to use for judging the merit of every proposal (*Grant Proposal Guide*, NSF 95-27 [National Science Foundation]). If used properly and creatively, this criterion would provide a reasonable vehicle for dealing with the questions of novelty and impact.

Another issue of federal funding is that programs demanding institutional matching seem to be on the increase. Have-not institutions have a harder time meeting the matching requirements than wealthier ones. The rich get richer. A recommendation was that NSF re-examine the rules for matching funds in all programs.

Collaboration

Questions about collaboration informed the entire forum discussion. Some forms of collaboration were explicitly identified in the agenda; the discussions suggested others. The deans were committed to collaboration between colleges of science and colleges of education on the same campus, but there were reservations about their ability to bring this about between the two faculties. As one dean of science put it: the faculty of his college have no interest in seeing teachers made; they just want to teach science and leave to the education faculty the professional portion of teacher preparation. Modeling good teaching for prospective teachers, for example, does not interest many science faculty.

One dean of science pointed out that there were two hundred faculty members in his college but only one science educator and one mathematics educator in the college of education. He wondered what faculty collaboration might mean when two hundred are to cooperate with two. An implicit response to this was that some form of differentiation of assignment might be considered. Since the science college must serve several agendas and needs, at least a portion of the faculty might dedicate some effort to collaboration with education faculty. This situation might require adapting college of science norms for salary increments, promotion, and tenure.

That universities ought to work more closely with elementary and secondary schools came up quite often. The idea of *partnership*, which implies even stronger ties than *collaboration*, was emphasized. University and school ties that now exist typically work through the college of education. The partnership discussion at the forum was about engaging also college of science faculty members in school-based activities. It was argued that even institutions that do not have formal programs for the education of teachers should develop such ties and can benefit from them. But, spelling out roles in schools for science faculty members is a challenge, as is getting science faculty to adopt them.

Development of stronger collaboration between universities and schools may depend on the role taken by higher education in implementing the *National Science Education Standards* and the mathematics standards developed by the National Council of Teachers of Mathematics. The presentation on the *Standards* brought participants to consider the question of an explicit role for higher education. The National Research Council plans little, if any, further interpretation of the *Standards* or suggestions of roles for higher education. Project 2061 suggests that its products and materials are relevant to higher education, especially in its relationships with schools and teachers. Thus, higher education is expected to assume a role in interpreting and implementing the standards, but what it should be has not yet been well-defined. This is another opportunity to be seized.

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Public service as a mission is well-developed in agriculture and veterinary medicine at land grant universities. In a state with a big poultry industry like Arkansas, Georgia, or Maryland, a chicken can't catch a cold without receiving the ministrations of specialists in avian medicine, summoned from the state land-grant university by the county extension agent. This form of active and relevant outreach is not well developed in human service fields like education and social services (but is certainly envisioned in the concept of the Professional Development School) and appears to be limited to a regional impact rather than the extensive range of outreach in agriculture. Perhaps broadening the definition of service and university extension to apply to education can be an active part of the reform agenda to rebalance the mission. The use of technology along the lines being developed for "telemedicine" in many states would also be helpful.

Strategies for Change

Deans do not design substantive academic programs; the faculty do. As enablers and facilitators, the deans discussed the structural and administrative features of change.

The need to reform the value system that reinforces research achievements and pays only lip-service to teaching is a matter within the purview of deans that came up over and over again. Presenters, discussants, and participants frequently cited Boyer's *Scholarship Reconsidered* as providing useful guidelines for implementing the needed changes. Participants identified *position descriptions* and *criteria for selection, promotion, and tenure* as instruments for articulating the university's expectations for teaching and for the scholarship of teaching. The *procedures regarding appointment, promotion, and tenure* are devices which deans and other administrators can use, together with the faculty who implement them, to stimulate desired change.

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Deans have a number of other means for effecting reform in the value system, even without added resources. They can use their office as a bully pulpit: *keeping reform on the agenda*, as one dean put it. They can *convene* faculty members and department heads through meetings, formally organized conferences, recognition ceremonies and other academic events. They can call for *program reviews*. Every college and university has an internal program review and self-study mechanism, usually tied to accreditation and planning. This mechanism can center faculty attention and effort on the need for change. There is always *discretionary funding*, even if quite limited, that deans can use to provide incentives for faculty. *Start-up funds* are a typical feature of faculty appointments, especially in the sciences. Beyond their use in traditional ways, such as for laboratory equipment, start-up funds addressed to teaching matters should be considered as part of the strategy to use established and expected procedures as incentives. *Recognition* through such things as annual awards and special professorships was mentioned as part of the reexamination of faculty incentives and their relation to priorities.

Participants also suggested that *joint appointments* and *joint committees* in selection, promotion, and tenure processes could provide multiple perspectives on the implementation of the criteria. Joint appointments were mentioned frequently, but there were warnings of the inherent difficulties: each party, for example, expecting more than its due share of effort. This discussion led to suggestions of variations on joint appointments referred to in the discussions by terms such as "dual appointments" which are in occasional use by some institutions.

RECOMMENDATIONS

- Design and implement strategies addressing the fundamentals of values, rewards, and incentives, along with the rebalance of the university mission to teach, inquire, and serve.
- Place the emphasis on learning rather than teaching. This shift is essential to the reform of teaching and the enhanced effectiveness of teaching. It includes the college teacher's willingness to serve as a model for the prospective school teacher.
- Be sensitive to context. Designing programs for the preparation of science and mathematics teachers is important in itself, but it is embedded in movements for reform in many parts of the educational system.
- There are significant curriculum issues associated with the reform of undergraduate education and the teacher preparation programs, but curriculum issues should not be confused with issues of teaching and learning.
- Define and develop standards for the scholarship of teaching. Implementation of these standards is essential for rebalancing the mission that the movement for higher education reform is endeavoring to effect.
- Build collaborations based on strengths and mutual benefits. Collaborations within the university (especially between the college of education and the college of science), among the university, schools, and community, and across institutions are necessary, but involve sensitivities that must be understood and accounted for.
- Have a sense of role and the distribution of responsibilities. Faculty design academic programs; deans facilitate. Teacher education and undergraduate education, moreover, are institutional responsibilities and must involve provosts and presidents in their re-design.
- Use all available leverage for reform. Fresh resources are always desirable, but their absence is no reason to be discouraged. Employ all institutional incentives creatively and, for ideas and information, examine other projects such as NSF Education and Human Resources projects and programs at other institutions that were discussed at the forum.
- Develop a resource of expertise and expert assistance on best practice which institutions seeking to rebalance their mission could call upon to help faculty and administration to recognize that teaching is subject to analysis, to understand the results of research on teaching and learning, and to apply them in the local context.

Small Group Reports

Group 1 Report

Moderator: *Charles Stegman*, Dean, College of Education, University of Arkansas

New Faculty Appointments

One way to effect change is through appointments to the faculty. Job descriptions, search committees, and deans can together insure that candidates are committed to teaching. Members of search committees acquire a strong sense of ownership of the appointments in which they have been involved, so a joint committee (for example, education and the sciences) could promote collaboration.

In the discussion of this point, it was recommended that for faculty searches in teacher education programs, K–12 teachers sit on search committees, along with faculty from education and arts and sciences. It was also proposed that the idea of joint search committees be extended to joint promotion and tenure committees.

Start Up Costs

We talked a lot about the start-up costs for new faculty members, ranging from purchasing a computer to equipping an entire laboratory. If the university acknowledges the importance of teaching, start-up support can be provided for costs related to teaching or curriculum development. In some cases such costs might be lower than equipping a research laboratory. Arguing for start-up costs can be a means of stressing curriculum development or teaching.

Foster the Scholarship of Teaching

In the letter to *Science* that we signed* we spoke of making science and mathematics teaching a legitimate scholarly activity by establishing standards and spreading the word of its importance through professional meetings or publishing in journals. The American Statistical Association, which emphasizes teaching statistics, provides a good example of how this can be done. We can work to have other professional organizations publish proceedings and articles on teaching in their areas and encourage faculty members to publish such articles.

Faculty professional development efforts and teaching academies are other ways of promoting this goal. A number of institutions have formal mechanisms to work with their faculty, and examining pedagogy is an important part of the process.

We talked about the difficulty of trying to improve and measure an activity as elusive as teaching. But there are ways of addressing this issue. Portfolios, for example, can document and study successful pedagogy. The portfolios can be used in the promotion and tenure process.

In the discussion that followed, participants warned of the danger of overlooking distinctions among activities. If teaching is important, good teaching is important *as* good teaching;

*During one of the plenary discussions, a suggestion was made that publication of research papers on science education in prestigious scholarly journals, such as *Science*, would enhance both the visibility and the credibility of this form of scholarship. A letter to the Editor of *Science* advocating publication of peer-reviewed scholarly research in education was drafted, signed by 52 of the participating deans, and sent to the Editor. The Editorial response was that there is no prohibition on such submissions.

we need not confuse it with scholarship of the same sort as the publication of archival research. But Boyer's *Scholarship Reconsidered* makes a strong case that good teaching is in itself a scholarly activity. We should be inquiring into our teaching. We should be asking questions about the effects, impact, and nature of our teaching, and we need to integrate the three into our scholarship. Part of what we are talking about is finding ways to reflect scholarship in different ways than just the traditional kinds of research and publications. I hope we do not miss that point. Maybe we should spend more time on it.

Science Faculty in Clinical Supervision in K–12 Schools

The brunt of the task of clinical supervision of prospective teachers has traditionally been borne by the faculty in education. The involvement of science and mathematics faculty will promote better understanding of the challenges of teacher education and encourage stronger collaboration.

Focus on Learning Outcomes

All of us at this conference have had extensive involvement in teaching, but the forum has introduced a new perspective, evaluating teaching by its objective, learning. Think about concentrating on the learning achievements of students in our college classes. What is it that we really want them to learn? One of the important differences between elementary and secondary schools on the one hand and colleges and universities on the other is that college and university faculty have a great deal more discretion in what they teach. We should put this kind of discretion to use as we attend to curriculum design, teaching, and learning.

Recruitment into Teaching

There is still a great deal of national concern about the need for mathematics and science teachers. The numbers of undergraduate majors in mathematics and science are ample, but they have other employment options. Indeed, many faculty in the sciences actively discourage students from going into teaching. We might, instead, recognize that teaching is a very important profession to consider as a career and actively encourage more of our students to consider it.

Topical Coverage vs. In-Depth Learning

We have heard much at this conference about the need to consider the effectiveness of the curriculum as an instrument of learning. This might lead us to spend less time on coverage and more time on what we want our students to know and understand in depth and the skills they need to be lifelong learners.

In the discussion, the maxim *no pain, no gain* — which is deeply embedded in the culture of the university — came up as characterizing an academic mentality convinced that existing curricula define intellectual standards. Any change that attempts to replace coverage with learning in depth may be thought lacking in rigor. We cannot ignore the real difficulty of making a trade-off between coverage and understanding.

Many things beyond habit or the egos of the scientists reinforce the case for coverage. One of the realities of science today is that it rests upon an enormous and growing amount of information. We have to give the students some sense of how to manage that information, and that means touching on a lot of it. Just the ability to find the connections among different pieces of information means coming to terms with a great deal of it. So one of the skills we have to teach people is how to manage big sets of information, how to not settle for sorting out one thing and saying, "Well, I got that," in the course of the semester. As has been put quite aptly, the question is not only, "How do we teach students to organize material?" but also, "How we teach them to think about the material and reorganize it?" The issue of reconciling coverage and understanding raises the question of what students are bringing to their college classes, what standards prevail in K–12. Another issue is that we cannot expect them to either know or understand everything.

Research Participation

Participation in science research is important for teacher preparation. We need to engage students and potential teachers with scientists. There are successful in-service programs that put teachers from the schools into laboratories with scientists. We can also do some of this in our pre-service programs.

Group 2 Report

Moderator: *John Petersen*, Dean, College of Science, Wayne State University

Communication Between Science and Education Faculty Members.

Our group believes that this is a serious problem and that deans need to take a far more active role in addressing it. The problem is rooted in differing value systems and creates a need to convince science faculty that there is *validity* in education and pedagogy issues. The science deans in our group believed that their faculty members had at best a minimal understanding of what the *National Science Education Standards* are. Crafting a solution to this problem sometimes requires subterfuge. If science faculty ignore distinguished education faculty brought in as speakers, we might bring in distinguished science speakers to speak on education issues. We will suggest some more direct approaches later.

Curricula for Science Literacy

We discussed curricula, especially for science literacy among non-majors, including prospective teachers. We recognize that it is simply not realistic to expect prospective teachers to study as long as medical doctors have to study in order to go out and practice. If they did so, they might as well go into medicine and make a much higher salary than they would by going into teaching.

How do we structure our courses so that we are addressing those issues that we think are of value not only to scientists but to society in general, and relate them to the demographic changes that occur in the country as well? This is a very significant problem that requires collaboration among science faculty, education faculty, and teachers in the schools. Once again, deans have to take a leadership role to help make collaboration a valued thing to pursue.

Responses to the problems

We discussed several strategies. These included the composition of search committees, the character of joint appointments, and the guidelines for promotion and tenure decisions. Each of these devices requires or describes a reward system that requires central administration involvement and commitment. Deans of education and science working together should be able to get them involved and committed. Leadership at the deans' level is critically important. If it is important to educate teachers and modify the curriculum so that we have a scientifically more literate society, then deans have to apply to that end decisions on tenure and promotion, merit salary, and other resources.

We considered the need for success stories to bring to both science and education faculty examples of what work — stories that describe some strides we are making in teacher education and in education of our undergraduates.

The National Science Foundation is very helpful not only in providing support but in being a good model. The way NSF structures its funding has increased interest in science education. There would be an awful lot more interest in teacher training on our campuses if we designed our funding to fit that model. We cannot ignore this by claiming that not enough money is available. Even when we seek outside support, we have to consider what is to happen when the NSF support is gone, how to institutionalize the programs NSF helps us develop.

Discussion

The discussion began with the question of whether science and mathematics faculty who teach poorly know that they are doing so. This question is related to the first item, which notes the second-class role of colleges of education. Disappointment was expressed that on college and university campuses full of enlightened people a class structure values one kind of knowledge over another and one mode of inquiry is more legitimate than another. Part of the reason for devaluing the study of teaching is that those who do not study it have a simplistic populist view of what teachers are and do. Because we have all been to school and have been students in classrooms for years and years, we look at what happens in front of us and we think we can do that just as well as the professionals.

We do not take that posture with regard to our physicians. We do not say, "Well, I could hold a stethoscope up to someone's chest and listen and make a judgment about that." We do not take that view of people who drive an automobile and say, "Well, driving an automobile must be a simple thing to do because you just sit there and put your foot on the pedal." So this false notion that teaching is a simple set of actions that results in learning is a notion that we all must combat, and to do that in higher education is a very important challenge for deans. They must find a way to persuade their faculties to recognize teaching as an activity subject to analysis, to embrace research on teaching, and to apply the results to their own acts.

The thought was also expressed that many people who are regarded as poor teachers are simply too rigid in how they want to teach. It is not that they do not know that they are not reaching the students. That is abundantly clear. But they are unwilling to change. They simply are too rigid in what they think the students ought to do in response to their teaching style. At the same time, our students, in general, are also too rigid. They are not as receptive to idiosyncrasies in teaching. They think they know what kind of teacher they ought to have and that is what they want.

It is not always clear what criteria are being used to judge good teaching. When students and colleagues acknowledge certain faculty as good teachers, the usual reasons are that they speak with crystal clarity and that the students enjoy listening. It is not clear that these are related to student understanding and ability to use the material. This was the challenge of the *Private Universe* tapes, for example. So in considering good teaching, we really have to start with student learning.

There was also discussion about the nature of NSF programs. It was argued that NSF has transferred into science education programs certain criteria that are more relevant to the research support activities it engages in, specifically a constant emphasis on doing something that has not been done before. There comes a time, if things that work in education have been developed, that it would be useful to fund some implementation and adaptation rather than always exploring new possibilities. This is a way that NSF funds can serve as a catalyst in getting institutions to do new things that then have a better chance of being institutionalized.

Group 3 Report

Moderator: *Dale Andersen*, Dean, College of Education, University of Nevada, Las Vegas

Good Teaching

In the initial session, we asked: What is good teaching? Particularly within that discussion we wondered: Should teaching look the same at all levels? After spirited discussion, we came to a consensus that teaching does not necessarily look the same at all levels. The experiences the students bring with them, their developmental levels, and other normative factors require adjustment by the teachers. But we agreed that good teaching at all levels can be centered on the students and, whether you are teaching on a one-to-one basis or in a lecture hall facing four hundred students, can incorporate elements of student-centeredness. Good teaching is driven by continuous assessment and accurate feedback, and that is the same at all levels.

It was also observed that good teaching should be judged by what students have learned rather than by how material has been presented. That is one of the paradigm shifts that we identified, and it came up on a couple of other occasions in the course of our discussions, as well. Good teaching can best be measured by the answers to the questions: Have the students understood what is being taught? Can they apply the knowledge? and Can they explain the concepts and the principles involved? We also recognized that explanations may range from simple to very complex.

Deans can promote good teaching. By application of the institutional reward system, they influence the quality of teaching, the amount of collaboration, and even the faculty's familiarity with research on teaching and learning. This reward system lies within the domain of control of both deans of education and deans of arts and science.

One attitude, representing a barrier to improvement that needs to be addressed, but we are not sure how, is the attitude that the classroom is the private domain of each professor. To have others come in, observe, and make suggestions for improvement or modifications in instruction is very difficult to effect if that attitude permeates the campus.

Collaboration

In our second session, it was stated that there is quite a bit of literature and some research on collaboration, and the question was raised: Why don't we, instead of reinventing the wheel, go back and examine some of the data and the writings on collaboration, such as those that evolved out of the teacher corps experience? We went through years and years of teacher corps programs. They were collaborative efforts involving K–12 school systems, colleges of education, and sometimes other colleges. They focused on collaboration, and there must be some good stuff there if we would just go back and reread it, and relearn it.

The campus culture affects the ease of collaboration. All colleges should be involved in the improvement of instruction. We noted that across the country more and more universities seem to be establishing centers for the improvement of education, or centers for the improvement of instruction, or centers for the improvement of teaching, and these are available for faculty in all colleges.

Some specific examples mentioned. We had two people in our group who had previously been at the University of Cincinnati when the College of Engineering asked the College of Education for members who were specialists in instructional strategies, in assessment, and other aspects of teaching to come to the College of Engineering to work with faculty who volunteered to try to improve their methods and modes of instruction and their teaching effectiveness. It made a difference. Schools of medicine at several institutions have utilized the expertise of the faculty in colleges of education. Schools of business have done likewise. Perhaps we are at a point of readiness now to incorporate that model or expectation into the university culture. With the collaborative support of deans of arts and sciences and deans of education such collaboration can occur in the sciences.

We identified some paradigm shifts that are possible and can be nurtured by deans. The shift to integration of preservice content and pedagogical knowledge could happen now on many university campuses. A proper atmosphere appears to be there for it in many cases. A shift in emphasis from teaching variables to learning variables for evaluating instructional effectiveness is being driven by program objectives, by accreditation standards in some of our professional areas, and by teacher licensure or teacher certification in several of the states. The end-task model of outcome or competency standards is replacing the traditional model based on how many credits have been accumulated or how many years have been spent in college. Another possible paradigm shift is establishing K–16 collaboratives, as we had talked about it in the plenary session earlier.

We wondered why there were not more deans of engineering at a conference like this, because we believed that both schools of education and colleges of arts and science could learn from engineering. This is especially true in relation to the commitment to cooperate with practitioners and with the private sector. That happens in colleges or schools of engineering because of accreditation requirements, but we can all learn from the results of such cooperation.

Models and Their Adaptation

In the session on institutionalization, we heard about a number of programs that can be looked at and learned from. We also added our own.

We had admiration for the University of Texas-El Paso (UTEP), and the presentation by UTEP deans. It seemed to be a bit more of a closed system than most of us function in, with students coming from the public schools in large percentages and teachers being returned to those same public schools from the university in very large percentages. But we thought that it did provide some stimulating ideas. Collaboration by K–12 systems with arts and science as well as education could be fruitful. The Colorado and Maryland presentations each provided some helpful ideas and projects that we could learn from. In every case, however, we believed that we would have to modify them to fit our own situation. In our group, we heard a lot from their representatives about the University of Missouri at Columbia, where more and better collaboration seems to be taking place with few if any new resources.

If we are going to set about to modify the entire faculty reward system of institutions, then we probably need to co-opt the president and provost. In order to do that we can use the power of numbers. If we can agree between the college of education and the college of arts and sciences that this is a worthwhile enterprise and that the reward system of the university *should* be changed, we will represent a very large proportion of the campus, and we can and should use that clout or power in a positive way to affect the institutional culture and the institutional mission. It is a real possibility that, working together, we can modify the system.

We talked a bit about the indications that the hard sciences are facing a shrinking market for their graduates and the question was raised: Can't we simply take the people who are not getting jobs who have this background and training in mathematics and science and sort of retread them into teaching? We decided that it might indeed be feasible, but we also recognized that it would extend the program of those individuals considerably, a couple of years in many cases. It seemed to be much better to use the bulk of our energy to address the idea of collaboration up front so that the people coming into the pipeline are the ones who benefit from collaboration and the marriage of content knowledge and pedagogical knowledge. Students become scientists who can also teach effectively because they have been exposed to good teaching themselves.

A provocative set of questions that came up — we did not all agree on the responses to any of these — was: Should the NSF funding guidelines be changed to *require* collaboration involving K–12 arts and sciences and education? Shouldn't a very much larger proportion of the NSF monies be contingent on collaboration? Shouldn't it be required in the proposal? and Shouldn't it be verified as a prerequisite to the proposal?

Another intriguing question was: Should the Research I universities simply drop K–12 teacher education? Research I universities train the professoriate in both arts and sciences and education. If the future professoriate is being inculcated with the attitude that research takes preference over teaching, won't prospective teachers adopt that same attitude? We ended up by agreeing that Research I universities should not drop K–12 teacher education, but the issue did bring to the surface some of the questions about the campus culture at the universities that train the professoriate.

We talked a bit about systemic change and how expensive it is and how difficult it is. We wondered whether there is an easier way to do it. But we ran out of time, so we did not come to any resolution on this issue.

Discussion

A question was raised about the extent to which assessment was a part of this group's discussion about reform in colleges and universities. The report says that teaching ought to be student-centered, that we ought to move from an emphasis on teaching to an emphasis on learning. But if we are not having a discussion in higher education about how we know what students know and how we can come to understand what they understand, then how are we going to make this paradigm shift? The response was that the group had actually talked a good deal about assessment at different levels and in different forms. A lot of time was spent talking about assessment of students, the notion that feedback from student achievement is necessary for making modifications in teaching, promoting collaboration, and marrying content and pedagogical knowledge. We also talked about assessment as it relates to the expenditure of resources by the university, funding agencies, and other sources of support. So we saw assessment as very important in all enterprises, from student to institution.

One of the participants shared about twenty years of experience related to changing the focus from teaching to learning, from input to outcomes at her institution. In 1972, all the faculty had decided upon the outcomes for all the graduates. They spent unbelievable time talking about outcomes for every department. But when the faculty considered the interrelated questions, how do we think about teaching, how do we think about learning, and how do we think about assessment, they kept sort of scooting away from learning. They decided that if they were going to teach for learning they had to create assessment instruments. They thought they had wonderful outcomes until they started trying to create assessments for them, and then recognized they had gotten picky, and had to redo them. This was and is all part of ongoing professional development in teaching for each faculty member, regardless of her or his discipline.

This faculty has come to realize that the higher education community lacks a language to describe teaching, learning, and assessment that are designed to insure student outcomes. They did not and do not have a good language and they were afraid to change, but having made that decision back in 1972, they produced an extraordinarily collaborative institution. The entire institution is committed to teaching. The forum participant was from the science division, not from the education department. They have tremendous collaboration with industry, with higher education, and K–12. The faculty sought very little NSF funding to facilitate what they did because they had to work through for themselves what they were trying to do and that didn't lend itself to grant proposals. Their message is: money helps, but its lack should not be used as an excuse for not changing. The will to change has mostly to do with what you really want your students to be able to do after they graduate. When you make that change, it affects everything.

Turning to collaboration, Malcom, our moderator, pointed out that a large proportion of NSF funds are already supposed to be awarded on the basis of collaboration, for example, research grants for centers and large-scale enterprises already require outreach, connection to the K–12 system, and ties with other institutions. Moreover, the fourth NSF criterion for review of research proposals is directly related to collaboration. The first three criteria are the intrinsic quality and merit of the idea, the capability of the performers, and the technical capability of the institution. The fourth concerns the impact of the proposed work on the infrastructure for science and incorporates the issues of teaching, of outreach, of human resource development, and of diversity. Malcom wonders how many people really know about this criterion, how reviewers treat it, and how many program officers are actually using it to make distinctions between proposals of roughly equal merit. But she is convinced that this is an issue that has to come to the table as the buying power of the money shrinks over time.

The issue of NSF criteria for granting brought up a related issue, the increasing insistence on institutional commitment in the form of matching funds. The ILI guidelines are quite blunt: if the institution is not prepared to pick up half the cost, don't bother to send the proposal. The NSF apparently is putting pressure on the institutions to move in a particular direction. However, the drawer of money out of which that match comes has incredible demands on it and the NSF needs to recognize that the result of this policy is to make the rich richer. Institutions may have to say to some faculty who have a high success rate in getting ILI grants that the number of proposals submitted has to be reduced because not enough institutional funds are available to cover the required matching. So the NSF funds are going to go to richer institutions, because other places where there is a lot of creativity, where you would like to have some impact, cannot afford the match. There has to be some way that the NSF can make an honest assessment of where people are trying to make an effort but don't have the resources to put up half the cost.

One of the engineering deans present reinforced the point about the dearth of engineering deans at the conference. He went on to make a few points about the role of engineering schools in teaching and teacher education.

For about twenty-five years, he observed, engineering has been holding conferences called Frontiers in Engineering. These conferences have been exploring teaching and education, particularly related to engineering. At the last conference, a number of collaborative efforts between university colleges of education, engineering colleges, arts and science colleges were presented. About four hundred attended that conference and interest in the meetings seems to be growing. Forum participants were urged to encourage their faculty to attend.

Another issue that concerns schools of engineering is that somewhere between fifty and sixty percent of their expenditures come from outside research support. The pressure has been on the schools to maintain or increase that support, because university funds have just not supported their technological programs. It is very hard to make the shift to teaching when administrations believe that schools of engineering should bring in more research money.

Another point brought up by this dean was that there are instances where the decisions of deans have been overridden by the administration on tenure and promotion. In some cases an individual was denied tenure and promotion by the dean because of poor teaching, but fear of legal action caused higher administration to override the dean's decision. Once a dean loses an argument like that, his or her authority is undercut, which raises the question of whether a dean really has any power.

Group 4 Report

Moderator: *Mary Briscoe*, Dean, College of Arts & Sciences, University of Pittsburgh

Before presenting the report, I have some preliminary comments.

In conversations in this group, there was a great deal of discussion about communication and our need to do that at our home institutions. One of the shrewdest things about this conference was to get at least two people from the each campus to participate as a team. As a dean from arts and sciences, I have had more conversations, here, with our dean of education than we have had for a long time. Whether we can continue that when we go back home is an interesting question.

As we look for plans to collaborate more widely, I think one of the things we ought to notice is the difference between the numbers on our two sides, education and sciences. At my university, we have, I learned last night, two faculty in the school of education who do mathematics education and two who do science education. In the arts and sciences college, we have more than two hundred faculty in mathematics and science. We are going to have to recognize such a difference in numbers and be realistic about collaborative projects if we are going to get from the margins into the center through collaboration.

Reform of Introductory Courses in Mathematics and Science

There seems to be much agreement on the need to reform the introductory courses in mathematics and science. A lot of that is going on already — calculus reform, for example, as we heard yesterday.

Our group had a lengthy discussion of service courses; these courses serve students who are headed toward a wide variety of academic destinies. We discussed whether a single introductory course should serve diverse functions or whether different versions of the course should be developed. We kept coming back to three questions: How well do these courses serve arts and science majors? How well do they serve non-science majors? and How well do they serve pre-service teachers at all levels? The anwsers lead to action-oriented questions such as: If students are not doing well, what can we do? and Can the pedagogy in service courses be changed so that separate courses for different audiences are not needed?

We also asked how educational methods courses prepare students to teach in science and mathematics. Are there currently any links between what happens in the schools of education and what happens in courses that are taught in arts and sciences? These issues are put in the form of questions so that we can ask them in our own institutions. That is basically where we were at the end of the day yesterday in raising lots of these questions.

As part of their requirements in education, pre-service science teachers sometimes take education courses that are more general than is useful for their intended career. This varies among institutions. Sometimes the required general program in education is, by request of the science and mathematics departments, the same for prospective science teachers as for all students. Could a collaboration between arts and sciences and education increase efficiency here within the education requirements? Several of the institutions here are in the Holmes Group or involved in Project 30. For these, especially, students preparing to be teachers are completing a baccalaureate program in the college of arts and sciences. What are the education requirements for that degree, and could there be, through collaboration, any merging of credits that would be useful in the preparation of teachers?

Faculty Development

Several institutions already have requirements for considering teaching and demonstrating teaching ability as part of promotion and tenure processes. At my institution, we now are requiring a demonstration of teaching ability at time of initial appointment and maintenance of a teaching portfolio thereafter. If that begins at the beginning and is required all the way up the professoriate ladder, then some momentum and credibility are gained. Instituting such requirements is one way we as deans can make a significant difference in the culture. Our provost and board of trustees have pushed these initiatives over time. Our board of trustees passed a resolution in 1985 to require peer evaluation of teaching. Nobody did anything about it for a long time until a provost and some of us deans decided we would indeed enforce the rules.

Given the disproportionate numbers between education and arts and sciences faculties, how do we engage faculty in collaborative educational reform? Several things have already been discussed here at this forum: seminars and workshops on teaching, a day-long festival celebration of teaching or a two-day conference in which you have people presenting things like the use of technology in teaching. With so many people using technology in teaching now, we ought to be able to find ways to use the energy and excitement constructively in our faculty development efforts.

Technology might be especially helpful in motivating some of the people who are most resistant to educational reform in mathematics and sciences to get interested in how students learn. A valuable strategy is to begin by sharing what is already being done on campus, but then work into trying to introduce faculty members to what is being done elsewhere. Many of our discipline professional organizations already have sections on pedagogy.

Coming from this meeting, we might be able to invent means of disseminating ideas based on the *National Science Education Standards*, Project 2061, and other reforms by using, for example, the dean's small grants fund for curriculum development. It is true, as has been said here more than once, that even moral support of teaching and learning initiatives is useful. But small amounts of money, even to scientists who are used to big money, can be extremely useful in getting something started in teaching enhancements.

When we go back home we ought to find ways to involve faculty with collaborative K–12 partners. We have talked a lot about accountability. With money as short as it is, when we send people away to "learn something at a conference," we should hold them accountable when they return — and that includes those attending this meeting. We should be held accountable by the organizers to report back what we have accomplished or tried to accomplish within the next year.

The last three things in my notes seemed like good specific ideas to consider. One concerns advisory boards or boards of visitors as they are sometimes called. Typically, they include alumni and business and corporate representatives. We might also include people tied to the local or state-wide community. Another is to encourage K–12 teachers to visit universities for sabbaticals. Finally, all universities have strategic planning processes. We need to address in those strategic plans the issues we are discussing here.

Discussion

The discussion was driven by interest in the issue of introductory service courses serving multiple functions and student audiences. An informal poll (show of hands) showed that a majority of institutions offered undifferentiated, single versions of introductory courses. There was agreement that this situation constituted a real problem. The courses do not function well, and consideration should be given to differentiated courses in science designed specifically for non-science majors. But there is a lot of disagreement in the science community about whether there should be a difference at all.

The question was raised as to whether there are separate courses for non-majors in other areas such as English. The response from the floor was that there were such. One participant described an example at his institution of writing across the curriculum. The basic writing composition courses occur in English, but the follow-up courses occur in the departments with all the faculty members interacting with students in the writing. This participant noted that many other institutions probably have writing across the curriculum projects, but the one at his institution appears to work well. How about science across the curriculum? One participant reported that her institution was working on a movement to have quantitative reasoning across the curriculum, computer literacy included.

This discussion of undergraduate courses and the functions they serve reminded participants of earlier comments by Solo. He expressed frustration, as a school principal, about teachers who had been through science programs in our universities, but could not do what he needed them to do in school.

The problem of coverage was also raised. How do we devise the subject matter in sciences and mathematics that can then be translated into teaching, recycled as it were? For an answer, we must be willing to look at the nature of introductory science courses and what they do now. At this point, this is not an argument that we should have different introductory courses. But we ought to see what they are doing where they exist and see how well they are working for their intended audiences.

Group 5 Report

Moderator: *Jerry Whitten*, Dean, College of Mathematical & Physical Sciences, North Carolina State University

Let me begin with something that our group felt very strongly about, and that was to affirm the importance of good teaching, good teaching K–20 — that includes graduate education and doctoral study. Good teachers inspire, students learn, and through good teaching we have a lifetime impact on the students.

Changes in the External Environment

These changes include changed expectations: our own, our state legislature's, and our national programs'. The changes have produced pressure on universities to do less with less or to do more with less. There is a broad spectrum of viewpoints on how to deal with the changing expectations. One view is that we need to reduce research and increase emphasis on teaching. Some believe that we should shift completely and make good teaching the focal point of the university. Still others think that we can do both, that we can blend what we are currently doing: maintaining a focus on scientific research and doing a good job of improving our teaching.

Changes in Elementary and Secondary Education

We are seeing increased variation among elementary and secondary schools in the quality of the educational experience. School choice has a great deal of popular support, even though choice by using vouchers is controversial. We are seeing a lot of interest in charter schools and home education. Does this represent a threat to the viability of our educational system in the United States, or is it an opportunity? If you do a better job in these alternative approaches, it is an opportunity for the students who happen to be involved in that alternative, but for those students who are left behind, it certainly is not an opportunity.

But school structure is not the only issue. There are highly variable socioeconomic conditions and changing demographics. This has been talked about briefly in the forum, but the issue is central to whether school systems as we know them will remain viable.

There is also the issue of the status of the teaching profession. Teachers are called upon to do too many things that are not what we regard as teaching. Our group can be an advocate for teachers, and we need to think carefully about how we can influence all components of the educational process.

Science Faculty Should be Models for Good Teaching

One way universities can bring the science faculty a little bit more in resonance with the educational faculty is to encourage cooperation and commitment to good teaching. How far are we from doing that now? Let me give you an example of how far we may be. Science departments sometimes hire science *educators*. This might be someone in physics or chemistry who also has a specialty in science education. What sometimes happens is that the science educator arrives and takes over an unwanted part of the physics or mathematics or chemistry educational program so that other faculty can become disengaged. I do not think that is what we want to have happen. We would like to bring science educators into our programs in order to help and collaborate with other faculty — for example, make it easier for faculty to work with large course sections.

Role of the Dean

What is the role of the dean? Certainly, the arts and science and education deans can facilitate collaborations between our different kinds of colleges and work with the administration to bring about institutional change. We are doing quite a bit of that. But let us look at institutional change more closely.

To reduce scientific research expectations and increase teaching expectations, we think, would be very foolish. We should not pit scientific research against teaching. We need to work together and invent ways to address this kind of conflict. There is absolutely no doubt that in a research university there are multiple missions and that the faculty who are hired are strongly motivated to succeed in their profession. Scientific research is one of the requirements. Setting up a competition between research and teaching will assuredly fail, or at least it will set us back many years. Moreover, it would not be good for the country to downplay scientific research.

Does that mean research should have the same emphasis at every institution? Certainly not. Institutions are different. They have different opportunities, different missions and we need to sort all of this out. And we should be able to provide a more effective setting for research faculty to be good teachers, to draw on their research expertise, and have it more effectively impact what they do as teachers. The problem is that, at many institutions, we are not currently doing this very well. We need to accelerate our efforts. If things are not quite right, we need to involve more of our research faculty in our teaching programs.

Promotion and tenure guidelines should be more reflective of the teaching mission of the university. No one in our group was opposed to that. Everyone believes that we need to affirm, seriously affirm, the importance of good teaching and write that into the promotion and tenure documents. But there are difficulties in interpreting the term, "good teaching." Is it sufficient for promotion and tenure to be a good classroom teacher, or do we look for some other kind of teaching scholarship, evidence analogous to what is used in the research community such as publications, setting new directions. That is debatable and I think it depends on the field and institution.

Some institutions, my own for example, have explicitly written into promotion and tenure guidelines an option that raises the expectation of getting tenure by doing a good job in teaching scholarship. We want this understood, however, by prior agreement. We would like to know in advance where a person wants to make his or her mark and, if we know in advance of the tenure decision date, we have no problem with defining different kinds of faculty in the institution. In addition — and this came from several participants in our discussion — we want these faculty to make education their principal activity and to draw in others so that we will have a cooperative venture.

Most of us believe that to be competitive these days, we will need to collaborate a lot more. If an arts and science college wants to be competitive in education, it is pretty smart to team up with a college of education. The Lone Ranger approach, carving out a little piece of the turf and cultivating it yourself, is simply not going to be as competitive as in the past. We all recognize that.

We want to maintain university research quality even with reduced resources, though we would like to maintain research quality with increased resources. At many universities, there is a call for increased efficiency. To some, that seems to mean getting the students through faster — whether it be in larger sections or by better grades — anything that just gets the students processed better. When we talk about efficiency, it does not reduce to efficiency of processing. We must keep clearly in mind the need to educate well the students who are entrusted to our care.

Collaborations Between Universities and Schools

We have said a lot already about such collaborations. Many, many fine programs represented by the participants in this forum reach out to the public schools. They include student teaching, various forms of science outreach programs, and collaborations with science and mathematics teachers.

General Discussion

Moderator: *Shirley Malcom*, Director, Education and Human Resources Directorate, AAAS

Malcom: What I hope you would be willing to do in this last period is to share reflections you might have on this forum. Making a personal commitment and personal statement here — in a public kind of a way — helps to assure that we hold ourselves to some of the things that would otherwise get lost. In that spirit, let me begin.

I plan to report on this forum at the next meeting of the National Science Board and its Committee on Education and Human Resources and raise several of the questions that you have raised here: Do required matching funds contribute to rich institutions getting richer? Is there an equity issue in the size of the required match in some programs? How do we address the continued focus on novelty when there is as well a need to support adaptation to local contexts?

Briscoe: I would like to extend the novelty question just a bit further. We heard the hypothetical question about an institution working up a proposal that turns out to be similar in concept to that of another university. When we are in a period of reform, reform bubbles up in many places at once. For example, if you listen to the language that we are beginning to use in common at this forum, you will note an emphasis on the use of "learning" in our discourse. This is a real shift in our use of language and what we mean by it, vis-à-vis teaching. Something like this can be extraordinarily novel within an institutional context. The people there may or may not know what happened in a state across the country. What is most important is what is novel and useful at that particular institution, apart from what may be happening at other places.

Malcom: Let us try to get further clarification of the novelty issue. If an idea comes from the community and it exists, unknown to them, someplace else, that is not necessarily an argument for not supporting it. That is a different issue from knowing that something exists someplace else and wanting to adapt it to the local environment. The origins of new ideas comprise one question and deciding how to propose or fund what may be an adaptation is another question. The two are different sides of the same kinds of concern.

Shipley: What I would like to do is fairly simple: include teachers in more of the things I do in the college and find a way to reward them for their interaction with us. I plan to have teachers on our advisory council, bring teachers to our faculty selection committees, and possibly include them on promotion and tenure committees. I want to take advantage of the time they are willing to commit and reward them through such things as collaborative research in the schools, teaching in the schools, and creating a more specific dialogue than we now have.

Burch: Someone earlier commented that scholarship is defined as that which gets into print. We came here talking about collaboration, and we all have learned a good many things that work. Sometimes this happens by accident, you just happen to be in the right place at the right time. We should consider finding a better way to identify, codify, and access our best practices. I think the best practice issue is a major one facing us in teaching and learning, from pre-school through graduate school. What I have in mind arose in a conversation with a physician friend who is a general practitioner. He said that computer access to information on diagnosis or treatment options is an absolutely essential tool for him.

We do not have an analogous capacity in education. The challenges of the things that we have talked about here — improving teaching and learning in the university for all students in the sciences, better ways of recruiting the kinds of people we need to come into the sciences as teachers, and better ways of linking the schools — would be helped by a communication and information system on best practice.

Malcom: One of the challenges in disseminating best practice is that we talk about the things we try that prove to be effective, but tend not to report what we try that is not effective. We need to do both of these things. The National Diffusion Network (NDN) of the U.S. Department of Education promotes implementation of effective practice, but the criteria for inclusion are quite rigid. We also need ideas that are promising, if not proven.

Finley: A common thread that ran through much of our conversation is an interest in research on issues of what our students are learning and how the results can be used for faculty evaluations and assessments, improved instructional designs, and so forth. One of the areas in which collaborations can be very powerful is research on our own teaching and the teaching of specific subjects. NSF should take a look at its own programs: there is relatively little money for research on the teaching of particular subject matter. Much of the funding is for development that is important and useful, but is best if based on the results of research.

Missing in our conversation was much about our graduate students, the next generation of scholars who will be teaching the courses with which we are concerned. Putting together opportunities for them to study pedagogy in the context of their scientific, engineering, or mathematics work seems critical and is an area in which colleges of education can participate. There would be several benefits. It would immediately improve instruction at our institutions, because our graduate students provide a great deal of that instruction. In the longer term, it would improve their employability at small and mid-sized colleges and universities because they would have a background in pedagogy as well as subject matter.

Dickinson: To capitalize on a shared interest in research, I intend to go back to my institution and talk to two of my colleagues in the college of education who might be interested in using our students as their research subjects and our classes as research settings. Now they go out to the high schools, but bringing them into our classes in a shared research mode, rather than as critics, might actually work.

Hall: We have faced a major drop in the number of students in teacher education programs. We have, however, a large number of students who wish to go to medical school, but there is usually a waiting period to get admitted. We have suggested to these students that they qualify for teacher certification in science or mathematics while they are waiting to be admitted to medical school. That has worked so well that we moved over to the school of liberal arts and are recruiting students majoring in political science who are waiting to go to law school. We have been successful enough that we are now graduating some of the largest numbers of African American males in education.

Malcom: A large number of these students will stay in teaching. They will decide that they really love it and don't want to go to medical school. As medical practice moves toward managed care, it will not be as lucrative. Some people will perceive that it's a good deal after all to do something they really love, teaching, and not have the hassles of medical practice.

Stegman: The Department of Education seems to be in a precarious position. What are we going to do if the Department of Education goes away? There needs to be a lot of strategic planning, coordination, and cooperation at the national level. Some of us from colleges of education should be involved in those strategic planning initiatives as we will involve public school teachers, arts and science faculty, education faculty, and so on.

Malcom: The federal structure is basically reactive. There is very little long-term vision because money comes from the Congress on an annual basis. The President can propose, but it is the Congress that disposes. Within the Congress, jurisdiction for education ranges over many committees and subcommittees of the House and the Senate. It is very difficult for people to operate in any way that looks coherent. In a way, you almost have to wait until the money gets to the local level to find coherence. The way the Department of Education monies flow down to the local system is totally arcane. Within the National Science and Technology Council structure of the Executive Branch, the Education and Human Resources Committees could discuss these strategic issues.

Clark: One of the problems getting many of our science faculty engaged in cooperative efforts with the college of education is that the scientists also must deal with students heading toward medicine, nursing, and agriculture. We have partnerships at a large Research I university that go everywhere. It isn't realistic to expect all of our science faculty to be engaged with the college of education because there are so many different other things they also have to do.

I want to put in a plug for colleges of arts and science and teaching. Every major initiative to increase the importance of teaching on our campus started in the college of arts and science. The college of arts and science was the first unit on campus to demand that every personnel action had to include at least two different kinds of evidence to evaluate teaching. It passed unanimously in the college of arts and science and then it went to the rest of the campus. It isn't fair to say that there is no demand within colleges of arts and science to improve what we are doing on the educational front. Combining what we are trying to do with what the college of education is trying to do in training teachers is a completely different matter. We have had some long, hard, and fruitful discussions based on our commitment to improve teaching, because it was already clear that everyone wanted that to happen. Teaching, as a discipline, is not confined to colleges of education; colleges of arts and sciences may be just as interested in the discipline and scholarship of teaching.

Watson: Our goal at NSF is certainly not to contrast colleges of education and of arts and sciences, but to do what we can to facilitate collaboration in K–12 teacher education. There is no general basis for saying that improvements are greater in one or the other of the two places. There are lots of good efforts in both. I will add a reference to graduate students from an NSF point of view. In the undergraduate faculty enhancement program, whose purpose is to help get and keep college and university faculty up to date in teaching and in their subject fields, there is this year for the first time an invitation for projects targeted at improving graduate student teaching and knowledge of pedagogy.

Malcom: These discussions have been rich and fruitful, and it is impossible to capture all of the things that have happened in a brief report. If, when you get back home, you act on an idea you have gotten here, please let us know. It is important that we continue this dialogue, but one of the justifications for continuing is that it be useful and one measure of usefulness is follow-on action. *[Editors' note: Readers who were not at the forum are also invited and encouraged to share your results with us, if you act on an idea from this report.]*

Text of Presentations

What is a good teacher?

Charles W. (Andy) Anderson
Michigan State University

I want to begin by noting that I think there is a problem in talking about a "good teacher" in the singular. I want to talk about the scholarship of teaching, and like other forms of scholarship, good teaching cannot be done alone. Throughout these remarks, I will share with you examples of good teaching, which show that teachers need to share their work with others in order to become teacher-scholars.

Student Understanding

I would like to start with an example drawn from my own experience at Michigan State University. I am working with several colleagues to improve the teaching of Michigan State's two-semester introductory chemistry sequence, which enrolls about 1,800 students each semester. There are four lecture sessions of 450 students each, and ninety recitation sessions of twenty students each. A laboratory is conducted separately which some students are taking concurrently. Each section attends three one-hour lectures a week and one hour-long recitation session. In this way, all these 1,800 students are somehow supposed to be learning chemistry.

Not long ago, students would come into the recitation session and the graduate assistant who serves as the session leader would ask: "Any questions about homework?" The students would then proceed to talk their way through the homework problems. Everybody thought it was pretty dull. So some of the course faculty and staff recently started doing things differently in the recitation session. Now the session leader begins the recitation session with a question that requires students to think and to show or write. The twenty students in the session work in groups of three or four to come up with a response. The students' group responses represent the collective best thinking of the members of the group. I would like to discuss some examples of how students responded to these questions in Chemistry 142, the second course of the sequence.

One question, for example, asked students to draw three molecules of hydrogen bonded water (a topic they had "covered" in Chemistry 141). Only about eighteen percent of the groups came up with something roughly resembling what chemists think hydrogen bonding means. They showed hydrogen bonds as somehow connecting one water molecule with another water molecule. The rest had all sorts of interesting, but incorrect, interpretations about hydrogen bonding, none of which has to do with connecting the hydrogen of one molecule with the oxygen of another. Some of them, for example, just drew a water molecule separately and said the hydrogen bond is the bond between the oxygen and hydrogen. Others had the idea that some molecules get an extra bond between the oxygen and the hydrogen. Others came up with really imaginative ways of putting them together with double bonds, triple bonds, and all sorts of interesting things.

Another question concerned polluted air. Students were given some information about polluted air and were asked to draw a picture of the molecules of this polluted air. Fifteen percent of the groups came up with something that roughly resembles what you might expect. They showed separate molecules in a homogeneous mixture in about the proportions that were given. Others groups sort of drew one of each molecule. Then there were groups that just gave up on this molecule stuff. A few put it all in layers — oxygen in one layer where you can breathe, the ozone as the layer on top, and the other molecules somewhere in between. And then about one out of every four groups did fascinating things trying to figure out how to fit all into one great big molecule.

Chemistry 142 students, then, passed Chemistry 141 in ignorance of some basic chemistry concepts. It is very possible for students to pass tests without understanding much of anything at all. Here is an example, attributed to Judith Lanier, of how that happens.

The Montillation of Traxoline

"It is very important to learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then bracter it to quasel traxoline. Our zionter lescelidge may make traxoline one of our most lukizes snezlaus.

Now try answering the questions below:

- What is traxoline?
- Where is traxoline montilled?
- How is traxoline quaseled?
- Why is it important to know about traxoline?"

Most students can answer these questions. Like the rest of us, they have a set of well-developed strategies for producing correct answers to questions that they don't understand. While this is sometimes a useful skill, we aspire to more in our science and mathematics classes. To achieve our goals, however, we will need new and more scholarly approaches to teaching.

The Scholarship of Teaching

Providing evidence of unsuccessful teaching may seem a peculiar way to begin a talk on what makes a good teacher. I want to make a case, however, that the faculty and staff in the example from Michigan State are beginning a process that will make them better teachers and will make Chemistry 141/142 better learning experiences. This process embraces *definitions of proper student learning, development of teaching strategies and materials*, and *qualitative assessment of student learning*. The examples from Chemistry 142 concern qualitative assessment. The course instructors are using those assessments not only to measure student learning, but to think about new teaching strategies and materials. We are also using these assessments to think about goals for student learning — what is important for us to teach in this course and what is achievable. The three objectives reinforce one another as we work back and forth among them. At Michigan State, engaging in this process will improve our teaching and make Chemistry 141/142 better courses. But I don't think that this process, in itself, can be termed *scholarship*. To be considered scholarship, those engaging in this three-part process need underlying principles and tools, as well as the opportunity to interact with others engaged in similar activities in other places. I believe that teaching needs to become a scholarly activity so that those of us who teach, either at the K-12 or at the college level, can do a more effective job. And I would like to mention some of the principles and tools that show promise for improving the quality of our teaching.

Goals for Student Learning

During the last decade we have made considerable progress toward consensus about the science and mathematics curriculum at the K–12 level. This progress can be seen in several resources that are now available. One set of resources consists of two publications issued by Project 2061 of the American Association for the Advancement of Science (AAAS). In 1989, AAAS released *Science for All Americans* which defines what students should have learned by the time that they have finished high school. Following this report, Project 2061 published *Benchmarks for Science Literacy* (1993), which lays out steps and milestones for implementation of *Science for All Americans*. Three publications issued by the National Council of Teachers of Mathematics (NCTM) also reveal a convergence of opinions. In 1989, NCTM released *Curriculum and Evaluation Standards for School Mathematics, Professional Standards for Teaching Mathematics* followed in 1991 and *Assessment Standards for School Mathematics* in 1996. The National Academy of Sciences has just published the *National Science Education Standards*. These documents and others have a good deal to tell us about tools and principles for goal setting, assessment, and strategies and materials for science teaching.

These publications all make serious attempts to specify what it means for the students to *understand* course content, as opposed, say, to just memorizing by rote for the test. Understanding is not all-or-nothing — there are degrees of understanding. I find it useful to measure understanding by the *usefulness* and the *connectedness* of students' knowledge.

A component of understanding something is to be able to use it for its intended purposes. To understand hydrogen bonding is to be capable of using it to explain why water has a high boiling point or how two molecules are held together or why alcohols have higher boiling points than ketones or things like that. If connectedness — the ability to see connections among various ideas and, in particular, between the ideas that come of experience and the scientific ideas under study — is added to usefulness, then a student achieves understanding. And so, to return to the example of air, when students get information about the composition of the air, they have to be able to connect that information with other ideas about air that they have encountered.

Qualitative Assessment of Student Learning

These ideas about understanding have been around for a long time. What is different now is that we are making progress in developing a technology to describe and assess what useful and connected knowledge looks like when people have it. During the last fifteen years, educators also have made a great deal of progress in assessment of what students understand, rather than only of how wide is their superficial knowledge. A variety of techniques are available, including the ones I have already mentioned: asking students questions with open-ended responses that require drawing, writing, and applications of ideas.

These qualitative assessment techniques have produced a growing body of evidence that while teachers are covering much content students are filled with misconceptions about the material. Many teachers, including science faculty responsible for teaching undergraduates, show a lot of resistance in believing this about their own students. They evidently believe that any lack of a true understanding of content is because others are doing a poor teaching job. In their own classes, however, they are confident that course content is explained in the right way and the students understand. Qualitative assessment methods can help them see that the problem exists in their own classes.

Teaching Strategies and Materials

What can we do differently? The reform documents I mentioned all have recommendations about how we can change our teaching. These recommendations in the various documents may look different, but they all have a common base. The apparent differences are attributable to the absence of a common language. One point in common is an emphasis on offering students "worthwhile mathematical or scientific tasks." This refers to introducing tasks that challenge and help students make *connections* and *use* their knowledge. Another important thing to do is re-examine the way that teachers talk to students and the way the students talk with teachers. Even within large lecture sessions there are ways to change the classroom discourse. For example, in Chemistry 141/142 at Michigan State, one lecturer asks an open response question at the end of every lecture. Every student who returns a response receives one point of credit toward the grade. Flipping through the stack of these bubble sheets with written responses for a few minutes after each lecture provides the lecturer with a good idea of the students' understanding of the lecture. Simple methods such as the one described above create learning environments that are more sensitive to students and more conducive to two-way communications between students and teachers.

This leads me to a major point about analysis of teaching and learning. Individuals teaching in isolation are rarely capable of developing effective goals, teaching strategies, and assessments. Effective teaching is a communal enterprise.

I think a medical analogy might be useful here. Sometimes a physician will base a treatment on a diagnosis that another doctor has made. Similarly, one teacher could make use of an assessment by a colleague that reveals what students are failing to understand. Without a diagnostic scheme linked into the dynamic system we have described, we have the educational equivalent of patent medicine. In general, patent medicine assumes that there are easy answers to complicated problems and that there is a single treatment that is going to work for everybody. I suggest this is as inappropriate for education as it is for medicine.

Barriers

But there are significant difficulties in improving teaching and the scholarship of teaching. Much solid evidence indicates that although college students — including prospective teachers — take science and mathematics courses and pass them with respectable grades, they leave those courses with the same misconceptions about the content that they had at the beginning of the course. The academic community seems to sidestep the problem rather than face it. The reason for this can be found in the values of academe and the priorities of the faculty.

For one thing, faculty members identify themselves with a disciplinary community and with research, not with teaching. This is closely linked with a faculty predisposition to see accommodation to student difficulty as a threat to rigorous standards. The failure of some students is seen as inevitable while sensitivity to the adverse effects of failure is seen as advocacy of a softer, weaker standard that coddles students. Having students draw pictures or tell stories are frequently perceived as "soft and mushy stuff." The prevailing commitment is to the "hard stuff," like real achievement data and multiple choice tests. The scores tell the teacher what grade to give. While these ideas about rigor may be appropriate for students headed toward advanced graduate work in the disciplines, they are misguided and counterproductive for future teachers. True rigor in teaching lies in engaging students in the hard work of improving their understanding, not just in punishing them for failing to understand.

But the students also present problems. Data on college student attitudes show that many students have negative attitudes toward science, ranging from mere distaste to real fear. While this might be interpreted as evidence of laziness, it also suggests *alienation*.

Two communities, scientists and students (some of whom will be K–12 teachers), are mutually alienated. Too often, the result of this mutual alienation is a traxoline-like "compromise" that allows one side to pretend to teach while the other pretends to learn. Then each side can get out of the other's way as quickly as possible.

Recommendations

To create communities that nurture a culture of teaching as scholarship, administrators have these tasks:

- Development of a reward system that supports good performance in teaching, and scholarly work in teaching.
- Encourage communities of teaching as scholarship within institutions that include colloquia, seminars, and discussions for faculty and graduate students along with time or work-load credit for discussion, debate, and empirical work.
- Nurture communities of teaching as scholarship across institutions that include contact and communication through publications and professional meetings with others teaching similar courses in other places; and provide opportunities to share work and ideas.
- Make available worthwhile educational research, new teaching methods, materials, and technologies.

We know quite a bit about how to improve science and mathematics teaching and learning, but this knowledge is not easily translated into action. To do so requires not only new ways of acting in the classroom and new ways of thinking about teaching and analyzing teaching, but institutional support for values and communities that are larger and more robust than the supporting communities are now. Formidable budget constraints and many competing demands make this an especially difficult time. But we must respond, for the rewards for success and the penalties for failure are great.

Discussant: William Badders

I have been asked to reflect on some of the significant events of my teaching career in the hope that this may give you some perspective on the experiences that shape classroom teachers. I had been teaching at the elementary school level for about seventeen years when I became involved in a major K–6 science curriculum development project funded by the National Science Foundation, which resulted in the creation of the Insights Elementary Science Program. The project, which began in the summer of 1988 and continued through 1993, was managed by the Educational Development Center (EDC) Newton, MA, and brought together a group of fourteen teachers, along with consultants from the Cleveland Education Fund to develop, field-test, and pilot inquiry-based science materials for elementary-age students.

The work of the project was significant because we began by meeting with other professionals and thinking about what we were doing in the classroom. Of course, I had done some reflection informally with other teachers, such as in the lunch room where an instructor complains about the kids and somebody's brother and somebody's mother, and so on. But until that day at EDC I had never really sat down with other teaching professionals and talked about what and how I taught. Most school districts, both urban and rural, do not have structure to encourage teacher reflection and collaboration.

During that first summer, the teachers involved in the project spent a lot of time examining curriculum, studying inquiry, and practicing hands-on science activities. When I returned to the classroom in the fall, I began using the content and methods we had talked about during the summer. I thought I had learned a great deal, but I slowly realized that I had only learned mechanical applications for hands-on science materials. I did not have any deep understanding of inquiry. My questioning strategy was weak. I lacked content knowledge. I did not understand assessment, and I had not addressed my own misconceptions in science. All of these weaknesses hindered my ability to do inquiry science with children.

The lack of a content background in my training is important to highlight. As an elementary school teacher with a strong language arts background, I came to realize that content understanding was critical to my ability to provide the children in my classroom with good opportunities for inquiry. The depth and breadth of the content I needed to know was directly related to the age of the children I was teaching. The level of content understanding for teaching a first grader about forces and motion would differ from that in teaching a sixth grader about those same concepts. It also became clear that my content training had to be connected to the actual teaching materials I was using in the classroom.

My work with EDC, although providing the oportunity to collaborate with other teaching professionals, made me aware that there was no support community for me as an elementary school teacher. When I realized that there was so much more to learn and to do in order to be effective in the classroom, I began to search for ways to learn more about the craft of science teaching. I went to professional meetings and summer institutes funded by NSF, colleges, and universities. I found the intensive, lengthy summer institutes valuable to increasing my understanding of every area of science. I targeted programs addressing physical, life, earth and space science because I did not have that content, and my school system was unable to provide me with it.

I learned through these professional development programs that there is a bewildering array of issues with which teachers must be familiar. Teachers must know about constructivism, inquiry, content, questioning, assessment of skills, classroom management, preparation of materials, equity research, learning cycles, interdisciplinary approaches, cross-curricular methods, selection of materials, pedagogy, facilitation, curriculum planning, and appropriateness to the age of students. Teachers must know about state and national education goals. And, of course, I have only mentioned what a science teacher must know!

Along with the Presidential Award for Excellence in Elementary Science Teaching that I received in 1992, came a $7,500 grant which I used to form a study group for ten teachers. Our group has spent the last four years exploring and reflecting on our teaching. I used the $7,500 grant to provide the mechanism to involve group members in state and national professional organizations for science teachers and to provide them with support to attend conferences. The information that had been acquired, both collectively and individually, was then shared in our meetings. For instance, if we went to a seminar about constructivism, then we talked about how constructivism is reflected in our classrooms. We studied the use of science portfolios in the elementary school. We discussed and practiced the use of exemplary science materials. We practiced inquiry strategies. And we have continued that kind of study.

Even after the money from the grant ran out, the group decided to stay together. Teacher networks, particularly in urban settings, are often marginalized. Teachers are seldom asked what we think about new curriculum or standards. We feel that our group is important to our work and that it established a community of learners for us. As a result, our group of ten has been meeting about once or twice a month for the last four years. At this point, I want to emphasize that because professional development must take into account the deeply personal nature of improvement in teaching, it cannot be mandated. The ten teachers in our group have made a choice to participate in a collegial process of self-reflection and self-evaluation about their teaching and to search for professional experiences that their undergraduate training and school district staff development did not and cannot provide. So in thinking about how to structure programs between colleges of arts and sciences and colleges of education that will enhance the preparation of elementary science and mathematics teachers, consideration must be given to increasing knowledge of the content of science and math, while the emphasis continues to be on inquiry-based teaching in the elementary classroom.

Discussant: Susan Henry

Carnegie Mellon University (CMU) does not produce many teachers. In fact, CMU does not have a college of education and its Science College has other priorities such as training research scientists and mathematicians and providing science and mathematics instruction for engineering and humanities students. Nevertheless, for a number of reasons, CMU and other similar research universities have a vested interest in participating in discussions about preparing science teachers, as well as other related topics addressed at this forum. I have outlined some of these reasons why research universities have a vital interest in the broad discussion of science education.

It is crucial that we develop a collegial environment and partnerships for science education which span all levels — elementary school through college. This collaboration and communication needs to be in both directions. University and college faculty need to know what kind of preparation students have received before they arrive at college, and teachers at the secondary level need to know what knowledge and skills the university faculty expect to see in the freshman class. In research universities like my own, the faculty have very little knowledge of our students' pre-college academic work. Collaboration with colleagues working at the K–12 level can give university faculty this invaluable understanding and perhaps influence the form and content of pre-college science and mathematics education.

We also need to share, across the grade levels, information learned about effective teaching strategies and assessment procedures. There is currently a great deal of emphasis on reform of K–12 education in science and mathematics. This discussion needs to be coordinated with the parallel and related discussion ongoing at colleges and universities. At CMU, for example, we have been much concerned about high failure rates in mathematics and science courses, particularly at the freshman level. I know that these same discussions go on at universities and colleges all over the country. One of the most urgent and immediate reasons for this discussion is the effect high failure rates have on college attrition rates. Since attrition rates affect position in national ratings such as the annual *U.S. News and World Report* rankings of institutions and programs in higher education, this issue has been pushed to the forefront among the concerns of university administrators.

When the issue of freshman failure rates came to the forefront as a major university concern several years ago, the first reaction at universities was often that the high failure rate was the fault of the students: if students worked harder or were better prepared, they would not fail or, alternatively, if the admissions staff recruited better students, then failure rates would decline.

Until recently however, university faculty have not commonly approached the issue of failure rates in freshman mathematics and science courses as a problem amenable to systematic application of pedagogical methods and research. At CMU we have been working systematically to determine the reasons for high failure rates in freshman courses. We have developed data that indicate that the entering class is far more heterogeneous in educational achievement and experience than SAT Scores or high school records predicted. For this reason, our Department of Mathematical Sciences now routinely assesses student mathematical competence at the beginning of the freshman year and then administers gateway examinations during the first semester. We now have data indicating what students know when they begin a course, as well as when they complete it, so that we can determine they have actually learned. These data have been instructive for faculty members in designing courses and evaluating the success of new curriculum components and teaching methods.

In general, university faculty are coming to appreciate the role of assessment in determining not only a student's grade, but also how effective the teaching has been. Our colleagues at the elementary and secondary levels more routinely use assessment in this way and are much more accustomed than university faculty to approach pedagogy in this fashion. Assessment is, therefore, an important issue for educators at all levels and much of what we are discussing at this meeting is just as significant for college teaching as it is at the elementary and secondary levels. It would be extremely valuable if there were more forums, nationally, where educational issues of this sort could be shared across the K–12 and college levels.

All of us have a responsibility to develop collegial environments to support one another as educators. Research universities, which in response to requests from students are beginning to play a role in training teachers, are seeking such cooperation.

Although CMU does not have a formal teacher education program, we are beginning to feel its absence. Many of our undergraduate students wish to pursue teaching careers when they graduate from CMU, and until recently, we did not have any way of providing them with the appropriate background for doing so. For this reason, we began to forge alliances with local colleges and universities that offer formal teacher training. I suspect that similar collaborations are being formed at other research universities that, until recently, had no formal involvement in teacher training.

Because of the strong interest of many CMU faculty in pedagogical research, particularly in our Department of Psychology, CMU has recently formed the Center for Innovation in Learning (CIL) to promote interdisciplinary research in education. Graduate students studying for Ph.D.s and Master's degrees can now receive training within a discipline while doing research at CIL on problems in teaching and learning.

Our university, like many other research universities, is already active in K–12 education partnerships. For example, we are working with the Pittsburgh public schools to provide an in-service program for all high school science teachers that will enhance their computer skills in the science classroom. This program, called the Science Education Partnership Awards (SEPA), was initiated in 1991 and is supported by grants from the National Institutes of Heatlh and the Howard Hughes Medical Institute. The program has enabled us to put together a true partnership between high school teachers and CMU faculty members.

In this partnership, our faculty have learned more from the teachers than the teachers have learned from us. CMU faculty who participate in the SEPA Program experienced for the first time some of the obstacles that prevent secondary school teachers from improving or changing the way that they teach. For example, CMU faculty believed that in order to improve computer skills, participating teachers had to have access to computers and the Internet in their own schools. But this was initially difficult or impossible because the Pittsburgh Schools had frozen the purchase of new computer equipment and few, if any, modems or telephone connections were available in classrooms. Thus, most teachers could not have access to the Internet even if they had a computer. To overcome these problems, we worked in partnership with the schools and the business community. The local business community made donations of used computers for the teachers' use and our students retooled the computers, adding applications useful for the teachers. The computers were then placed in classrooms and a collaborative grant from AT&T provided telephone connections and modems.

Recently, in another example of a partnership with a different kind of educational institution, CMU faculty from the Colleges of Science, Fine Arts, and Computer Science formed a collaboration with the Carnegie Science Center and received a grant from the National Science Foundation to produce a show for the planetarium entitled, "Journey Into the Living Cell". This interactive, three-dimensional exploration of the cell, using images derived from our research laboratories, is thrilling children of all grade levels in Pittsburgh and will soon travel nationally. In partnership with K–12 educators, we will be preparing educational materials derived from this show to use in their classrooms.

Although these partnerships are but limited examples of the kinds of collaboration possible between research university faculty and educators at other levels, I believe that more research universities should become involved in these partnerships. Science deans and Education deans need to come together more often to look at how we can work with K–12 teachers and administrators to improve the preparation of teachers of science, mathematics, and technology. By working with the teachers, we help their students who become our students.

In the past, collaborations of the type that produced the SEPA program and the "Journey Into the Living Cell" were isolated examples of individuals brought together by idealism and chance. Now, however, the federal funding agencies are providing powerful financial incentives via their funding policies to promote such interactions. If a common concern for education does not bring us together across the disciplines and across the educational boundaries of elementary, secondary, and college education, then surely these shifts in funding and national priorities will.

To remain vibrant educational institutions, we must pursue this type of collaboration. Together as a continuum, we educate the students who become teachers and subsequently teach the students who come to college as freshmen. We must begin to see ourselves as interacting and collaborating members of a common enterprise. If we do not, we can blame no one but ourselves for the continuing problems facing science education at all levels.

Building Teacher Knowledge: A Principal Arena for Collaboration in Teacher Preparation

Jerome Odom
University of South Carolina, Columbia

Every university that is represented at this meeting has its own unique set of problems and opportunities, but we share much. We all perceive a real change in higher education today. It appears that federal funding may decline precipitously, the size of our faculties is shrinking, and we are being held more accountable by our constituents — be they legislatures, Boards of Trustees or alumni. We must adapt to this rapidly changing environment, and when I say "we," I am talking not only about the deans who are assembled here, but about our faculty. At my institution and in many of the institutions represented here, funding for new projects especially in an area such as teacher preparation projects is not available unless deans are willing to make some hard internal budget decisions and reallocate funds. Sometimes those are unpopular decisions with certain members of the faculty.

First, I would like to tell you how we are trying to solve the problem of preparing qualified K–12 science and mathematics teachers at the University of South Carolina. That will then lead to a more general discussion of how deans of science and deans and of education and their faculties can collaborate to improve teacher knowledge.

The University of South Carolina has just initiated a five-year program leading to the Master of Teaching degree. The program is designed for students who want a career in teaching science or mathematics at the secondary level. A student pursues a B.S. degree in the college of science and mathematics, majoring, for example, in chemistry or biology just like any other student in the college. In addition to the major, each student takes approximately twelve hours of undergraduate courses in the college of education. Upon receiving a B.S. in the major field, the student immediately begins taking education courses in the summer. Students take nine to twelve hours of education courses during the summer, and fifteen hours of education courses during each of the next two semesters. In the fall semester they also begin a year-long internship program in local schools. As an undergraduate, each student has an advisor in his or her major department. Upon beginning the fifth year with its emphasis on education methodology, the student is assigned an advisor in the School of Education.

Although the five-year degree appears to increase the cost to students to become teachers, there are advantages. Students have multiple career options. The starting salary in the State of South Carolina for a teacher with a master's degree is about $3,000 per year higher than for the holder of a bachelor's degree. A student, moreover, can obtain loans for all five years.

This program has created an opportunity for greater collaboration between education faculty and science faculty. At the moment, however, the degree of collaboration is lower than I would like. The science and mathematics faculty have decided that their involvement in shaping teachers will be minimal. They will provide students with a content background, but they want the students to go to the college of education for the professional part of their programs. This situation has been very disappointing to me.

We are here to talk about how we can change this attitude. But at the same time, I think, everybody here who is a dean of arts and sciences knows the problems that we and the faculty face. The faculty are war-weary. We are making many demands on our faculty right now. For example, we are asking them to write more and bigger proposals and produce more publications. But the faculty are very protective of their time, and the deans are very protective of their resources. Thus, we face a problem when we ask science faculty to participate in a program that takes time away from writing grants and papers.

We all know that the reward structure in research universities clearly favors those faculty engaged in research, sitting on editorial boards, bringing money into the university. It does not favor those dedicated to good teaching; it does not favor those who are receiving good teaching evaluations from students or their peers. This is an issue that must receive our attention. I could go on and on, but it is clear why the faculty rebel when their dean asks them to become involved in yet another activity that they perceive to be a significant consumer of their time offering little in the way of reward.

Much of the impetus for change is going to have to come from the top. We must seek the support of presidents and provosts to endorse a change in the reward system to allow us to be creative in teacher preparation programs and new degree programs. The master of teaching degree that I described has fostered some interaction among faculty, but the interaction is limited; we need much more. Here are some suggestions for how we might do this.

- Research experiences for all undergraduate students, particularly prospective teachers. These experiences expose prospective teachers to scientific inquiry. Teachers who work with their students will be able to impart to them the excitement of scientific discovery.
- Science education researchers in science departments. Science education researchers interested in obtaining grant funds in education and in publishing peer-reviewed re search are assets by their colleagues in science departments because they are produc tive in normal professional activities and can be used as information sources with re spect to teaching. They can work with science faculty, particularly through team teaching, to improve science instruction.
- Joint appointments between the college of education and the college of arts and sciences. These individuals serve as bridges between what can be conceived as two different cultures.
- Department of science education in the college of arts and sciences. I am unclear about the success of this approach, and I would be interested in hearing from deans who find this arrangement fruitful.
- Collaboration between the college of education and the college of arts and sciences in the inservice education of science teachers. The University of South Carolina has a successful project led by a chemist and an educator to provide a master's degree course for prospective science teachers.
- Collaboration with K–12 schools. Partnerships with local schools will give preservice teachers an extensive school experience that is essential for their preparation.

At a recent conference in Tucson, Arizona concerning the pursuit of a competitive research and development agenda, it was noted in a panel discussion that sixty percent of science and mathematics teachers in the United States did not major in the subject in which they teach. If we assume that this statistic is correct, then that reality represents a major problem. We, as deans, are the problem solvers. I believe that close collaboration between the college of arts and science, the college of education, and local schools provides a way for universities to prepare qualified teachers who are excited about science and mathematics and will be able to convey this excitement to their students. As deans, we must make the time and resources available to faculty who wish to participate in this important collaborative effort.

Discussant: Jo Ellen Roseman

I want to make two points this evening. First, science illiteracy is rampant in this country. And second, Project 2061 is developing tools to help educators, including college faculty and administrators, promote science literacy.

Most college students lack a basic understanding of science concepts even after successfully completing course work in science. As *A Private Universe* videos demonstrate, many students — even from our most selective and prestigious universities — display misconceptions about natural phenomena after completing an entire baccalaureate program. (Developed by the Annenberg Foundation and the Corporation for Public Broadcasting, the videotapes in the *A Private Universe* series demonstrate how children's misconceptions about science persist in the face of typical, but inadequate, instruction over many years in school.) Addressing science illiteracy is more than a question of improving science courses for prospective school teachers, however; arts and science education must do a better job of preparing all of its graduates — citizens, future parents, and prospective politicians alike — to understand and make informed decisions about science and technology.

In one of the recent *A Private Universe* videos, an interviewer asks students graduating from Harvard University and the Massachusetts Institute of Technology to explain where a log derives its mass, given that it started out as a very tiny seed. Every graduate refers to water or to the soil, but not a single graduate talks about the mass composed primarily of carbon derived from the air's carbon dioxide. The graduates are then queried further by the interviewer, some of them confronted with the notion that the mass of the log is derived primarily from carbon. Puzzled, one graduate asks how carbon dioxide could be the primary constituent of the log when that same volume of CO_2 would not hold much mass at all. Other graduates appear puzzled, even shocked , that air could play such a role. The videos are pretty startling.

The videos illustrate that these students, many of whom have had college science courses, have learned many science terms and concepts but are unable to put them to practical use. Apparently, they have never been asked to use what they learn in their science courses to explain scientific phenomena. I would argue that we can add many courses to the undergraduate curriculum in an effort to better educate our students, but if faculty do not change fundamentally what students are doing in those courses, we will not improve the learning of prospective teachers, parents, politicians, or anyone else who enters our institutions of higher education.

Now for my second point, that Project 2061 is developing science literacy tools helpful to higher-education faculty. The Project's 1989 report, *Science for All Americans*, recommends a coherent set of science literacy goals for high school graduates. These goals serve as minimum requirements for all high school graduates. However, when we consider how Harvard and MIT graduates respond to rather basic questions about science, the goals in *Science for All Americans* seem rather ambitious even for college graduates.

Project 2061's 1993 report, *Benchmarks for Science Literacy*, provides further help to curriculum planners. It lays out learning goals for earlier grades that build toward the goals for adult science literacy in *Science for All Americans*. (The National Research Council's *National Science Education Standards* does likewise.) Project 2061 is also about to release a set of CD-ROM tools, *Resources for Science Literacy: Professional Development* and *Resources for Science Literacy: Curriculum Materials*, that should be useful in improving college courses. The first contains a variety of databases (including one on science trade books, and another on college course syllabi) to help users improve their understanding of concepts central to science literacy. The second offers a procedure for analyzing and improving curriculum materials around specific learning goals, as well as sample analyses of some popular curriculum materials.

Systemic reform calls for changes not only to the K–12 curriculum and to teacher preparation programs, of course, but to all areas of the education system, including education research, finance, policy, resources and technology, school organization, and so on. Several of the policy documents prepared for Project 2061 by experts in these areas (and eventually to be published together as *Blueprints for Reform*) might be of particular interest to higher-education faculty. For example, our *Teacher Education Blueprint Report* and the *Higher Education Blueprint Report* summarize many of the problems discussed already at this Forum.

Finally, Project 2061 has begun working with a number of colleges and universities that are interested in reforming teacher preparation and undergraduate education. We hope that Forum participants working to improve teacher preparation and undergraduate education will stay in touch with us and consider contributing innovative syllabi to *Resources for Science Literacy* (which we will update in a few years).

Project 2061 and related reform efforts have laid the groundwork for reforming K–12 education around explicit learning goals for science literacy. In recent years, a number of colleges and universities have also begun to rethink, seriously, their science, mathematics, and technology curricula. Now is a good time to start coordinating reforms — in K–12 education, higher education, and teacher education — for the greatest benefit to all students. Project 2061 reform tools can help educators at all levels to recognize and work toward shared goals.

Discussant: Frank Murray

Congratulations to Dick Ishler and Jerry Odom on starting a master's program for teachers. At the University of Delaware, we discussed starting a similar program, but when I heard it pronounced the MT degree (empty degree), I lost confidence and we changed it to the masters of instruction, the MI degree.

I think I can respond best to the general themes Jerry Odom raised in his remarks by talking about the Project 30 Alliance, because Project 30's goals are similar to those of the program at the University of South Carolina. The Project 30 Alliance is an organization of about forty colleges and universities devoted to the reform of the arts and science component of the teacher education program. Each university is represented by teams of faculty from arts & sciences and from education. The goal of Project 30 is to improve the education of teachers; it does so by providing a penetrating analysis of the function of the education of prospective teachers at the college level. Membership in the Project 30 Alliance is open to any postsecondary institution with the equivalent of a college of arts and science and a college of education. The current president is Roger Kova, a chemist at the University of Northern Colorado. Jon Englehardt, executive dean of education at the University of Northern Arizona, is secretary-treasurer.

The Alliance is dealing with four basic issues:

1. We want our students to be educated in material they are *not* going to teach, which some universities refer to as general and others as liberal education. We want the student to have a broad store of basic knowledge and a lively mode of intellectual inquiry, even about matters the student may never be specifically charged with

teaching. The Project 30 Alliance has a number of members dealing with this issue as well as the difference between general education, which is about information, and the liberal education that is about the point of things.

2. How are students to be prepared in the subject that they will be teaching? An academic major is the usual answer to this question. But it is not a good device. It turns out that people who complete the major are unable to stand up well to young children's questions about it. At the University of Delaware, we addressed the issue of what is an appropriate academic major for an elementary school teacher. Such programs generally do not exist and have to be invented.

3. We are concerned for a pedagogical content that is the interplay between pedagogy and subject. It is hard to find a literature that supports our decisions here. While teaching about electric current in physics, a teacher might use a hydraulic metaphor. Are metaphors like this any good? Where is the literature to help us decide this? In teaching division by fractions — three quarters divided by one-half — a student asks for a real-world example. That's a fair question. It is very hard to come up with multiple representations of that situation, but it is the teacher's stock in trade. Connecting division of fractions with division of pizza pies or using a balance scale to represent an equation in algebra — are these productive? Millersville paired with an education professor a mathematics professor teaching the general education mathematics requirement. The education course, paired with the mathematics course, was a seminar that discussed the mathematics professor's teaching. It was a great success. The mathematics professor discussed such things as why he had made the decisions he made in teaching his course. Meanwhile, the education professor was placing the issues being discussed in the context of the education literature. Our field is desperate for high level scholarship on these questions.

4. The curriculum that is taught in the public schools and the universities is largely ethnocentric. Other voices need to be brought in. This issue is substantially related to that about content pedagogy and refers to how subject matter knowledge is both corrected by the recent scholarship and tailored to the needs of students who are very different from their teachers. The Project 30 Alliance believes these are the right questions and that it is productive to address them vigorously.

University, School and Community Collaboration*

Rodney J. Reed
The Pennsylvania State University

As we face the millennium, we can acknowledge that the 20th century was a period of significant progress in science and technology, in health care and medicine, in economic growth, and in the general expansion of knowledge. Yet as we face the future, we do so with some unease: We find a growing mistrust of government by the American public (The Washington Post/Kaiser Family Foundation/Harvard University Survey Project 1996); social and political upheavals throughout the world; growing economic disparity between the "haves" and "have-nots," between developed and third world countries, between those with power and privilege and those without these advantages. We find a society characterized by increasing levels of intolerance and racism, growing percentages of individuals who do not participate in civic, social and political activities, and, high levels of concern about the quality of our public educational system. In fact, "Two-thirds of American voters surveyed in a recent USA Today/CNN/Gallup Poll list the quality of public education as their top national priority." In this national poll, education emerged as a priority for the first time and was listed by 67 percent of those polled, over the usual priority areas of crime, the economy, health care and drug abuse.

What causes many to question the quality of schooling received by our youth, and the educational process that occurs outside the formal school setting, is the recognition that all students must be well educated in the future, if we are to maintain our democratic ideals, continue our scientific technological and social progress, and remain a competitive force in the emerging free market world-wide economy. The AAAS Project 2061 reminds us in its publication, *Benchmarks for Science Literacy* (1993), that:

> *The terms and circumstances of human existence can be expected to change radically during the next human life span. Science, mathematics and technology will be at the center of that change — causing it, shaping it, responding to it. Therefore, they will be essential to the education of today's children for tomorrow's world.*

As we face the future, we also must recognize that children in tomorrow's world must be citizens who value equity, diversity and social justice, who embrace democratic principles and civic responsibility, and whose humaneness is forged and tempered by tolerance and respect for others, and by an appreciation of the humanities and the arts.

Today's children and youth, however, are challenged by a number of problems which unless successfully addressed, will prevent the level of educational attainment necessary to achieve societal and individual goals. Hodgkinson highlights some of the causes of problems affecting our children and youth that serve as barriers to educational attainment and success. Although the statistics reported are a few years old, they nevertheless represent the magnitude of the problems associated with our children and youth (Hodgkinson, 1991).

* Not to be quoted without permission of the author.

Problems . . . Where They Begin

- *Each year, about 350,000 children are born to mothers who were addicted to cocaine during pregnancy. Many of the surviving children have strikingly short attention spans, poor coordination, and other physical problems, including drug addition.*
- *About 40,000 children annually are born with alcohol-related birth defects, which can cause a range of impairments, including mental retardation, hyper-sensitivity, and language problems.*
- *About 6.7 percent, or 260,000 children, are born each year with lower than normal birth weights. Those babies are one-and-a-half to twice as likely to need special education services.*
- *Twenty percent of America's preschool children have not been vaccinated against polio.*
- *One-fourth of pregnant mothers get no physical care of any sort during the crucial first trimester of pregnancy. About 20 percent of handicapped children would not be handicapped if the mother had received just one physical examination in the first trimester.*
- *Since 1987, one-fourth of all preschool children in the United States have lived in poverty.*

In addition,

Problems Added to Problems

- *Still other problems have critical implications for a significant portion of the entire school-age population:*
- *In 1987, 2.2 million reports of child abuse or neglect were made to child protective service agencies. This was triple the number in 1976.*
- *Today, 15 million children are being reared by single mothers, whose average family income is about $11,000. This is within $1,000 of the poverty line, which in 1988 was set at an annual income of $10,000 for a family of 3. (The average family income for a couple with children was slightly more than $34,000 per year in 1988.)*
- *At least 2 million children of school age have no adult supervision after school.*
- *On any given night, from 50,000 to 200,000 children have no home. In 1988, 40 percent of shelter users were families with children.*

And if these problems are not enough, Acquired Immunodeficiency Syndrome (AIDS) is the leading cause of death among 29 to 44 year olds and the sixth leading cause of death among 15 to 24 year olds in the United States. Moreover, racial and ethnic minority populations have been disproportionately affected by HIV (Human Immunodeficiency Virus) infection and AIDS since the beginning of the epidemic in this nation. "Through mid-1993, 48 percent of all reported AIDS cases were among Blacks and Hispanics," although these population groups represent only 21 percent of the total U.S. population. Among children under 13 years of age, 79 percent of AIDS cases through 1993 were reported for African American and Hispanic children (Center for Disease Control and Prevention).

Another factor that serves as a barrier to achieving desired levels of educational attainment inheres in high school dropout rates (Hodgkinson, 1991). Of interest is the correlation between high school dropout rates and prisoner levels. States with the lowest dropout rates also have the lowest prisoner levels. Those with high dropout rates have correspondingly high

High School Dropouts

States with the lowest dropout rates also have the lowest prisoner levels. Those with high dropout rates have correspondingly high prisoner levels. Rates are given per 100,000 residents.

Lowest dropout rates (and lowest prisoner levels)		Highest dropout rates (and highest prisoner levels)	
1. *Minnesota*	*9.4*	50. *Florida*	*41.2*
2. *Wyoming*	*10.7*	49. *Louisiana*	*39.9*
3. *North Dakota*	*11.6*	48. *Michigan*	*37.6*
4. *Nebraska*	*13.3*	47. *Georgia*	*37.5*
5. *Montana*	*13.8*	46. *New York*	*37.1*
6. *Iowa*	*13.8*	45. *Arizona*	*35.6*
7. *Wisconsin*	*15.6*	44. *Mississippi*	*35.2*
8. *Ohio*	*17.2*	43. *Texas*	*34.9*
9. *Kansas*	*17.9*	42. *California*	*33.9*
10. *Utah*	*19.4*	41. *Alaska*	*33.3*
11. *Connecticut*	*19.5*	40. *South Carolina*	*33.1*
12. *South Dakota*	*20.3*	39. *Kentucky*	*32.6*
13. *Pennsylvania*	*21.3*	38. *North Carolina*	*32.2*
		Tennessee	*32.2*

Source: H. Hodgkinson, The Same Client, *Institute for Educational Leadership, Washington, DC, 1989, p.15.*

prisoner levels. As a consequence of high prison populations in many states, fiscal appropriations to build prisons have a higher priority than appropriations for education. This is ironic since the cost to construct a prison cell is five to six times as much as per-pupil-expenditures in public schools. Yet the educational dividends for investments in education significantly outweigh similar investments in prisons.

Of further concern is the fact that incarceration rates for African Americans and Hispanics are disproportionately high compared to their representation in the general population. This reality should be cause for alarm not only because of the societal and economic circumstances that are associated with incarceration, but also because the nation's future workforce must rely on people of color, most of whom, given demographic projections, will come from these two racial groups.

This brief contextual overview of some of the societal issues and challenges associated with our children, youth and young adults serves to indicate that before we can achieve desired educational results we must have the will to address systematically the many persistent problems noted that cannot be viewed as the responsibility of schools alone. There is some recognition of this actuality as schools become linked to social, health and community agencies. Using an integrated service paradigm, such full-service schools find strength through collaboration and have enjoyed a modicum of success.

A fundamental concern for us here assembled is how will schools meet successfully the national education goals that were formulated by the National Governors' Association in 1989 and reinforced and expanded in *Goals 2000: The Educate America Act* passed by Congress in 1994. Recall that these goals state that "by the year 2000 —

GOAL 1: *All children in America will start school ready to learn.*

GOAL 2: *The high school graduation rate will increase to at least 90 percent.*

GOAL 3: *All students will leave grades 4, 8, and 12 having demonstrated competency over challenging subject matter including English, mathematics, science, foreign languages, civics and government, economics, arts, history, and geography, and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our nation's modern economy.*

GOAL 4: *The Nation's teaching force will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century.*

GOAL 5: *United States students will be first in the world in mathematics and science achievement.*

GOAL 6: *Every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.*

GOAL 7: *Every school in the United States will be free of drugs, violence, and the unauthorized presence of firearms and alcohol and will offer a disciplined environment conducive to learning.*

GOAL 8: *Every school will promote partnerships that will increase parental involvement and participation in promoting the social, emotional, and academic growth of children.*

To achieve these goals means that as educators we must rethink the processes of teaching and learning. Schools and schooling of the future *must* include the creative uses of technology, *must* recognize the many talents and skills of students and build on these, *must* integrate in-school and out-of-school learning more effectively, *must* ensure that every child and adolescent acquire the skills, knowledge and attitudes necessary both to become productive and contributing members of our democratic society and to attain personal fulfillment and satisfaction, and *must* prepare students for lifelong, continuous learning.

To accomplish these imperatives means: 1) rethinking how schools are organized; 2) placing greater emphasis on student performance; 3) holding high expectations for all children and youth regardless of individual or group differences; and 4) through collaborative arrangements, bringing together and employing the resources of universities, parents, community and business groups, and other agencies and organization as appropriate.

To bring meaning to these imperatives, educational standards should provide the guidelines necessary to make decisions regarding the allocation of fiscal and human resources. In considering educational standards in these instances the following distinctions can be made among them:

content standards — what should be learned in various subject areas

performance standards — satisfactory levels of learning as measured by demonstrations, portfolios

opportunity-to-learn standards — the prerequisites for equal opportunities to learn; to meet performance standards

world class standards — expectations and content geared to best or superior academic performance based on international comparisons (Lewis, 1995).

In addition, these imperatives require colleges and universities, in partnership with schools, to prepare exemplary teachers. Such teachers will possess not only depth in content areas, but also understand curriculum and pedagogy, multiculturalism, human growth and development, and be committed to achieving excellence in the school performance of every student. Moreover, such exemplary teachers will give validity to the aphorism that one of the greatest professional satisfactions derives from helping children to grow intellectually, socially and emotionally. These teachers will also view continuous professional development as necessary to their success.

If constructive educational change is to occur, all facets of schooling, from preschool through postsecondary education, including the preparation of teachers and other education professionals, must be carefully and critically scrutinized. What is called for is systemic or coordinated school reform which incorporates in coherent ways all programs and activities associated with schooling, from preschool through postsecondary education, to reach agreed upon school outcomes. This is no easy task, but the quality of life and the quality of our society in years to come will depend on how effectively we can prepare future generations of students. At stake may well be the future of public schooling in our nation. The constant attacks on, and eroding fiscal support for, public education at a time when it is crucial to provide access, equity and excellence in the public educational delivery system are disturbing trends.

As we seek to attain educational excellence through reform initiatives, we must be mindful of experiences gleaned from prior efforts as summarized by Cetron and Gayle in their book, *Educational renaissance: Our schools at the turn of the century*. These authors cite nine lessons learned (Cetron and Gayle, 1991):

Nine Lessons Learned

1. RAISE EDUCATIONAL STANDARDS AT ALL LEVELS
   The one reality that teachers everywhere must accept if we are to make any great progress in educational reform is that few students who fail do so because they lack the ability to learn; they fail because teachers fail to teach them.
2. MAKE SURE SCHOOLS AND TEACHERS MEET NEW EDUCATIONAL LEVELS
   Accountability
3. SPEND MORE TIME IN SCHOOL
   All else being equal, the more time you spend at it, the more you will get done.
4. REWARD EVERYONE INVOLVED WITH EDUCATION FOR PERFORMANCE, NOT FOR THE TIME SERVED OR OTHER IRRELEVANCIES
   The reward system in our schools is wholly out of touch with the goal of learning.
5. ESTABLISH A COMPREHENSIVE NATIONAL PROGRAM OF PRESCHOOLS AND DAY CARE CENTERS
   When children who spend a year or two in a program like Head Start arrive in Kindergarten or first grade, they are better prepared to learn than those who miss that opportunity.
6. RAISE SCHOOL BUDGETS SO THAT WE CAN PAY OUR TEACHERS A LIVING WAGE AND GIVE THEM THE EQUIPMENT THEY NEED TO DO THEIR JOBS
7. USE COMPUTERS BOTH TO MAKE UP FOR THE SHORTAGE OF HUMAN TEACHERS AND TO TAKE ADVANTAGE OF THEIR OWN UNIQUE BENEFITS
   The question here is financial, not educational.
8. SEEK HELP FROM BUSINESS WHENEVER IT CAN BE HAD
   It is a resource that should not be overlooked.
9. IN ANY EFFORT TO REBUILD A FAILING SCHOOL SYSTEM, MAKE CERTAIN THAT EVERYONE INVOLVED HAS "BOUGHT INTO" THE PROGRAM
   It is seldom possible to impose reform from on high.

Additionally, the American Association for the Advancement of Science emphasizes that

> *Reform must be comprehensive and long term, if it is to be significant and lasting. It must center on **all** children, all grades, and all subjects. In addition, it must deal interactively with all aspects of the system — curriculum, teacher education, the organization of instruction, assessment, materials and technology, policy and more, all of which take time.*

To this view I would add that reform requires fiscal and human resources, and collaboration between and among schools, universities, community agencies and groups, businesses, private and philanthropic organizations, and professional associations.

Collaborative Educational Linkages

In these regards, let me now turn to the subject of collaborative educational linkages. The magnitude of the problems schools are being asked to ameliorate and eradicate cannot be accomplished, as earlier pointed out, by schools alone. It is essential, therefore, that interorganizational collaboration become a primary arrangement to achieve common goals.

Collaborative partnerships between schools and universities are not new. They have existed for more than one hundred years. As an outgrowth of the "Committee of Ten" which was chaired by Harvard's president, Charles Eliot, in 1892, conferences between school and university representatives were convened to examine curriculum and instruction and the improvement of teacher preparation. These conferences, however, led to the establishment of the College Entrance Examination Board and the development of the Scholastic Aptitude Tests. Conflicts arose, and might have been predicted, as colleges assumed the role of experts and manifested the attitude of we know best what is good for practice (Ludwig and Stapleton, 1991; Wallace, 1993).

Collaboration for educational aims takes many forms. Typically, we have seen partnerships and collaborative endeavors between education faculty and engineering or arts and sciences schools and colleges, schools and businesses, schools and community groups or agencies, schools and governmental agencies, and schools and reform groups. Sometimes such linkages are designated as alliances or coalitions. Whereas one might draw distinctions between partnerships, alliances, collaboratives, coalitions and the like, in my view it is useful to think of these arrangements as external or internal linkages. External linkages include those such as previously mentioned. Internal linkages include, for example, cross disciplinary, interdisciplinary or interinstitutional associations, as well as collaborative and cooperative learning, cross-age tutoring and counseling, and team teaching.

In establishing and maintaining external or internal linkages to improve or reform education Kunesh and Farley (1993) provide the useful set of guidelines on the next page.

Participants in partnerships must believe that collectively they will accomplish an objective creatively and effectively. They must agree to the feasibility of the objective to which their energies will be directed, for example, improving the mathematics performance of at-risk youngsters, and experience progress through the attainment of acceptable and established benchmarks. Most importantly, they must derive intrinsic and extrinsic rewards from their collaborative participation. Intrinsic rewards include recognition, status and personal satisfaction; extrinsic rewards include validation through assessment of performance for promotion and tenure decisions in colleges and universities, and opportunities for planning during the school day through release time and during the summer months with compensation in the schools.

Effective school-university partnerships call for new roles for university faculty in which they might be expected to spend part of the year in schools teaching and working with teachers. This sort of arrangement provides an opportunity for university faculty in education, as well as in the Arts and Sciences, to understand the changing dynamics of schools, current teaching and learning issues, to focus their research on practical and pedagogical concerns, and to use the knowledge gained to better prepare teachers and other education professionals who will be appointed to positions in these and similar schools. College and university faculty must realize that the quality of students who are admitted into their fields of study is directly related to the

Guidelines for Effective Collaboration

- *Involve **all key players** so that collaborative decisions and activities will receive widespread support and recognition.*
- *Ensure that the collaborative's **leadership** is visionary, is willing to take risks, and facilitates change rather than directs it.*
- *Establish a **shared vision** of how the collaborative should progress and of the **expected outcomes** for children and families served by the collaborative partners.*
- *Build **ownership at all levels.** Commitment to change must be mobilized at all organizational levels of member agencies and among community members involved in the collaborative.*
- *Establish **communication and decision-making processes** that accept disagreement among actors as part of the process and establish ways to address conflict constructively.*
- *Institutionalize change by encouraging member agencies to include **collaborative goals** in their own institutional mandates and by **earmarking funds** to carry out collaborative activities.*

quality of education students generally receive in elementary and secondary schools. It is thus in their best interests to work collaboratively with schools. Similarly, teachers can be used to effectively bring real world experiences to students in the college and university setting, and to assist in shaping meaningful research agendas. In addition to the examples of collaborative arrangements already cited, two types of linkages deserve special mention: academic alliances and collaborative learning. Another form of collaboration is the academic alliance.

> *Academic alliances result from a simple concept: adults who teach the same subject in the same geographic area share a collective responsibility for the quality of each other's teaching and learning.*

Academic alliances are what I would describe as an external linkage and may involve secondary school faculty only or secondary school and postsecondary level faculty. These alliances are communities of inquiry in the disciplines, e.g., history, math, science, literature, foreign languages, and participants develop a sense of shared ownership for continuous professional development, the definition of quality instruction, and concomitantly, expectations held for student performance.

The second linkage might be considered as an internal linkage and is framed as collaborative learning. Collaborative learning is designed to assist individuals to work together to construct knowledge by challenging and dissecting assumptions and evaluating, confirming and, if necessary, revoking knowledge authority. Collaborative learning is cooperative, but the group process is not assessed. Rather, the individuals involved in this arrangement are assessed on their demonstrated knowledge of what they have learned collectively. It is a form of self-governed, peer-negotiated relationships in college settings.

Cooperative learning, on the other hand, helps students in elementary schools work together on academic (e.g. math) and social issues or problems, e.g., tolerance. Students learn to work interdependently in small groups within a traditional school authority structure. That is, the teacher defines roles and tasks within the group. Cooperative learning seeks to eliminate competition between individuals. The group rather than the individual student is accountable for the achievement of a specified end (Bruffee, 1995; Gamson, 1994).

Perhaps the most visible form of collaborative arrangement designed to foster school reform and the reform of the preparation of education professionals is the Professional Development School to which we turn.

Professional Development Schools

Advocated initially by the Holmes Group (1986, 1990, 1995) and the Carnegie Forum on Education and the Economy (1986), and later by John Goodlad's National Network for Educational Renewal (1990, 1994), the National Center for Restructuring Education, Schools and Teaching (1994), and the American Association of Colleges for Teacher Education (1994), Professional Development Schools are seen as promoting the simultaneous renewal of schools and the preparation of teachers.

The precursor of Professional Development Schools is the late 19th century established university laboratory school, which was attached to a school of education and served selected students, many of whom were the children of university professors.

As conceptualized by the Holmes Group (1990), now reconstituted as the Holmes Partnership,

Definition of PDS — Holmes (1990)

The " . . . 'Professional Development School' . . . [is not] just a laboratory school for university research, nor a demonstration school. Nor . . . [is it] just a clinical setting for preparing student and intern teachers. Rather, . . . [it is] all of these together: a school for the development of novice professionals, for continuing development of experienced professionals, and for the research and development of the teaching profession.

The basic principles that characterize the PDS as indicated by the Holmes Group are:

Principles of PDS — Tomorrow's Schools

1. *Teaching and learning for understanding.*
2. *Creating a learning community.*
3. *Teaching and learning for understanding for everybody's children.*
4. *Continuing learning by teachers, teacher educators, and administrators.*
5. *Thoughtful long-term inquiry into teaching and learning.*
6. *Inventing a new institution.*

A PDS is a learning community in which collaboration between school and university, or among school, university, community, business, and/or professional associations serves to transform teaching, schooling and professional development (Darling-Hammond, 1994). It accomplishes these aims by —

1. *providing a place for preservice teachers to practice the skills needed to become professional educators;*

2. *making opportunities available for inservice teachers to continue their professional growth; and*

3. *having university and public school educators become involved in research that will contribute to advancing the pedagogical and theoretical knowledge base of the education community (Ishler and Edens, 1995).*

The most challenging component in the process of establishing a PDS is that of developing trust. This requires time and patience as there frequently is distrust and misunderstandings of the faculty cultures in schools and university settings. For example, in K–12 schools faculty are less autonomous than faculty in higher education. K–12 faculty enjoy less freedom to decide on course content and textbook selection than university faculty. K–12 faculty move up a salary scale according to time and training, while university faculty have the power to select, evaluate, promote, tenure and dismiss their faculty colleagues (Irvin, 1990).

To build trust involves understanding the culture of the respective organizations and a decision to work collaboratively on small scale do-able projects. (At Penn State, for example, this has meant working with the local schools in developing their strategic plan and on the curriculum design of a new middle school. Building trust also means that the decision to form a PDS not be made by administrators in a top-down fashion. Rather, the development of the PDS should stem from the positive working relationships between teachers and university faculty (Duffy, 1994).

Decision making in the PDS must be shared between and among stakeholders. Each stakeholder brings strength to the enterprise and participates as a colleague in teaching, action research, and problem solving. This also means that required classes of instruction will be held in the university setting as well as in the schools with instruction delivered by teachers or university faculty in either setting.

As exemplary schools for the preparation of educational professionals, PDSs further adopt and implement the values of equity, diversity and cultural competence. In these schools it is essential that *all* students perform academically at the highest levels of expectation and agreed upon standards. As such, teachers must become knowledgeable about, and understanding of, cultural differences and their relationship to school achievement. They also must acquire understanding of the effects of stereotyping, intolerance, racism, xenophobia, and tracking on student performance. In the rapidly changing complexion of our school population, the dimensions of equity, diversity and cultural competence become essential areas of expertise for teacher preparation and professional development programs. Restating differently a well known motto, it is a terrible thing to waste a mind. We cannot afford to continue the past school performance gaps associated with students' economic circumstances, membership in minority racial and ethnic groups, gender, or handicappedness.

To be viable, PDSs require designated funding since teachers associated with them will require release time for planning and other activities, and travel between the PDS and the university will be required thereby increasing budgetary allotments. Moreover, reduced class teaching loads and smaller preservice classes also will increase expenditures. At yet another level, to ensure that university faculty involvement in PDSs will be rewarded in promotion and tenure decisions, clear guidelines and policies should be enacted.

Maintaining the PDS partnership necessitates the sustainability of mutual benefits to the partners, the ability to tolerate uncertainty, the nurturance of trust, and a commitment to the professional development of educators. PDSs represent a powerful paradigm for building and refining teaching, improving student outcomes resulting from schooling, preparing exemplary teachers, and expanding the knowledge base that undergirds effective teaching and learning.

Challenges to Educators

Some of the challenges to collaborative linkages have been cited earlier. In this concluding section I wish to reemphasize the challenges we must overcome if we are to derive the benefits of university, school and community collaboration.

In the university culture, particularly in land grant universities, teaching, research and service are valued missions. Yet there is much evidence to suggest that research is more valued than teaching, and teaching more valued than service in the university reward structure as reflected in decisions of tenure and promotion. Collaborative participation of faculty in research universities with teachers in K–12 schools has traditionally been viewed as service and while applauded, has not been seen as an important activity in the university reward structure. The challenge to those in the academy is to place greater value on field based collaborations and to reward faculty who constructively and meaningfully engage in these activities. This may mean establishing a clinical faculty similar to such faculty found in medical schools, but this arrangement has the disadvantage of creating a category of professors who might be regarded as second-class citizens.

Alternatively, faculty assignments might be differentiated to accommodate changing career interests. As a form of faculty development and renewal, tenured faculty might elect to spend a couple of years focusing on field collaboration as opposed to engaging primarily in research in the academy.

What ultimately is called for is a redefinition of what it means to be a scholar in the university setting. Instructive in this regard is the conceptualization of Boyer as elaborated in his very provocative book, *Scholarship Reconsidered*. According to Boyer, " . . . the work of the professoriate might be thought of as having four separate, yet overlapping, functions. These are:

Scholarship Functions

The scholarship of discovery
(research)

The scholarship of integration
(making connections across the discipline

The scholarship of application
(service, applying knowledge to consequential problems

The scholarship of teaching
(educate and entice future scholars; active learning encourages students to be critical, creative thinkers, with the capacity to go on learning after their college days are over)

Boyer's conceptualization of scholarship is not only compelling, but also provides a wonderful basis for supporting the work of faculty in Professional Development Schools and in other forms of collaboratives. At a time when higher education is being criticized for perceived light teaching loads and the quality of teaching, particularly at the undergraduate level, as well as for the usefulness of much of the research conducted, Boyer's notions of scholarship, if enacted, holds the possibility of reestablishing public trust and confidence in higher education. As a result, the willingness of public officials to support more adequately public higher education will be enhanced. Additionally, through the school-university-community collaboration that views schooling from a P–16 and beyond perspective, the improvement in the school performance of all students will assume greater urgency and benefit from the multiple strengths each partner brings to the partnership. Universities and community groups, agencies and businesses must recognize that their destiny, indeed the social good, is closely tied to the quality of the educational foundations students acquire in the K–12 public schools.

At another level, it is clear that those who teach must have command of the subject or body of knowledge they desire to teach. It is also clear that the knowledge we now possess on how the brain functions, on psychobiology — the influence of social groups, emotions and attitudes on behavior (McClintock, 1995), on cognitive psychology, on pedagogical content knowledge (Shulman), on pedagogical *context* knowledge, on the relationship of socio-cultural influences on learning, on the use of technology to enhance learning and redefine the role of the teacher, and on developmental field-based clinical experiences cannot be mastered in a brief one year period following the normal "four year" period of study leading to the Bachelor's degree in a discipline based area of concentration. These considerations argue for a more extended period of preservice preparation and for the continuing professional development of teachers assisted through collaborative linkages between and among colleges, schools and other private and community agencies and organizations.

Finally, collaborative linkages hold the promise of stimulating change and sustaining the results of educational reform. This is particularly true as we strive to meet the national education goals that speak to performance in discipline areas in general and math and science in particular. "By the year 2000 United States students will be first in the world in mathematics and science achievement." The importance of science and mathematics to the future of society cannot be diminished. As stated by the Education Commission of the States —

The National Importance of Science and Mathematics

- *Quantitative literacy is a prerequisite to decision making in an information age and, therefore, to full participation in a democratic society.*
- *New and emerging technologies are key to remaining internationally competitive. Most of these are mathematics-based.*
- *One-third of the country's gains in national productivity has come from technology.*
- *The rate of growth in mathematics-related occupations is about twice that for all occupations.*
- *Eight of the 10 fastest-growing jobs this decade will be in science-based occupations.*

To achieve the level of scientific, mathematical, and technological sophistication indicated by ECS demands first and foremost excellence in teaching math, science and technology. It further calls for well-designed on-going professional development programs to raise the level of scientific knowledge of current teachers and those who will enter the teaching profession. Given the inadequacies of science, math and technology labs and equipment, and the lack of in depth preparation of teachers in these areas at the elementary school level, which is considered to be crucial in establishing the foundation for later achievement in science and math at the secondary school level and beyond, collaborative linkages between and among schools, universities and communities in the broadest sense are mandatory.

There is an African proverb that states, "When spider webs unite they can tie up a lion." Similarly, when schools, universities, and communities unite we will find the solutions necessary to raise student performance levels and understandings not only in science, math and technology, but in all areas of knowledge and human discourse.

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Discussant: Dennis Sorge

I am delighted to be able to tell you about Purdue University's efforts to enhance the teaching of K–12 science and mathematics in Indiana. We became interested in working in this area because of our concerns about the inadequate preparation in science and mathematics of students entering their first year of studies at Purdue. As a result, in 1989 we initiated a program called the School of Science Outreach. The intent of the program is to increase achievement and interest in science and mathematics for all precollege students in Indiana, not just students headed for Purdue.

The School of Science Outreach concentrates largely on two types of activities: teacher enhancement, which accounts for about eighty-five percent of its programs, and student motivation and science demonstrations, which makes up the reminder. Teacher enhancement workshops are provided both on and off campus. They include but are not limited to Advanced Placement Summer Institutes, programs on assessment, standards, the implementation of computers in teaching and learning, earthquakes, planets, remote sensing, the World Wide Web and surfing the net, and the use of scientific instrumentation in teaching chemistry and biology. Our effort to facilitate teacher training and the loan of scientific instruments by the university to secondary schools has become a nationally recognized model.

To accomplish the ambitious goal of raising the science and mathematics literacy of all precollege students in Indiana, Purdue employs six outreach coordinators. Each department in the School of Science (Biology, Chemistry, Computer Science, Physics, Earth and Atmospheric sciences, and Mathematics and Statistics) has a coordinator on staff. In addition to my work coordinating the School of Science Outreach, I serve as the Outreach Coordinator in the Department of Mathematics and Statistics. The coordinators act as the link between science faculty and K–12 school personnel. They spend a great deal of time traveling throughout the state doing workshops, serving on state-wide committees, and visiting with K–12 school staffs. For instance, I have met with approximately fifty school superintendents to enlist their support for our efforts. I have also worked to gain the support of the business community. We need their financial resources for our program, and in return, they benefit from a better educated workforce.

Within the last five years Purdue has invested about $2.5 million in K–12 education programs; in 1995 alone, we spent about $800,000 on elementary and secondary education. Our financial investment is an indication of the significance we attach to this program. We have touched fifteen hundred teachers and two hundred thousand students. As a result, we have learned a great deal about inservice programs, teacher preparation, and collaboration between schools and universities.

One of the striking things that have come out of our inservice program is substantive feedback on our inservice programs. We have discovered that we are teaching things to teachers in the field, things that we are not teaching in our campus classrooms, such as assessment, standards, and the use of computers and scientific instruments. In our inservice programs, we are devoting a great deal of time making up deficiencies in teachers who had graduated from Purdue as well as a variety of other institutions. As a result, we are meeting with our faculty who hold joint appointments in science and education (an arrangement that is over thirty years old at Purdue) to determine how to incorporate lessons from the field into our teacher preparation curriculum.

We also found that in K–12 schools we were using scientific equipment that we were not using in our lower-division classes at Purdue. Perhaps most importantly, we found that the School of Science could not provide all of the inservice development that the teachers with whom we were working required. Within Purdue, we needed to utilize the knowledge of our colleagues in the School of Education. For instance, I have teamed with a colleague in Education to conduct workshops for K–12 teachers on the use of computer technology in science and mathematics instruction. I bring knowledge of content and computers. He contributes his expertise in instructional design. Outside the university, we have worked to engage in these activities, school superintendents and leaders in business and industry.

The School of Science has made a commitment to improving precollege education in science and mathematics. We have worked with our faculty to help them recognize that a school based in disciplines in a strong, research-oriented institution can contribute to precollege education. Gradually, our faculty are beginning to realize that they have a role in teacher preparation, teacher enhancement, and the education of our young people. Thirty faculty members are involved in our outreach activities; a few more join our efforts each year. We hope that faculty interest in our efforts will continue to increase as we work to improve science and mathematics education for students in our state.

Discussant: Leonard Solo

I will begin my discussion with a confession: in twenty-five years of managing student-centered schools serving kindergarten through eighth grade, I have never hired a new college graduate for my teaching staff. The reason is that these new graduates simply do not know enough. They do not know enough about literature, mathematics, science, and social sciences. They do not know enough about how to develop curriculum, how to use materials and resources, how to teach effectively, and how to work with their colleagues and parents.

Graham & Parks Alternative Public School is a citywide school of choice, enrolling approximately 370 students from a variety of socioeconomic backgrounds. Half of our students are white and half of our students are of color; one-third of our students are Haitian. Thirty-five percent of our students are receiving special education services. Graham & Parks features self-contained, multi-graded, open classrooms for students in kindergarten through sixth grade, and offers a flexible program in the seventh and eighth grades. Our practices are based on the work of John Dewey, Jean Piaget, and Vogotsky, as well as the experiences of the British infant schools of the 1960s. We are regarded as a highly successful urban school, with students achieving levels equal to those of good suburban schools.

Our school has had a long history of collaboration with businesses, community agencies, and area colleges and universities, so it was a natural extension of our past efforts to enter into a large-scale collaborative effort called TEAMS-BC, Teacher Education Addressing Mathematics and Science in Boston and Cambridge. This collaborative funded by the National Science Foundation involves the U Mass/Boston, Harvard University, the Massachusetts Institute of Technology, Lesley College, Wheelock College, four high schools, and five elementary or middle schools in Boston and Cambridge.

Graham & Parks School is participating in TEAMS-BC as a professional development school with U Mass/Boston and MIT. We see this collaboration as a means to experiment with developing a more effective teacher preparation program, with an emphasis on math and science. As a professional development school, we are able to work closely with faculty from U Mass/Boston and MIT in providing student teaching placements, designing curriculum with faculty in education and in the disciplines, and co-teaching undergraduate education courses. We are designing a number of courses that we plan to co-teach at U Mass/Boston and in our school, including mathematics for children, science for children, the nature of science, and a seminar in science and mathematics. We have a large number of students from MIT and U Mass/Boston teaching and observing our classes. Currently, an on-site supervisor coordinates the practicum students and teaches a seminar. A secondary goal of this project is to continue to improve our knowledge and skills in teaching math and science at Graham & Parks by conducting a variety of seminars utilizing the faculties in the three institutions involved.

Significant structural and management issues are associated with our role as professional development school. My staff is committed to this program, but implementation issues can seem overwhelming at times. Our teachers develop all of their own curriculum (No basal readers for us!), work collaboratively with other teachers and specialists, meet frequently with parents, and serve on shared decision-making committees with parents and administrators. Not much time is left for PDS activities. We are evolving structures to deal with this. We have hired a site-based university coordinator and a part-time school coordinator; we have a small planning committee; we pay staff for their work; and course planning occurs on evenings, weekends, and during the summer. We are also thinking of giving short- and long-term leaves to staff to work on PDS activities.

There are other issues we are dealing with: What is the role of university faculty in a K–8 school? What experiences are needed for a college student to learn how to be a good teacher? How will this project be financed in the future?

TEAMS-BC does have a larger, overarching structure. A coordinating committee with representatives from each of the fourteen institutions involved in this program meets on a regular basis to share progress, to plan collaboratively and to develop new ideas and structures.

We devote extensive time to staff development. We are beginning a course for our teachers that will address issues central to good teaching. Our first topic is the same as the title of this Forum's first session: What constitutes a good teacher? We will be conducting this course with faculty from MIT and U Mass/Boston. We want this course to evolve into a seminar for our teachers that will give them the opportunity to design some additional courses offered at Graham & Parks for the practicum students.

We are just two years into this project, but undergraduate students who have participated in the professional development program at Graham & Parks should be well prepared to enter the classroom. I hope that as a result of these efforts, I will be able in a few years to end our longstanding practice and hire new graduates with the experiences that are necessary for their success as educators.

Discussant: Linda Slakey

I want to describe activities at U Mass that exemplify the theme of the conference; to articulate what a dean of science can do to encourage education reform in spite of severe constraints on resources; and to comment briefly on some of the forces that favor the change we are trying to make.

For the last two and a half years, the deans of the nine schools and colleges at U Mass have met together to discuss our own role in managing the various crises and challenges that face us. That has built trust. I want to acknowledge the leadership of our Dean of Education, who was the first convener of the group. This has been a very successful experiment, and I urge you to try it in your home campuses if you don't already do such a thing. The campus reviews annually the number of individual activities that it does in interaction with the K–12 sector in the state and the region. Of 120 such activities last year, twenty-five percent came from the College of Natural Science and Mathematics. Activities include small initiatives by individual faculty, and a group of substantially funded projects. Four funded by the NSF include an in-service teacher training project for active learning based on environmental issues, two projects that support modernization of high school physics, and a project that provides user-friendly network access to teachers across the state. In addition we have two large prograns that involve high school students in intensive summer experiences, one funded by the NIH and one by the Hughes Foundation. The Hughes Program also provides teacher training.

Funding is an important issue in the thinigs that have been successful. I think we must influence the federal and private agencies to continue substantial support of interactions between the university and K–12 schools. Having made the perhaps Pollyanna suggestion that we need to exert political pressure to maintain external funding, I want to acknowledge how severe the resource pressures within the university are. Many deans face the dilemma reported last night by Jerry Odom: pressure to achieve prestige through research. Brutal pressures are brought to bear upon the faculty, especially the young faculty, given the competition to stay above the threshold for research funding. This draws faculty energy away from reform. Scarce university resources that might otherwise fund educational innovation must also be husbanded for investment in grant matches and support of research facilities.

Another core problem is that the faculty have a deep and pervasive culture that make them quick to view as compromising standards and watering down the curriculum any changes in pedagogy or the attempt to reach out to a larger group of students. We have to work with faculty to change this mindset. The underlying value is a commitment to excellence. We must find common ground with this value in proposing pedagogic change.

So what can a dean of sciences do, given the various constraints, especially that there is no spare money to throw at creative activities, to support improved teaching in his or her college?

A dean can reward and support innovation and commitment to teaching by providing moral support to faculty engaged in those activities. The members of the college who work on issues of teaching and learning should know that they have the respect of the dean. For some of them that makes a difference.

A dean can also press hard to see that members of the faculty, who are extraordinary teachers but have discontinued their active participation in laboratory science are promoted to full professor. This struggle may cost some points with the college personnel committee and the dean may have to allay the provost's fear that this would encourage applications for promotion from individuals who are less distinguished in research or teaching. But by insisting that there are members of the college whose teaching is so good and so recognized by a wide community that it was unacceptable for them not to have professorial rank, partisans of excellent teaching can win that fight. That kind of moral support is within our grasp. Truly respecting the work yourself will show, and it will make some difference.

Another thing a dean can do is keep the question of good teaching on the agenda. A dean can bring it up in department heads' meetings and ask colleagues repeatedly what they are doing about encouraging better instruction. The dean, after all, controls resources, and people need the dean's good will and respect for what they are doing in the departments. So again, make it clear that this item has to be on the agenda. Talk about the nature of pedagogy. Ask whether we are rewarding faculty for instructional innovation and for improving the quality of the education that we provide.

I caught myself just at the end of that sentence doing something that I would like to change. I said: "the quality of education that we provide." Deans of science must make a language shift that our colleagues in education have already made: stop talking about teaching and talk about learning. The faculty regard teaching as an activity they do. It is astonishing how little attention goes to learning beyond obvious assessment like classroom tests. That is not so in the school of education, which looks to the nature of learning. I now try to stop talking about teaching and find a way to say "learning" or some variant. We need to shift our view from the faculty's to the student's activity. Of course it follows that faculty activity has to be effective for learning to occur.

Finally, I want to say a few things about what I regard as the advantages of having to perform in a scarcity of resources.

I think that one thing that has fueled my faculty's creativity in working with their students is their need to deal with the large introductory courses as finances diminish. Four of my departments are now committed to the extensive use in introductory courses of instructional technology based in computers. One of the strengths of the college is that we have a splendid computer science department, which has some members willing to work with us on instructional issues. We already do instruction grounded in computers, of course, but our attention to that is now increasing, and we have a substantial cadre of faculty whose commitment to excellence has become engaged by the challenge of using computers for instruction.

I believe also that in a bizarre way the competition for research resources is going to help swing the pendulum back towards teaching and student activity. For one thing, it is simply not going to be possible for all of the faculty to continue to stay funded for research in the way they have in the past. I do not think it is realistic to expect that we can continue to have a faculty of individual empire builders. At the very least, people are going to have to increase by collaboration the extent to which they achieve funded work. The expectation that everyone must be a high-profile, successful researcher will have to diminish. This should allow us to move a little more gently and gracefully back into a distribution in departments between people who focus on teaching and people who are expected to be highly visible and highly funded research professors.

The faculty have to be concerned about the long-term health of the enterprise of doing science. They know that even under the pressure to compete in research they need to be concerned both with the quality of students coming forward and with society's willingness to continue to believe that what they do should be supported. I think we have a painful interval to pass through, but a new balance between research and education in university departments will emerge.

The National Science Education Standards

Rodger W. Bybee, Executive Director, Center for Science, Mathematics, and Engineering Education, National Research Council

In 1995, the National Research Council released the *National Science Education Standards*. At the NRC, we think that the *Standards* are going to have a substantial impact on the work of faculty in colleges of arts and sciences and colleges of education. This view is widely shared by the science education community. I am going to give a brief overview of the *Standards*, discuss a specific example of a standard, and then discuss some of the implications of standards for the reform of science education. I hope we will have an opportunity for questions and discussion.

The *Standards* are intended to point this nation in one direction with regard to the teaching and learning of science in grades kindergarten through twelve. Prior to the development of the *Standards* this was not the case; there was a clear perception in science and mathematics that the people involved in K–12 science education — teachers, students, policymakers, teacher education faculty — were not moving in one direction. It was common, for example, to find that while curriculum had been implemented at the school district level, assessment of students had not been altered to match the curriculum. Or the tests had changed, but the curriculum that guided learning had not. Or if both curriculum and testing had changed, teacher education programs had not adjusted the preparation of teachers to reflect this new reality. So, the problem that the science education community confronted was to establish a steady course, look in one direction, and stay with that direction for some time.

The mathematics education community had led the way by establishing a steady course for its discipline through the publication of two documents produced by the National Council of Teachers of Mathematics: *Curriculum and Evaluation Standards for School Mathematics* (1989) and *Professional Standards for Teaching Mathematics* (1991). They were received so well that they became the model and incentive for developing standards in the disciplines of English, science, history, and geography, mentioned in the National Education Goals that were adopted by the nation's governors and the President in 1989.

We now have three documents that aim at establishing a steady course for science education. The *National Science Education Standards* is one. There are also *Science for All Americans* and *Benchmarks for Science Literacy*. The differences between the *Standards* and the *Benchmarks* in terms of content are insignificant, so we will put aside that issue right from the beginning. Why are there two documents? The reasons concern politics and history, but what is really significant is that while the two groups appeared to be going down different paths, they arrived at similar results — two documents that actually complement each other.

So to point the nation in one direction in science education, we now have standards and benchmarks. The immediate task is now to explain to the public why that direction is best for the nation. The explanation can vary. In talking to the Congress these days, the explanation has to include issues of economic benefit and global competitiveness. Legislators probably want to hear also about how the *Standards* address equity issues. In fact, the *Standards* do address them.

We need, in any event, to explain to the public why we are moving in this direction and not some other. Just talking among ourselves in the science education community will not suffice. Still, the ultimate goal is to bring about improvements in what teachers do and what students learn.

The standards on professional development focus on teacher education broadly conceived. They embody a different level in understanding of subject and pedagogy that current and future science teachers are going to have to develop. And the skills that these teachers must master will come, of course, from undergraduate programs and many graduate programs of colleges and universities, as well as what goes on in the field in the way of professional development.

In the early days following the establishment of the National Education Goals, the goal that we heard about most often in relation to mathematics and science was Goal 4: by the year 2000 U.S. students will be first in the world in science and mathematics achievement. First in the world — great politics, good speech — but how many of us thought it was achievable? We have learned that there are other goals, that propose achievement by all students in core content areas including science and mathematics. Goal 3 seeks to bring students to higher levels of critical thinking to help them become better citizens and contribute to the economy in this country. This goal is certainly achievable. We should concentrate on that goal.

I have given many talks on the *Standards* over the last three or four years, and it is very easy to get in an abstract discussion of standards and never look at a standard. But here I would like to take a look at one. What we have been doing for the last four years is to address the question:

> *What should the scientifically literate person know, understand, and be able to do after thirteen years of school science?*

There is a context, of course — 180 school days a year, there are teachers, classrooms, and so forth. There are other things we can sometimes count on — among them that students will go to the museum, the zoo, or the environmental education center.

So what should count as a content standard in relation to the above question? We identified unifying concepts and processes: scale, evolution, equilibrium, patterns of change, and so on. Science's inquiry is a content standard. We identified the core subject matter areas — physical, life, earth, and space sciences. We also added science and technology. Here, technology is a domain of study, what the *Benchmarks* refers to as *the designed world*, and not educational technology (like computers) as a tool for teaching and learning. The rationale behind this is a focus on science and personal and social perspectives, as well as the nature of science and its history.

Categories of Content Standards

Unifying Concepts and Processes
Science as Inquiry
Physical Science
Life Science
Earth and Space Sciences
Science and Technology
Science in Personal and Social Perspective
History and Nature of Science

Now, I will digress here for a moment to make a point. What does this say about the education of future teachers? These standards are consistent from kindergarten through grade 12. Teacher education programs may be doing a fairly reasonable job of teaching students something about physical, life, and earth sciences. But I am not so sure about preparing teachers in technology and personal and social perspectives relative to science, or the nature of science and its history. We are not doing very well in these areas. Nor are we doing very well in teacher education programs to help students understand inquiry or develop the abilities associated with inquiry. So right here we can stop and find that the *National Science Education Standards* provide some very serious implications that teacher education programs must address — implications for what we might be doing in undergraduate and even graduate courses.

I will use an example, the cell, from the life sciences. The category "life science" is just a way of indicating the major conceptual organizers — that is a term that we came to: we found after a year or so we have to call these something in order to keep talking about them and communicating with each other. You will find that the major ideas in the life sciences, for example, of genetics, of ecology, and of evolution, are embedded in simpler form at the lower levels, and they become more complex at the higher levels. We tried to keep in mind the developmental appropriateness for the conceptual organizers that we placed in the Standards.

Fundamental Concepts for the Conceptual Organizer — The Cell

As a result of their activities in grades 9–12, all students should develop understanding of the cell:

- *Cells have particular structures that underlie their functions.* Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.
- *Most cell functions involve chemical reactions.* Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by a large set of protein catalysts, called enzymes. The breakdown of some of the food molecules enables the cell to store energy in specific chemicals that are used to power the many functions of the cell.
- *Cells store and use information to guide their functions.* The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.
- *Cell functions are regulated.* Regulation of cells occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division.
- *Plant cells contain chloroplasts, the site of photosynthesis.* Plants, and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment. This process of photosynthesis provides a vital connection between the sun and the energy needs of living systems.
- *Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of cells.* In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues, and organs that comprise the organism. This differentiation is regulated through the expression of different genes.

Adapted from *National Science Education Standards* (National Academy Press, Washington, DC, 1996).

The actual standards statement is:

As a result of their activities in grades 9-12, all students should develop understanding of the cell.

The development team that did the final round of work on this probably spent a hundred hours arguing and talking about this one statement. This is going out to the nation, and so we had to be very careful about what it said and what it meant. "As a result of their activities ..." is right at the beginning and refers to activities of students. It does not say: "This is what scientists think." Right at the beginning, the standards are centered in the students, referring to *their* activities, suggesting they are going to be doing things. The emphasis is on an understanding based not on reading or teaching, but on their *activities*, in grades 9–12.

Note that the standard talks about grades 9–12 (and this is consistent across all of the other standards). One reason for that is to avoid anything that begins looking like a national curriculum. Because biology is usually taken in the tenth grade, we might have written the standard that way. But we wanted to avoid making the standards look like a course or a curriculum. What it is saying is that in considering courses and curricula, somewhere in grades 9 through 12 students should develop an understanding of concepts such as the cell. We are not going to say how or precisely when. That is up to state and local jurisdictions.

Note that the standard says "all students." Yes, we meant *all*. We know what that means. I have said in other talks in a humorous way, "Exactly what is it you don't understand about all?" All means all. That's a way of making explicit what we have talked about for decades, representation of underrepresented groups at higher numbers and attending to some of the issues we have not attended to for some time. This is a way of stating it right in the standards.

The implications of the statement "all students should develop understanding" in the standards are quite different from those in a declaration that we will *teach* students about the cell and molecular basis of heredity. We all need to consider the changes implied by "all students."

"Should develop understanding of" is significant, too. The standard does not use the word *know* or *knowledge*, and does not address *level* of understanding. There are some disabled students, and not all of them are going to understand cells and the molecular basis of heredity. The standards say that all students will develop understanding of, and provide some categories. The professionals in the field are going to have to make some decisions about how they interpret that and how far they can go. It is a way of recognizing that not all students are going to be molecular geneticists.

From the very beginning and almost continuously, some people were saying, "The standards are too broad, too abstract, we don't know what it means concretely."

Earlier, I mentioned the *Benchmarks*. The fundamental concepts and the standards generally parallel the benchmarks in *Benchmarks for Scientific Literacy*. For example: "Cells have particular structures that underlie their functions," a concept of structure-function. Or "Most cell functions involve chemical reactions." "Cells store and use information that guides their functions." "Cell functions are regulated. Plant cells contain chloroplast, the site of photosynthesis."

Let me use that to point out that we have not avoided *all* technical language in the *Standards*. What we have done is to reduce the emphasis on technical language. If you've got the technical language, you are going to understand the concepts.

Probably one of the greatest challenges in doing the *Standards* was getting the scientific community, with which we worked — actually, its members developed most of the statements —

to come up with six *fundamental* concepts and to keep them at the table saying, "No, you cannot come up with a list of a hundred different ideas about cells that you think all your postdoctoral associates should master before they enter into research. You've got to concentrate on somebody who is going to be somewhere in grades 9 through 12, something that you think all students should develop an understanding of, and the list has to be short." We usually said five, and then they would push to include six.

This is the way things came out. After national review of thousands and thousands of teachers, scientists, science educators, parents, and so on, we find these to be fairly consistently supported. The scientific community, especially, is saying that the *Standards* look pretty good. If all students understood those ideas, that would be fine; and those students who want to go on to further science study and pursue careers in science would have a solid foundation. There is nothing in the *Standards* that precludes further study, I might add.

All this has been an answer to the question: what should students know and understand? As to what students should be able to *do*: that we addressed through *scientific inquiry*. We took two views of scientific inquiry, and I alluded to them earlier: What should students understand about inquiry and what abilities should they develop? Without going through the list on the next page, I will give you a couple of examples to show the kinds of abilities that we identified. Think of cognitive abilities, not just skills of classifying:

- Formulate and revise alternative explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.

What we tried to do is to raise the level above the idea of "science as process" as this theme was developed in the 1960s and 1970s. We wanted to go beyond simply having students classify, infer, observe, form a hypothesis, and so on. Embedded in the *Standards* is something that might be called by a name such as critical thinking, reasoning, or logic — using evidence to form an explanation and making the association between the evidence, the explanation, and the logic of a position. This is what the *Standards* say that students should be able to do.

So far I have discussed content standards. There are also teaching standards. These were arrived at as you might think. Having developed the content standards, we asked what it takes to help students achieve them. We believe we have come up with a clear and consistent approach to teaching. The standards for professional development were distributed to you in preparation for this conference. Clearly, the *Standards* imply change on the part of teachers which we hope teacher preparation programs will address. We are going to have to change the assessments.

Program standards apply to classrooms. They call for a school science program from kindergarten through grade 12 that is consistent and coherent. This is not necessarily what we have in schools today. In some places, there really is no elementary school science; in other cases what is happening at middle school or junior high is not consistent with teaching at the high school, and so on.

Finally, the system standards address the issue of the kind of environment and support principals and teachers need for hands-on science or to teach by inquiry. There are elements of the system a little broader than just principles, by the way. There is an intellectual component, a political component, an economic component, governance, and policy makers — all of these have a role in making it possible to implement standards-based science education.

Science As Inquiry

- *Identify questions and concepts that guide scientific investigations.* Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate procedures, a knowledge base, and conceptual understanding of scientific investigations.
- *Design and conduct scientific investigations.* Designing and conducting a scientific investigation requires introduction to conceptual areas of investigation, proper equipment, safety precautions, assistance with methodological problems, recommendations for use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also include such abilities as identification and clarification of the question, method, controls, and variables, the organization and display of data, the revision of methods and explanations, and the public presentation of the results and the critical response from peers. Regardless of the scientific investigations and procedures, they must use evidence, apply logic, and construct an argument for their proposed explanation.
- *Use technology to improve investigations and communications.* Students' ability to use a variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard.
- *Formulate and revise scientific explanations and models using logic and evidence.* Student inquiries should culminate in formulating an explanation or model. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation.
- *Recognize and analyze alternative explanations and models.* This standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic thus revealing which explanations and models are better and showing that although there may be several plausible explanations, they do not all have equal weight. Students should appeal to criteria for scientific explanations in order to determine which explanations are the best.
- *Communicate and defend a scientific argument.* Students in school science programs should develop the abilities associated with accurate and effective communication including writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding to critical comments through the use of current data, past scientific knowledge, and present reasoning.

National Science Education Standards, Fundamental Abilities of Inquiry Grades 9–12

Almost all of you, I am sure, recognize what I have been saying as some variation on what you knew before you came to this forum. Making presentations like this is part of the work of the Center for Science, Mathematics, and Engineering Education at the National Research Council. The National Research Council has the capacity to convene governors and other representatives of the states to talk about the *Standards* and their implications for teacher licensure and credentialing. I am sure some of you were at the meeting in January 1996 under the joint auspices of the National Research Council and the Council of Chief State School Officers. The states were invited to develop plans of action to revise or change teacher licensing and credentialing. But they could choose what they mignt do and how to do it.

We are trying to work with fifteen thousand school districts, a hundred thousand schools. We are working with the National Science Teachers Association, for example, on a project that is trying to place copies of the *Standards* in every school in America. It is possible that some will get lost or thrown away, but working with the National Science Teachers Association, we plan to follow up and have an NSTA member in each school organize a faculty meeting or seminar to acquaint everybody with them. NRC has also placed the *Standards* on the World Wide Web and they can be seen or downloaded without charge.

Thinking about reforming education in this country — it can be science, mathematics, history, or any other discipline — might conjure images of professionals in classrooms deciding it was time to change and moving the change through the system. You could imagine the curriculum developers, as we did in sciences and mathematics in the 1960s and 1970s. The strategy to change science education was to develop new curriculum materials and put them out in the system. You can imagine the policymakers — governors, state legislators, opinion leaders — developing laws and regulations to change education. You can imagine planners looking at interactions between education and society.

Now, if you think about it, reform could probably occur at any one of these points and, with any luck, permeate the educational system. The Governors Conference on Education in 1989 set new goals, two of the goals I identified at the beginning of the talk. The goals are abstract, they are not concrete, and they are not very helpful for teachers and schools and curriculum developers. As a result, we have had to develop a set of policies. The *Standards* and the *Benchmarks* are a little more concrete, a little more helpful. They give direction and guidance, but they are not *the* curriculum. They are not curriculum frameworks, or instructional materials. They are policies on which we have built consensus and upon which we are going to have to build curricula.

At what stage are we in these efforts to reform science education right now? We are just beginning to think of how to revise and reform programs, such as teacher preparation programs, school science programs, curriculum materials development, and assessment programs. The community is beginning to ask where the programs are and what they should do. What we are saying to you now is we are giving the *Standards* to the community, to all of you, and now it is up to you. We think they are important and good, but it is now your move. And I mean that in a positive way.

Discussion from the Floor

Question: I noticed that in the system you discussed in your closing, you identified classroom professionals, policy makers, and strategists. Higher education is conspicuous by its absence in this image of the U.S. educational system. Would you comment on that?

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Bybee: Let's see how I get out of this. It is a good question, but there isn't a reasonable answer. The next time I talk about the standards higher education will be conspicuously present.

Question: What do you see as the role of higher education?

Bybee: Higher education is at the interface, at all the interfaces among the groups I mentioned. Teaching and teaching methods, program development, and assessment. In higher education, many graduate programs address policy development and implementation. Professional development is a major role at the undergraduate and graduate levels. Faculty in universities play a key role in professional organizations. A dean is certainly in a position to influence opinions. On the other hand, there is some need to move from the arena of the university and interact with other components of the system, in order to move from policy to program.

Question: It seems to me that a great deal revolves around one key word that you did not specifically emphasize in going through some of those early programs, and that is the word "understand." I am sensitive to this because we recently did our reaccreditation by the state Office of Education for our science education programs, and they have standards, and in every one of their standards there is the word "understand," and that was the entire crux of the thing. How I define *understand* and how they define it might be totally different. It is a very subjective term. So it seems to me that implies a need for some supplementary materials that would define how we measure understanding, for example.

Bybee: Shouldn't there be help to define "understand" and clarify what that means? The answer is, "yes." Many people are arriving at the National Research Council to say that "we," the NRC, should be doing things. The NRC is busy trying to say maybe the "we" out there, outside the NRC, should be doing more while the NRC "we" are doing less.

Should there be an effort to address such issues as the meaning of *understand*? The answer is of course, "yes." It would, I think, be a wonderful step forward in American education if your undergraduate students, your faculty, teachers — especially classroom teachers — engaged in a dialogue about the meaning of *understand*. What does *understanding* mean? Is it different from *knowing*? Have others talked about this issue? If so, who are they and what did they say? As a matter fact, you will find we did address it in the standards. So one of the things that we at the NRC have tried to do is engage the community in the discussion and the dialogue about standards and what they mean and what the terms mean. I think that can be a fairly rich and productive exercise.

Question: The standards evidently introduce, by making reference to them, the broad unifying concepts of science — you mentioned scale, evolution, equilibrium, patterns of change, and so on. There was no reference to whether a good job was being done on that. From my reading, when it comes to these broad unifying concepts like detailed systems of evolution, people don't know how to teach for that. They can teach to the standard on cells that you discussed, but there is a problem connecting it to a broad concept. Could you comment on that?

Bybee: "Yes," is the answer to your question. It is difficult, and what, unfortunately, many educators have done is lapse into a kind of, well, let's create these. They use an argument about the artificial nature of the disciplines of science, that we ought to have something else beside disciplines. Then they *artificially* create a new structure called unifying or integrated or interdisciplinary or something like that.

Here is how I have answered the question. Ask yourselves where in the natural world of doing science or technology do things get integrated? Inquiry, doing inquiry, or doing design problems tends to have people begin bringing a lot of different disciplines together. A second area has to do with studying science-related societal issues. If you will, it is a kind of Science–Technology–Society (STS) theme, but it is not an STS theme just in and of itself; it is saying that once you are engaged in studying an issue, you are going to start making connections in many, many cases to a lot of other disciplines. Also, I think if you look some at the history and nature of science, you will make some of those connections as well, because they connect to the other, the first two areas that I was referring to

Question: Is your organization going to provide transparencies like those you used?

Bybee: Yes, we have sets of transparencies, so if you would like to have a set of transparencies, we can send those out to you.

Question: What is the Internet address of your Web site?

Bybee: I knew you would ask that: http://www.nas.edu/nap/bookstore.

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Appendix B: Forum Participants

Russell Agne
Professor, College of Education
and Social Services
University of Vermont
Burlington, VT 05405
TEL (802) 656-3356
FAX (802) 656-0855
ragne@moose.uvm.edu

Rudolph P. Almasy
Acting Dean, College of Arts
and Sciences
West Virginia University
Morgantown, WV 26506
TEL (304) 293-4611
FAX (304) 293-7565
ralmasy@wvnm.wvnet.edu

Dale G. Andersen
Dean, College of Education
University of Nevada, Las Vegas
Box 453001
4505 S. Maryland Parkway
Las Vegas, NV 89154-3001
TEL (702) 895-3374
FAX (702) 895-4068
dalea@nevada.edu

Charles W. (Andy) Anderson
Department of Teacher
Education
College of Education
Michigan State University
319A Erickson Hall
East Lansing, MI 48824
TEL (517)355-1725
FAX (517) 353-6393
andya@msu.edu

Douglas Anderson
Chair, Department of
Mathematics
Syracuse University
215 Carnegie
Syracuse, NY 13244
TEL (315) 443-1473
FAX (315) 443-1475
anderson@euclid.syr.edu

Wyatt Anderson
Acting Dean, College of Arts
& Sciences
University of Georgia
Athens, GA 30602
TEL (706) 542-1538
FAX (706) 542-3422
wyatt@franklin.uga.edu

Richard L. Andrews
Dean, College of Education
University of Missouri,
Columbia
118 Hill Hall
Columbia, MO 65211
TEL (573) 882-8311
FAX (573) 884-5785
educra@showme.missouri.edu

Jane H. Applegate
Dean, College of Human
Resources Education
West Virginia University
PO Box 6122
Morgantown, WV 26506
TEL (304) 293-5703
FAX (304) 293-7565
jhapple@wvnm.wvnet.edu

Francis X. Archambault, Jr.
Associate Dean, School
of Education
University of Connecticut
249 Glenbrook Road, Box U-4
Storrs, CT 06269-2004
TEL (860) 486-4531
FAX (860) 486-0195
fasbuz@uconnvm.uconn.edu

Ted Batchman
Dean, College of Engineering
University of Nevada, Reno
Reno, NV 89557
TEL (702) 784-6925

Robert Bonner
Dean, School of Pure and
Applied Science
Hampton University
129 Turner Hall
Hampton, VA 23668
TEL (804) 727-5239
FAX (804) 727-5832

Steven T. Bossert
Dean, School of Education
Syracuse University
230 Huntington Hall
Syracuse, NY 13244-2340
TEL (315) 443-4751
FAX (315) 443-2258
sbossert@sued.syr.edu

Mary L. Briscoe
Dean, College of Arts & Sciences
University of Pittsburgh
Pittsburgh, PA 15260
TEL (412) 624-6480
FAX (412) 624-8265
mbriscoe@vms.cis.pitt.edu

John Bristol
Dean of Science
University of Texas, El Paso
El Paso, TX 79968
TEL (915) 797-5536
FAX (915) 747-6708

Carlton E. Brown
Dean, School of Liberal Arts
and Education
Hampton University
119 Armstrong Hall
Hampton, VA 23668
TEL (804) 727-5400
FAX (804) 727-5047

Fred W. Brown
Professor, Science Education
College of Education and
Psychology
University of Southern
Mississippi
Southern Station Box 5023
Hattiesburg, MS 39406-5023

Iva D. Brown
Director, Center for Science and
Mathematics Education
College of Science and
Technology
University of Southern
Mississippi
Southern Station Box 5087
Hattiesburg, MS 39406-5087
TEL (601) 266-4739
FAX (601) 266-5829

Barbara G. Burch*
Dean, School of Education
and Human Development
California State University,
Fresno
5241 North Maple
Fresno, CA 93740
TEL (209) 278-0120
FAX (209)278-0133
barbbu@csufresno.edu

Warren Burggren
Dean, College of Science
and Mathematics
University of Nevada, Las Vegas
Box 454001
4505 S. Maryland Parkway
Las Vegas, NV 89154-4001
TEL (702) 895-3487
FAX (702) 895-4159
burggren@ccmail.nevada.edu

Roger Bybee
Director, Center for Science,
Mathematics and
Engineering Education
National Research Council
HA 486
2101 Constitution Ave., NW
Washington, DC 20418

E. Rene Casillas
Dean of Arts and Sciences
New Mexico State University
Box 30001, Dept. 3335
Las Cruces, NM 88003
TEL (505) 646-3500
FAX (505) 646-6096
rcasill@asmin.nmsu.edu

Larry D. Clark
Dean, College of Arts & Sciences
University of Missouri-Columbia
118 Hill Hall
Columbia, MO 65211
TEL (573) 882-4422
FAX (573) 882-3404
asdnldc@mizzoul.missouri.edu

George A. Clarke
Dean, School of Arts & Sciences
Central Connecticut State
University
1615 Stanley Street
New Britain, CT 06050
TEL (860) 832-2600
clarke@ccsu.ctstateu.edu

Thomas H. Crawford
Professor of Chemistry
College of Arts & Sciences
University of Louisville
Gardiner Hall
Louisville, KY 40292
TEL (502) 852-5972
FAX (502) 852-6888
thcraw01@ulkym.louisville.edu

Elene S. Demos
Interim Dean, School of Education and Professional Studies
Central Connecticut State
University
1615 Stanley Street
New Britain, CT 06050
TEL (860) 832-2102
FAX (860) 832-2109
demos@ccsu.ctstateu.edu

William J. (Joe) Dickinson
Professor of Biology
University of Utah
201 S. Biology
Salt Lake City, UT 84112
TEL (801)581-6289
dickinson@bioscience.utah.edu

Arthur L. Dirks
Acting Dean, School of Arts
& Sciences
Bridgewater State College
Maxwell Library
Bridgewater, MA 02325
TEL (508) 697-1218
FAX (508) 697-1356
adirks@bridgew.edu

Barry Doolan
Professor and Chair, Department
of Geology
University of Vermont
Burlington, VT 05405
TEL (802) 656-0045
FAX (802) 656-0855
bdoolan@moose.uvm.edu

Larry Earvin
Dean of Arts & Sciences
Clark Atlanta University
JP Brawley Drive at Fair St., SW
Atlanta, GA 30314
TEL (404) 880-6770
FAX (404) 880-6771

Phyllis Edmundson
Dean, College of Education and
Human Development
Eastern Washington University
Cheney, WA 99004
TEL (509) 359-2328
FAX (509) 359-4822
pedmundson@ewu.edu

Frederick Eiserling
Life Sciences Dean,
College of Letters and Science
University of California,
Los Angeles
405 Hilgard Avenue
Los Angeles, CA 90095
TEL (310) 825-4959
FAX (310) 825-9368
frede@college.ucla.edu

Jon M. Englehardt
Executive Director,
Center for Excellence
in Education
Northern Arizona University
PO Box 5774
Flagstaff, AZ 86011
TEL (520) 523-7139
FAX (500) 523-1929
jon.engelhardt@nau.edu

David Ernst
Associate Dean, College of Arts
& Sciences
Vanderbilt University
Nashville, TN 37203
TEL (615) 343-6170
FAX (615) 343-8702
ernst@compsci.cas.vanderbilt.edu

Gladys Escalona de Motta
Acting Dean of Natural Sciences
University of Puerto Rico
University Station
Box 23302
San Juan, PR 00931
TEL (809) 765-9695
FAX (809) 763-4311

John Ettling
Dean, College of Arts & Sciences
University of North Dakota
PO Box 8038
Grand Forks, ND 58202-7189
TEL (701) 777-2749
FAX (701) 777-4397
jettling@plains.nodak.edu

Richard Ewing
Dean of Science
Texas A&M University
College Station, TX 77843-3257
TEL (409) 845-8817
FAX (409) 845-6077
ewing@ewing.tamu.edu

Eric Feigelson
Professor of Astronomy and Astrophysics
Pennsylvania State University
518 Davey Laboratory
University Park, PA 16802
TEL (814) 865-0162
FAX (814) 863-3399
edf@astro.psu.edu

Fred Finley
Professor of Science Education
College of Education and Human Development
University of Minnesota
Minneapolis, MN 55455
TEL (612) 625-2074
FAX (612) 624-8277
finleyfn@vx.cis.umn.edu

Viola E. Florez
Interim Dean, College of Education
Texas A&M University
College Station, TX 77843-4222
TEL (409) 845-5313
FAX (409) 845-6129
v-florez@v-florez.tamu.edu

Sally Frost-Mason
Acting Dean, College of Liberal Arts & Sciences
University of Kansas
200 Strong Hall
Lawrence, KS 66045
TEL (913) 864-3661
FAX (913) 864-5331
sfm@clasmain.clas.ukans.edu

Mary Hatwood Futrell
Dean, Graduate School of Education and Human Development
George Washington University
2121 Eye Street
Washington, DC 20052
TEL (202) 994-6161
FAX (202) 994-7207
mfutrell@gwis2.circ.gwu.edu

Karen Syms Gallagher
Dean, School of Education
University of Kansas
112 Bailey Hall
Lawrence, KS 66045-2330
TEL (913) 864-4297
FAX (913) 864-5076
kgallagh@kuhub.cc.ukans.edu

William H. Graves
Dean, College of Education
Mississippi State University
PO Box 9710
Mississippi State, MS 39762
TEL (601) 325-3717
FAX (601) 325-8784
whg1@ra.msstate.edu

Anita H. Hall
Assistant to the Dean, School of Education
Jackson State University
PO Box 18889
1400 John R. Lynch Street
Jackson, MS 39217
TEL (601) 968-2443
FAX (601) 968-7048

Kathryn Hanna
Assistant Dean, College of Biological Sciences
University of Minnesota
123 Snyder Hall
1475 Gortnor Avenue
St. Paul, MN 55108
TEL (612) 624-2244
FAX (612) 624-2785
khanna@biosci.cbs.umn.edu

Mary M. Harris
Dean, Center for Teaching and Learning
University of North Dakota
PO Box 8038
Grand Forks, ND 58202-7189
TEL (701) 777-2749
FAX (701) 777-4397
maharris@vm1.nodak.edu

Susan A. Henry*
Dean, Mellon College of Science
Carnegie Mellon University
4400 Fifth Avenue
Pittsburgh, PA 15213
TEL (412) 268-5124
FAX (412) 268-3268
sh4b@andrew.cmu.edu

Alice S. Huang*
Dean for Science
New York University
Room 31
6 Washington Square North
New York, NY 10003
TEL (212) 998-3800
huanga@nyu.edu

Michael Hynes
Assistant Dean, Graduate Studies
College of Education
University of Central Florida
Orlando, FL 32816
TEL (407) 823-2005
FAX (407) 823-5156
hynes@pegasus.cc.ucf.edu

Steven Ilmer
Associate Dean for Research
College of Education, Rm. 441
Wayne State University
Detroit, MI 48202
TEL (313) 577-8282
FAX (313) 577-3606
silmer@cms.cc.wayne.edu

Richard E. Ishler
Dean, College of Education
University of South Carolina, Columbia
Columbia, SC 29208
TEL (803) 777-3075
FAX (803) 777-3035
rishler@ed.sc.edu

Bailey W. Jackson
Dean, School of Education
University of Massachusetts
124 Furcolo Hall
Amherst, MA 01003
TEL (413) 545-0233
FAX (413) 545-4240

Susan M. Johnson
Associate Dean, College of Sciences and Humanities (NQ112)
Ball State University
Muncie, IM 47306
TEL (317) 285-1042
FAX (317) 285-8980
00smjohnson@bsuvc.bsu.edu

Timothy Killeen
Associate Dean, School of Liberal Arts & Sciences
University of Connecticut
241 Glenbrook Road, Box 98
Storrs, CT 06269-2098
TEL (860) 486-0475
FAX (860) 486-0304
killeen@uconnvm.uconn.edu

Frederick L. Kitterle
Dean, Liberal Arts & Sciences
Northern Illinois University
Zulauf Hall 214
DeKalb, IL 60115
TEL (815) 753-1061
FAX (815) 753-7950
fkitterle@niu.edu

Genevieve Knight
Professor, Mathematics Department
Coppin State College
2500 West North Avenue
Baltimore, MD 21216
TEL (410) 383-5422
gknight@coe.coppin.umd.edu

Evelyn C. Lynch
Associate Dean, Teachers College (TC 1008)
Ball State University
Muncie, IN 47306
TEL (317) 285-5452
FAX (317) 285-5455
blynch@wp.bsu.edu

Sharon Lynch
Associate Professor, Graduate School of Education and Human Development
George Washington University
2122 Eye Street
Washington, DC 20052
TEL (202) 994-6174
FAX (202) 994-3365
slynch@gwis2.circ.gwu.edu

Stephen MacDonald
Associate Dean
Dickinson College
PO Box 1773
Carlisle, PA 17013-2896
TEL (717) 245-1392
FAX (717) 245-1993
macdonas@dickinson.edu

Estelle J. McGroarty
Associate Dean for Student and Academic Affairs
College of Natural Science
Michigan State University
103 Natural Science Building
East Lansing, MI 48824
TEL (517) 355-4474
FAX (517) 432-1054
cem03@msu.edu

Heather McKean
College of Science, Mathematics, and Technology
Eastern Washington University
526 5th St., MS-72
Cheney, WA 99004
TEL (509) 359-6512
FAX (509) 359-6950
hmckean@ewu.edu

Robert W. Mead
Associate Dean, College of Arts & Sciences
University of Nevada, Reno
Reno, NV 89557
TEL (702) 784-6155
FAX (702) 784-1478
mead@scs.unr.edu

Gustavo Mellander
Dean, Graduate School of Education
George Mason University
4400 University Drive
Fairfax, VA 22030
TEL (703) 993-2008
FAX (703) 993-2001
i:gmelland@gmu.edu

Kenneth F. Metz
Dean, School of Education
University of Pittsburgh
5T01 Forbes Quadrangle
Pittsburgh, PA 15260
TEL (412) 648-1773
FAX (412) 648-1825
kenmetz+@pitt.edu

Joan J. Michael
Dean, College of Education
North Carolina State University
PO Box 7801
Raleigh, NC 27695
TEL (919) 515-5900
FAX (919) 515-5836
joan_michael@coe.ncsu.edu

Frank Murray
Founding Co-Director of the Project 30 Alliance
Center for Educational Leadership & Policy
University of Delaware
101 Willard Hall, Education Building
Newark, DE 19716
TEL (302) 831-2557
FAX (302) 831-3013
frank.murray@mvs.udel.edu

Alexander Nagel
Associate Dean for Natural Sciences
College of Letters and Science
University of Wisconsin, Madison
301 South Hall
Madison, WI 53706-1394
TEL (608) 263-7221
FAX (608) 265-2275
anagel@ls.admin.wisc.edu

Joanne P. Newcombe
Acting Dean, School of Education & Allied Studies
Bridgewater State College
Bridgewater, MA 02325
TEL (508) 697-1347
FAX (508) 697-1771
jnewcombe@bridgew.edu

Jane A. Nichols
Associate Dean, College of Education/280
University of Nevada, Reno
Reno, NV 89557-0029
TEL (702) 784-4345
FAX (702) 784-6298
nichols@admin.unr.edu

Jerome Odom
Dean, College of Science and Mathematics
University of South Carolina, Columbia
Columbia, SC 29208
TEL (803) 777-2507
FAX (803) 777-2451
odom@cosm.psc.scarolina.edu

Robert Orton
Associate Professor, Mathematics Education
College of Education and Human Development
University of Minnesota
Peik Hall, 159 Pillsbury Drive, SE
Minneapolis, MN 55455
TEL (612) 624-2301
FAX (612) 624-8277
rorton@maroon.tc.umn.edu

Arturo Pacheco
Dean, College of Education
University of Texas at El Paso
El Paso, TX 79968
TEL (915) 747-5572
FAX (915) 747-5755

Robert H. Pate, Jr.
Professor and Senior Associate Dean
Curry School of Education
University of Virginia
405 Emmet Street, Ruffner 102
Charlottesville, VA 22903
TEL (804) 924-0774
FAX (804) 924-0888
pate@virginia.edu

John D. Petersen
Dean, College of Science
Wayne State University
2226 FAB
Detroit, MI 48202
TEL (313) 577-2519
FAX (313) 577-8971
jdpeter@sun.science.wayne.edu

David L. Potter
Dean, College of Arts & Sciences
George Mason University
4400 University Drive
Fairfax, VA 22030
TEL (703) 993-8715
FAX (703) 993-8714
i:dpotter@gmu.edu

Rodney J. Reed*
Dean, College of Education
Pennsylvania State University
University Park, PA 16802
TEL (814) 865-2526
FAX (814) 865-0555
rjr7@psuadmin.edu

George S. Rent
Interim Dean, College of Arts and Sciences
Mississippi State University
PO Drawer AS
Mississippi State, MS 39762
TEL (601) 325-2646
FAX (601) 325-8740
rent@deanas.msstate.edu

Sylvia Rodriguez-Santiago
Dean, College of Education
University of Puerto Rico
Box 23304
San Juan, PR 00931-3304
TEL (809) 765-9695
FAX (809) 763-4311

Glennon Rowell
Associate Dean, College of Educational Psychology
University of Tennessee, Knoxville
212 Claxton Building
Knoxville, TN 37996
TEL (423) 974-2201
FAX (423) 974-8718
growell@utk.edu

David A. Rowley
Associate Dean, Columbian School of Arts and Sciences
George Washington University
Phillips Hall T-212
Washington, DC 20052
TEL (202) 994-8095
FAX (202) 994-0854
dar@gwis2.circ.gwu.edu

Anthony G. Rud, Jr.
Associate Dean, School of Education
Purdue University
1440 Liberal Arts & Education Building
West Lafayette, IN 47907-1440
TEL (317) 494-6542
FAX (317) 494-5832
rud@sage.cc.purdue.edu

William Schwab
Associate Dean, Arts and Sciences
University of Arkansas
Fayetteville AR 72701
TEL (501) 575-3701
FAX (501) 575-2642
bschwab@comp.uark.edu

Susan Jones Sears
Associate Dean for Programs
College of Education
Ohio State University
1945 N. High Street
149 Arps Hall
Columbus, OH 43210-1172
TEL (614) 292-5790
FAX (614) 688-3942
sears.1@osu.edu

Portia Shields
Dean, School of Education
Howard University
2400 Sixth Street, NW
Washington, DC 20059
TEL (202) 806-7340
FAX (202) 806-5302

Suzanne Shipley
Dean, College of Arts and Sciences
Northern Arizona University
PO Box 5621
Flagstaff, AZ 86011-5621
TEL (520) 523-2701
FAX (520) 523-0516
suzanne.shipley@nau.edu

Barbara Simmons
Dean of Education
New Mexico State University
Box 30001/3AC
Las Cruces, NM 88003
TEL (505) 646-5858
FAX (505) 646-6032
bsimmons@nmsu.edu

Ella Smith Simmons
Associate Dean for Student Services
School of Education
University of Louisville
Louisville, KY 40292-0001
TEL (502) 852-5597
FAX (502) 852-0726
elsimm01@ulkyvm.louisville.edu

Marcy Gabella Singer
Assistant Provost, Initiatives in Education
Peabody College, Box 318
Vanderbilt University
203 Administration Building
Nashville, TN 37203
TEL (615) 343-5691
FAX (615) 343-6481
gavella@ctrvax.vanderbilt.edu

Linda L. Slakey
Dean, College of Natural Sciences and Mathematics
University of Massachusetts
B722 Lederle
Amherst, MA 01003
TEL (413) 545-1785
FAX (413) 545-9784
lslakey@nsm.umass.edu

Dennis H. Sorge
Director, Academic Services and Coordinator, Mathematics Outreach
School of Science
Purdue University
1390 Mathematical Sciences Building
West Lafayette, IN 47907
TEL (317) 494-1990
FAX (317) 494-1736
dhsorge@vm.cc.purdue.edu

Charles E. Stegman
Dean, College of Education
University of Arkansas
Graduate Education Building 324
Fayetteville, AR 72701
TEL (501) 575-3208
FAX (501) 3119
cstegman@comp.uark.edu

Fredrick Stein*
Director,Center for Science, Mathematics, & Technology Education
Colorado State University
University Services Building
Fort Collins, CO 80523
TEL (970) 491-1700
FAX (970) 491-2005
fred_stein@cnsmail.mso.colostate.edu

Les Sternberg
Dean, College of Education and Allied Professions
Bowling Green State University
444 Education
Bowling Green, OH 43403
TEL (419) 372-7403
FAX (419) 372-2828
lstern@bgnet.bgsu.edu

Michael J. Subkoviak
Associate Dean, School of Education
University of Wisconsin, Madison
119 Education Building
1000 Bascom Mall
Madison, WI 53706-1398
TEL (608) 262-0458
FAX (608) 265-2512

Haven Sweet
Associate Dean, College of Arts & Sciences
University of Central Florida
Orlando, FL 32816
TEL (407) 823-2251
FAX (407) 823-5156
hsweet@pegasus.cc.ucf.edu

Stephen Thornton
Professor of Physics
University of Virginia
Physics Building
205 McCormick Road
Charlottesville, VA 22901
TEL (804) 924-6808
stt@va.edu

Alfonzo Thurman
Dean, College of Education
Northern Illinois University
Graham Hall 321
DeKalb, IL 60115
TEL (815) 753-9056
FAX (815) 753-2100
athruman@niu.edu

Sr. Leona Truchan
Associate Professor of Biology
Alverno College
3401 S. 39th Street
Milwaukee, WI 53234-3922
TEL (414) 382-6505
FAX (414) 382-6354

Trevor Turner
Dean, School of Education
Clark Atlanta University
JP Brawley Drive at Fair St., SW
Atlanta, GA 30314
TEL (404) 880-8504
FAX (404) 880-6081

Dorothy Walker-Jones
Associate Dean for Natural Sciences
College of Arts & Sciences
Howard University
2400 Sixth Street, NW
Washington, DC 20059
TEL (202) 806-6700
FAX (202) 806-4562

William L. White
Associate Dean, School of Science and Technology
Jackson State University
PO Box 18750
1440 John R. Lynch Street
TEL (601) 968-2153
FAX (601) 968-2058
wwhite@ccaix.jsums.edu

Jerry L. Whitten
Dean, Mathematical and Physical Sciences
North Carolina State University
Raleigh, NC 27695
TEL (919) 515-7277
FAX (919) 515-7855
j_whitten@ncsu.edu

Louise Cherry Wilkinson
Dean, Graduate School of Education
Rutgers University
10 Seminary Place
New Brunswick, NJ 08903-5050
TEL (908) 932-7496 ext. 117
FAX (908) 932-8206
lwilkin@rci.rutgers.edu

Clifton Woods
Associate Dean, College of Arts & Sciences
University of Tennessee, Knoxville
226 Ayres Hall
Knoxville, TN 37996-1320
TEL (423) 974-3585
FAX (423) 974-4352
clifwoods@utk.edu

Russell H. Yeany, Jr.
Dean, College of Education
University of Georgia
Athens, GA 30602
TEL (706) 542-3866
FAX (706) 542-0360
ryeany@uga.cc.uga.edu

Stanley Ziegler
Associate Dean, Natural Sciences
California State University, Fresno
5241 North Maple
Fresno, CA 93740
TEL (209) 278-3936
FAX (209) 278-7139

Discussants

William Badders
Science Resource Teacher
Cleveland Public Schools
1380 East Sixth Street
Cleveland, OH 44114
TEL (216) 574-8180

Jo Ellen Roseman
Curriculum Director, Project 2061
American Association for the Advancement of Science
1333 H Street, NW
Washington, DC 20005
TEL (202) 326-6752

Leonard Solo
Principal, Graham & Parks Alternative Public School
15 Upton Street
Cambridge, MA 02139
TEL (617) 349-6612

Rachel Wood
Secondary Science Teacher, on assignment with the Delaware Department of Public Instruction
P.O. Box 1402
Townsend Building
Dover, DE 19901
TEL (302) 739-3742

Observers

Luther S. Williams
Directorate for Education and Human Resouorces
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230

Herbert Levitan
James H. Lightbourne
Herbert Richtol
Robert F. Watson
Terry S. Woodin
Lee L. Zia
Division of Undergraduate Education
National Science Foundation
(703) 306-1669

Joan Ferrini-Mundy
Mathematical Sciences Education Board

Jacqueline Raphael
National Institute for Science Education

Staff

Jerry Bell
American Association for the Advancement of Science
1200 New York Avenue, NW
Washington, DC 20005-3290
TEL (202) 326-6670
FAX (202) 371-9849
jbell@aaas.org

Alphonse Buccino
Innovation Management
Contemporary Communication Inc.
5615 Glenwood Road
Bethesda, MD 20817
TEL (301) 718-6136

Betty Calinger
American Association for theAdvancement of Science

Mary Beth Lennon
American Association for the Advancement of Science

***Forum Planning Group**

Appendix C: Colleges and Universities Represented

Alverno College
Ball State University
Bowling Green State University
Bridgewater State College
California State University, Fresno
Carnegie Mellon Institute
Central Connecticut State University
Clark Atlanta University
Colorado State University
Coppin State College
Dickinson College
Eastern Washington University
George Mason University
George Washington University
Hampton University
Howard University
Jackson State University
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Purdue University
Rutgers University
Syracuse University
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University of Arkansas
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University of Georgia
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University of Missouri, Columbia
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University of Nevada, Reno
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University of South Carolina, Columbia
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University of Virginia
University of Wisconsin, Madison
Vanderbilt University
Wayne State University
West Virginia University

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

1200 New York Avenue, N.W.
Washington, D.C. 20005

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Sign here, → please

Signature: Betty J. Calinger
Printed Name/Position/Title: Betty J. Calinger/Sr. Prog. Associate
Organization/Address: Amer. Assn. for the Advancement of Science
Telephone: 202-326-6629
FAX: 202-371-9849
E-Mail Address: bcalinge@aaas.org
Date: 11/5/99

(over)