Part V

Resources

Chapter 20
How to Conduct External Reviews

The very word "review" triggers aversion: visions of a retreat into a Kafkaesque world of bureaucracy, paper trails, endless lists, and questionnaires. Where will it all end? And an even worse thought: How and where can we begin?

We all know, however, that taking stock is important. And it is particularly important in departments such as mathematics, which although sometimes large and unwieldy, are so central to the university's overall mission. Are the vision and the goals of the department consistent with those of the university? Do we do right by our undergraduates? Are they really learning what we think and hope they are learning? Are we listening to them? Are there improvements that might be made to the curriculum? Does the training and experience we give our students enable them to go on to further advanced study or get good jobs whatever their career choices might be? How is the graduate program doing? What will we do if the numbers fall? And how are our relations with other departments? Do our colleagues in other departments see us as fellow travelers on the road to discovery and a resource, or do they regard us as isolated and insular, completely immersed in a world of our own? Are we generating the kind of resources to do what we want to do? And what is it that we really want to do anyway? Are there any areas of mathematics we should be getting into? How would we like our department to look in five years' time? And most important, are we, as departmental colleagues, all on the same page?

We suspect that none of us would disagree that it is important to ask ourselves such questions from time to time. In fact, it has been the experience of the Task Force that departments which had an overall plan and a strategic view were by and large the most successful. To develop a plan, it is necessary to undergo some self-evaluation. The exercise of self-assessment focuses the mind, allows us to take note of, and take advantage of, changes and new opportunities. The exercise itself requires a little organization. It is important to begin by trying to write a self-assessment document and then asking colleagues from within or without the university to examine and scrutinize the outcome.

To begin the process, however, is sometimes difficult. Therefore, it is useful to have a stencil, a format, a plan to follow until the process at your department takes on a life of its own and the questions ask themselves. To help get started, we suggest the following self-study guidelines. They were prepared by the AMS

Committee on the Profession from self-evaluation materials used at several universities. Not all the questions will be of interest in your situation. Discard those that are irrelevant, and put in your own instead.

Many of us have found these exercises to be not only useful but absolutely necessary as a healthy check on our well being. Moreover, they can also be helpful in establishing the department's credibility with the administration. If you feel that your contributions are not being properly recognized, that you have plans worthy of investment, that you are underresourced, make the case in your self-assessment document and ask for external opinions. Such confidence has a curious effect on deans. It makes them both pleased and nervous at the same time.

THE "WHY AND HOW" OF EXTERNAL REVIEWS OF U.S. MATHEMATICS DEPARTMENTS[1]

This document is to be viewed as generic, answering the questions:

- Why should my department undergo an external review?
- How does my department and university prepare for an external review?
- How does my department conduct an external review?

Why Undertake an External Review

Some mathematics departments are required to have routine external evaluations, some departments have sporadic evaluations, while there remain many departments that have never undergone an external review. An external review requires a large effort by the department, school/college, and central administration. Thus there should be a large return for these efforts. Here is a list of potential returns from undertaking an external review.

- The process of the review will clarify the strengths and weaknesses in your curricular, research, and support programs.
- The process of the review will clarify the strengths and weaknesses of your relationships with other departments, schools and colleges, and the central administration.
- The review will establish evaluation and subsequent planning that focuses on the identification and resolution of issues that are likely to improve your mathematics department.
- The review can advertise the successes of the department to an external group of distinguished and influential mathematicians.

[1] These guidelines for external reviews were prepared by the AMS Committee on the Profession from documents used by several universities, including Brown University. The introductory remarks and editorial work was largely done by Ron Stern, whose contributions we gratefully acknowledge.

Preparing for and Conducting an External Review

The external review process itself requires work and resources from all levels of the university. The central administration should provide adequate funding for the external review. This includes all travel and local expenses as well as an honorarium for each external review committee member. A typical review team may consist of three or four distinguished mathematicians, and the on-site review could take only one or as many as two and a half days.[2] There are several issues to keep in mind when selecting members for the review team. The department should keep in mind that both positive *and* negative comments from an external review team are beneficial for the growth and development of the department. Thus the potential members of the review team should be distinguished mathematicians who are able to critically assess and evaluate a department and who also have the ability to express their findings.

Several months prior to the on-site visit of the external review team, this team needs to be invited and secured for service. One member should be invited as the chair of the external review team and should be assigned the responsibility of providing a written report (reflecting the external review team's on-site visit) in a timely fashion.

Your department should identify a mathematics faculty committee with staff support to assist in a self-study. This committee will be used to discuss and answer the questions posed in this self-study.

Your department should then undertake a self-study with some guidance from the dean. The goal is to prepare a written profile of the department that includes an overview of existing curricular, research and support programs, a written mission statement, and a written statement of planned future developments.

In consultation with the dean, the next step is to develop a schedule of meetings for the external review team. These meetings should include all constituencies of the department (faculty, staff, and students) and those served by the department, a walk-through of your physical facilities, and meetings with the department chair, dean, and vice-chancellors/vice-presidents for undergraduate, graduate, and research affairs, and the chancellor/president.

The external review team should be provided with a packet consisting of the departmental self-study, the tentative schedule for the on-site review, and a list of questions that they are expected to answer. This packet should be received by the external review team at least two weeks prior to the on-site visit. The chair of the external review team should be allowed to "fine-tune" the schedule and to add other people to the schedule.

At the end of the on-site visit, the external review team should present a verbal report of its findings. Thus time should be allotted in the on-site schedule to prepare for this meeting. One model is to have two presentations. The first should be a general presentation of the team's findings, including a critique and self-

[2] Taking the larger numbers, a department could expect to spend $2,400 in local expenses, $2,000 in airfares, and $5,000 in honoraria ($1,000 for each member and $2,000 for the chair of the team that will do all the writing of the report).

study. Those involved in the first presentation should include the external review team, dean or vice-president, the departmental chair, and the chair of the self-study team. In order to maintain confidentiality, the second exit interview should be limited to the dean or vice-president or president and the external review team.

It is then the (paid) responsibility of the chair of the external review team to provide a written report to the dean within one or two weeks.

What to Do with the External Review Team Report

The final step can consist of one of two possible actions. The first action is for the department and administration to develop and act on a plan to implement the recommendations. The other action is for the report and/or plan to sit on the shelf to collect dust until the next external review is undertaken. The bottom line is that this exercise will be important and influential if you, the dean, or the department chair make it so.

Self-Study Outline for Mathematics Departments Undergoing External Review

This document is intended as a generic framework for your department's self-study report, which will be forwarded to the senior academic administration and the external review team. Not all questions may be relevant to your department, nor should they be answered individually. These questions should be used to guide and facilitate a thoughtful and complete written discussion of your department's current situation and future plans.

You should aim for a finished document of no more than twenty typewritten pages, which should then be supplemented by appended data and other departmental documents. This self-study will be most useful if your text is interpretive and evaluative, and if it refers to the supporting documents rather than attempting to duplicate them.

A. Overview, Goals, and Recent History

- What are your department's major goals? (If you have a mission statement, please append it.) How have your goals and/or mission statement changed over recent years? How are they expected to change in the future? Include the role of graduate and undergraduate instruction, research, relationships to other academic units at your university, and community outreach.
- How is your department organized? Describe your faculty and staff administrative structures (attach an organizational chart if appropriate).
- Describe your program's history since the last external review or within the past five to seven years. In what ways has your program improved or deteriorated within this time period? How has your department addressed any issues raised by the previous review? (Attach a copy of the report of the most recent external reviews your department has undergone if such a report exists.)

- Identify three to five mathematics departments at other universities that provide targets of aspiration for your department. How does your department compare with others nationally? What evidence suggests this conclusion?

B. Faculty

- Describe briefly the profile of the faculty in terms of the areas of teaching and research expertise and their demographic characteristics.
- Describe the profile of any professional nonfaculty staff members who make significant contributions to the academic programs of your department.
- Summarize your faculty's overall strengths and weaknesses. What information has been used in identifying these strengths and weaknesses, and what other conclusions have been drawn from this information? What is the balance of scholarly depth and breadth in the faculty, and what is the balance of traditional views as contrasted with work taking place at the field's frontiers? Have there been any significant losses or additions of fields or subfields since the last external review or in the last five to seven years?
- Describe your faculty's overall strengths and weaknesses as a teaching faculty at both the graduate and undergraduate levels. How do you assess teaching performance and in what activities does your faculty participate that improve the quality of teaching in your department?
- Describe and evaluate the faculty's participation, leadership, and influence in the academic profession through such avenues as professional associations, review panels, and advisory groups.
- Describe your department's potential for responding to changing directions and new external opportunities. What indicators show the level of morale, commitment, and continuing self-improvement of your department?
- What efforts have been made to make your department more diverse with regard to gender and race/ethnicity?
- How are junior faculty mentored? How are tenure-track faculty evaluated and kept informed of their progress towards tenure?
- What is your faculty's collective view of the program's future, its desired directions, and its means for reaching its objectives? How do planning and incentives direct the program to these ends?

C. Scholarly Productivity/Creative Performance

- Evaluate the level of scholarly activity in your department, addressing the quality and quantity of your department's publications, presentations at academic and/or professional forums, and performances as appropriate.
- Evaluate the level of internal and external support for research, performance, or creative activity in your department. Is your department competing effectively for external support? Describe any deficiencies in facilities and resources which negatively affect your department's attempts to reach its research objectives.
- Describe any significant research interactions with other units at your university and with external entities (public or private). What have been the benefits of these interactions and the drawbacks, if any? How do they contribute to your department's research goals?
- Briefly describe how the research, performance, or creative activity in your department compares nationally and internationally.

D. Undergraduate Program

- Describe and evaluate the organization of and rationale behind your department's undergraduate curriculum and course offering.
- How is the undergraduate concentration organized, and why is it organized that way? What evidence is there of sufficient breadth and depth of course offerings, as well as balance among the various specialties to meet student needs and interests? Does an external accrediting body prescribe any portion of the concentration? If so, describe how the program measures up to accreditation standards, and append a copy of the most recent accreditation report.
- What introductory courses are aimed at a liberal arts education, and are the number, range, and level of these appropriate? By what standards do you evaluate the appropriateness and effectiveness of these courses?
- What courses does your department offer (if any) that primarily serve the needs of students who are concentrating on other fields or who are meeting preprofessional school requirements? Evaluate the effectiveness of these courses.
- If there are any enrollment limits on any of your courses, describe the rationale for imposing such limits, and evaluate the costs and benefits of having such limits.
- Describe the nature of your department's undergraduate curricular planning efforts. What specific efforts are made to incorporate new knowledge and areas into the curriculum? Is this generally left to individual

faculty to decide, or is the content of the curriculum reviewed comprehensively? How are proposed new course offerings evaluated? In general, what plans are under way to change or strengthen your undergraduate offerings and programs?

- Does your department substantially support or participate in multiple concentrations? What other departments actively participate? Are there sufficient teaching and advising resources to support these concentrations? Are there redundancies in these concentrations?
- What efforts are made to involve students actively in their learning through internships, undergraduate teaching assistantships, research projects, seminars, independent study? What are the criteria for honors in the concentration? Are eligible students gaining access and being attracted to your honors program?
- Describe and evaluate the organization of and rationale behind your department's allocation of teaching personnel. What percentage of your courses are covered by tenure-track or tenured faculty?
- What is the faculty teaching load in your department? How are teaching assignments determined in a way that is equitable to all faculty at the same time that quality of instruction is maintained?
- What proportion of courses in various categories are taught by full-time faculty, part-time or visiting faculty, and graduate students? If these categories of faculty are not in the right proportions, describe how and why the mix should change.
- What is the role of graduate teaching assistants in your department's instructional program? How are they selected and trained for their roles? How are they supervised and evaluated? What changes, if any, in the number of teaching assistants or in the nature of the work they perform seem warranted?
- What is the role of undergraduate teaching assistants in your department's instructional program? How are they selected and trained for their roles? How are they supervised and evaluated? What changes, if any, in the number of undergraduate teaching assistants or in the nature of the work they perform seem warranted?
- How is the quality of instruction assessed and improved in your department on an ongoing basis?
- Describe the students in the undergraduate concentration program.
- Are you attracting the number and quality of students to meet your department's needs and expectations? If not, how can changes be brought about? Please make your needs and expectations explicit.
- Explain any recent significant changes in undergraduate courses.

- Where do your undergraduate majors go, and what do they do after graduation? What indicators do you use to monitor the success of your graduates? How does the quality of the graduates compare with student quality in your field nationally? How do alumni of your program view their educational experience? Describe any honors or awards received by undergraduate concentrators.
- Describe and evaluate the process and structure of your undergraduate advising.
- Describe the nature of and evaluate any outreach activities in your academic department that impact on undergraduate education.

E. Graduate Program

Overview

- Describe, in general terms, the graduate program(s) offered by your department. What changes have occurred in recent years, and what changes are contemplated for the future?
- What evidence (e.g., reputation, recruiting and retention, outcomes) is available concerning the quality of your department's graduate program(s)? How is the information used to strengthen the graduate program(s)?

Curriculum and Courses

- What evidence is there of sufficient course and research opportunities and balance among the various specialties? How are the courses in your graduate program coordinated?
- Do students have adequate resources to carry out their studies (e.g., office and lab space, supplies, travel, library collections, and financial support)? What additional resources would be required to improve the quality of your graduate program substantially?
- Does your department offer graduate courses taken by significant numbers of students from other programs? Does your department depend upon courses offered by other units? Describe the planning process used for these courses, how the offerings are coordinated with the other units (including coordination problems encountered), and how well the courses meet the needs of all programs involved.

Graduate Students

- What mechanisms are used to recruit students? Is the program competing well for top students? What help is needed in recruiting? How does the quality of students in your graduate program compare with student quality in other similar programs? How does the quality and quantity of current students compare to the students in your program five years ago? Ten years ago?

- What is the current gender and race/ethnicity composition of graduate students in your program? How do these figures compare with similar figures for undergraduates? For graduate programs at other schools? What efforts are under way to attract and retain well-qualified students from nonmajority groups?

Professional Training, Advising, Placement

- Describe and evaluate the preliminary/qualifying examination requirement in your program(s).
- In what ways, besides individual thesis or dissertation research, do graduate students receive professional experience (e.g., research assistantships, internships, outreach efforts, etc.)?
- How do graduate students acquire professional skills other than those directly associated with research and teaching (e.g., learning how to write grants, give colloquia, etc.)?
- What is the nature and quality of the advising for graduate students, and how is such advising assessed?
- How well do your master's and Ph.D. students fare on the academic job market? On the nonacademic job market? How is placement information used to evaluate and modify the nature of the graduate program?

F. Administration and Support Services

- Describe and appraise any related support activities that impact your teaching, research, and/or service programs (e.g., outreach efforts).
- Describe and appraise the physical facilities associated with your department.
- Describe and appraise the current levels and types of staff support (both technical and office).
- Rank order you department's specific and most pressing support needs (for example, library, computer equipment/support, office personnel, technical assistance, etc.).

G. Summary Assessment and Future Directions

In no more than two pages, highlight the most salient points of this self-study. Place emphasis on plans, new directions, and remediation of existing problems and on ways your department is working to help itself.

Materials to Be Appended

- Department Profile (e.g. number of faculty, budget dollars, grant dollars, etc.) and area comparative data (to be provided by the dean).
- Graduate program data (to be provided by the graduate school).
- Mission statement.
- Copy of the report of the most recent external review committee.
- Faculty and staff administrative organization charts.
- CV's of all regular faculty and staff members that have regular teaching responsibilities at the graduate and/or undergraduate level.
- A copy of all departmental informational publications, including graduate and undergraduate program descriptions, graduate manual, the "department brochure" (if there is one), etc. Include any newsletters to graduate or friends of your department.

Chapter 21
Where to Find Data (and How to Use It)

How do you convince a distrustful dean that your declining number of majors is part of a national trend? How can you plan for changing applications to the graduate program? How do you prepare your doctoral students for the job market they face in the next few years? The answers to all these questions begin with data.

Accessing and understanding data is a key part of making a convincing argument. But it is also a key to planning for a department's future and understanding the environment in which it exists. If you want to expand a program that has successfully increased the number of majors, show the administration that you have reversed a national trend. Making arguments with carefully prepared data helps to convince the listener for two reasons: the facts themselves, and the fact that you gathered them. But data is equally useful for planning and understanding. Department chairs (and others in the department's leadership) need to know what major national trends are affecting their discipline, and they need to compare their own situation to those trends. Much understanding comes from that process.

Four key sources of data are listed below. The sources range from data specific to U.S. departments of mathematics to data on the national science and engineering enterprise. These sources often point you to other sources of related data.

Resources for Data on Mathematics in Academia

1. The jointly sponsored *Annual Survey of the Mathematical Sciences*, newly renamed with the 1998 survey cycle, collects data from academic departments in the mathematical sciences and from each year's doctoral recipients. Regular data collection efforts were begun by the AMS in 1957. MAA became a joint sponsor of the modern survey effort in 1989, IMS in 1993, and ASA in 1998. The survey currently gathers information annually on faculty salaries and counts of faculty by rank and sex, total and first-year counts of graduate students, undergraduate and graduate enrollments, and junior/senior majors. It also gathers information on doctoral recipients and their initial employment experiences, first from the doctoral-granting departments, then from the individual recipients in a follow-up survey.

Reports on the Annual Survey of the Mathematical Sciences are published periodically in the *Notices* of the AMS. A complete list of reports for the past five years may be found at http://www.ams.org/membership/survey.html, with links to those available electronically. Reprints are also available from the AMS by phone (401-455-4113) or e-mail (survey@ams.org).

2. The *Conference Board on the Mathematical Sciences Survey on Undergraduate Instruction in Two- and Four-year Institutions* has been conducted every five years since 1965. This survey gathers detailed enrollment data by individual course for the whole range of undergraduate mathematics and statistics courses. It also gathers counts of faculty by age, rank, sex, and, in recent years, race/ethnicity. The strength of this survey is its long-term trend data on undergraduate instruction. Each survey also includes a section of questions on topics of then-current interest.

Copies of the fall 1995 CBMS survey report, the most recent in the series, were mailed in June 1997 to all mathematics and statistics departments. Additional copies may be purchased from the MAA by calling 800-331-1622. An overview of the entire survey is available on e-MATH at

http://www.ams.org/membership/survey.html

Data on How Mathematics Fits into Science and Engineering

3. The Science Resources Studies (SRS) Division of the National Science Foundation is the unit that manages the survey efforts supported by NSF. It is by far the richest source of data comparing the mathematical sciences with other science and engineering disciplines. Access to the reports on these surveys has been made much easier by the World Wide Web. The starting point for information available through SRS is

http://www.nsf.gov/sbe/srs/stats.htm

Two of the valuable long-standing surveys managed by SRS are the annual Survey of Earned Doctorates and the longitudinal Survey of Doctoral Recipients. The first of these overlaps with the AMS Annual Survey, but it becomes available considerably later and does not provide as detailed a look at new doctoral recipients in mathematics as does the Annual Survey. Its advantage is that it provides comparable data for all the science and engineering disciplines, e.g., a measure of time-to-degree. The Survey of Doctoral Recipients is a longitudinal sample survey of the complete population of U.S. doctoral recipients over the past fifty years. It is designed to provide demographic and career history information about individuals with U.S.-granted doctoral degrees. A third survey of particular interest is the Graduate Students and Postdoctorates in Science and Engineering (GSS) survey, which obtains data on the number and characteristics of graduate science and engineering (S&E) students enrolled in U.S. institutions. The results of the survey are used to assess trends in financial support patterns and shifts in graduate enrollment and postdoctorates.

4. Another source of general data on postsecondary education is the National Center for Education Statistics (NCES), a unit of the Office of Educational Research and Improvement of the U.S. Department of Education. NCES maintains a number of ongoing surveys of postsecondary education, including detailed data

on undergraduate and graduate enrollments, degrees awarded, and staffing in postsecondary institutions. NCES's Web site,

http://nces.ed.gov/surveys/datasurv.html,

provides easy access to its many reports of these surveys (via PDF files), as well as access to public-use data sets. Some of this data is available for certain disciplines, including mathematics. A report on the view of mathematics enrollments provided by this data will be published by the AMS in the future.

The following examples illustrate the kinds of issues a department chair might encounter for which data is available from the sources above.

• What has been happening to undergraduate enrollments?

The enrollment in undergraduate mathematics courses within mathematics departments at four-year institutions declined 9% between fall 1990 and fall 1995, from 1,619,000 to 1,469,000. This decline in four-year institutions contrasts with a 12% increase in mathematics enrollments at two-year institutions, from 1,241,000 to 1,384,000. The fall 1995 enrollments at two-year institutions accounted for 49% of the total enrollment in undergraduate mathematics taught within mathematics departments. (From 1995 CBMS highlights by Donald Rung, *Notices of the AMS*, vol. 44, no. **8**(Sep 1997), 923–931.)

• What has been happening to enrollments in graduate courses?

Total enrollment in graduate courses in Ph.D.-granting mathematics departments declined 19% between fall 1992 and fall 1997, based on enrollments data collected in the AMS-IMS-MAA Annual Survey.

Fall Graduate Course Enrollments, 1992 to 1997

	Fall 1992		Fall 1997		
Departmental Groupings	**Count**	**% of Total Enrollment**	**Count**	**% of Total Enrollment**	**% Change 1992 to 1997**
Group I Public (19 of 25 responding)	6,892	33.0%	4,964	29.2%	-28.0%
Group I Private (14 of 23 responding)	2,101	10.1%	1,943	11.4%	-7.5%
Group II Public (33 of 44 responding)	6,361	30.5%	5,447	32.0%	-14.4%
Group II Private (6 of 12 responding)	556	2.7%	397	2.3%	-28.6%
Group III Public (31 of 51 responding)	4,339	20.8%	3,763	22.1%	-13.3%
Group III Private (9 of 21 responding)	610	2.9%	486	2.9%	-20.3%
Total enrollment (112 of 176 responding)	**20,859**		**17,000**		**-18.5%**

Table 1

The decline within the Group I Public departments was an even more dramatic 28%, while the decline within the Group I Private departments was a much less dramatic 8%. The above table is based on an unpublished retrospective analysis of data provided by the 112 Ph.D.-granting mathematics departments that responded to both the 1992 and 1997 Departmental Profile survey, one of four surveys that comprise the Annual Survey. These 112 departments account for 70% of the Ph.D.'s produced over the last ten years by the 176 departments in Groups I–III.

• What has been happening to numbers of graduate students?

The number of full-time graduate students in Ph.D.-granting mathematics departments declined 19% between fall 1991 and fall 1997.

Counts of Full-Time Graduate Students, 1991–1997

	Female			Male			Total		
	1991	1997	% Change	1991	1997	% Change	1991	1997	% Change
Group I Public (19)	624	507	-19%	1,981	1,514	-24%	2,605	2,021	-22%
Group I Public (Top 9)	370	296	-20%	1,296	920	-29%	1,666	1,216	-27%
Group I Private (17)	175	145	-17%	687	549	-20%	862	694	-19%
Group I Private (Top 8)	71	71	0%	373	308	-17%	444	379	-15%
Group II (39)	685	608	-11%	1,587	1,288	-19%	2,272	1,896	-17%
Group III (37)	432	399	-8%	854	711	-17%	1,286	1,110	-14%
All Departments (112)	1,916	1,659	-13%	5,109	4,062	-20%	7,025	5,721	-19%

Table 2

The decline within nine of the top twelve Group I public departments for which data was available was 27%, while it was 22% for the group as a whole. The declines were 19%, 17%, and 14% within Group I Private, Group II, and Group III respectively. Not surprisingly, the decline in first-year (full-time) graduate students was even more precipitous. Between fall 1991 and fall 1997 the decline within Ph.D.-granting mathematics departments was 26% while within Group I Public, Group I Private, Group II, and Group III departments they were 34%, 41%, 12%, and 28% respectively. These figures, taken from Tables 2 and 3 are based on a retrospective analysis of data provided by the 112 Ph.D.-granting mathematics departments that responded to both the 1991 and

1997 Departmental Profile surveys. (These responding departments differ slightly from those in Table 1.)

Counts of Full-Time First-Year Graduate Students, 1991–1997

	Female			Male			Total		
	1991	1997	% Change	1991	1997	% Change	1991	1997	% Change
Group I Public (19)	191	121	-37%	450	305	-32%	641	426	-34%
Group I Public (Top 9)	101	63	-38%	280	182	-35%	381	245	-36%
Group I Private (17)	50	38	-24%	172	92	-47%	222	130	-41%
Group I Private (Top 8)	20	18	-10%	83	48	-42%	103	66	-36%
Group II (39)	229	211	-8%	425	365	-14%	654	576	-12%
Group III (37)	173	135	-22%	308	209	-32%	481	344	-28%
All Departments (112)	643	505	-21%	1,355	971	-28%	1,998	1,476	-26%

Table 3

• What has been happening to tenure-track positions?

The total number of tenured faculty in mathematics departments remained almost constant between 1990 and 1996, around 13,400. Over this same time interval, the number of individuals in tenure-eligible positions, i.e., tenure-track but not yet tenured, declined by almost 30%, from approximately 4,700 to 3,300. In Group I, II, and III combined (the Ph.D.-granting mathematics departments) there was a 27% decline, from 1120 to 820. Figure 1 shows the recent trends in tenure-eligible positions and non-tenure-eligible positions for Groups I–III combined and Groups M and B combined. (See "Changes in Mathematics Faculty Composition", Fall 1990 to Fall 1996, *Notices of the AMS*, **44**, no. 10 (Nov 1997), 1321–1323.)

• What is the situation relative to the use of part-time faculty in mathematics departments?

In the Ph.D.-granting departments, the number of individuals holding part-time appointments increased slightly between 1990 and 1996, from 975 in fall 1990 to 1,090 in fall 1996. In master's and bachelor's departments, the numbers of individuals in part-time appointments declined slightly, from 5,200 in fall

1990 to 4,930 in fall 1996. (See "Changes in Mathematics Faculty Composition", Fall 1990 to Fall 1996, *Notices of the AMS*, **44**, no. 10 **(**Nov 1997), 1321-1323.)

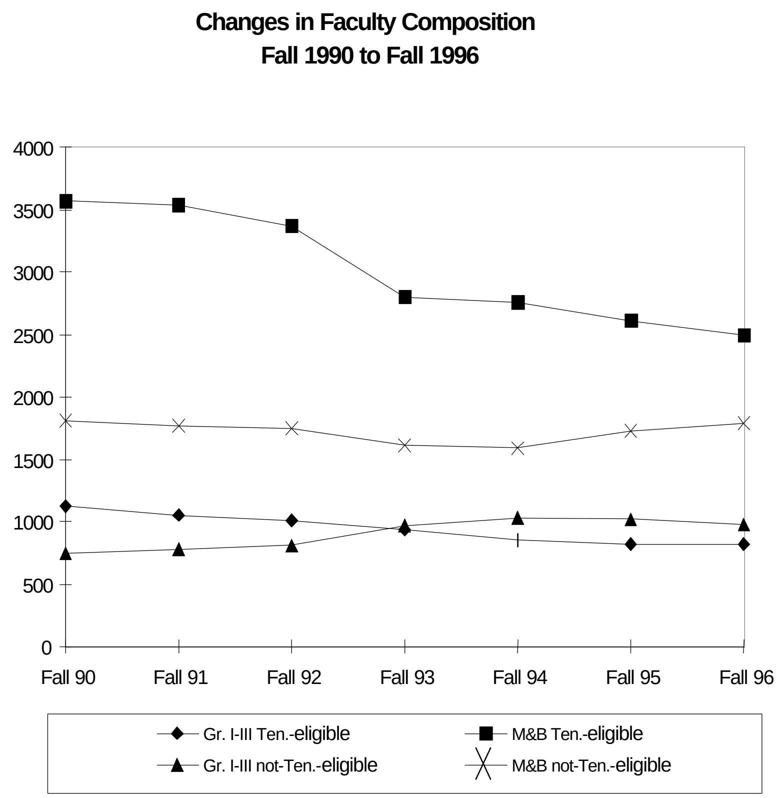

Figure 1

• What were the starting salaries for postdoctoral positions in fall 1997?

The median salary for a 9–10-month appointment for a postdoctoral position in academia in fall 1997 was $38,500. A report on starting salaries for new doctoral recipients is a regular feature of the Annual Survey reports. Starting salaries for fall 1997 appear in the "Second Report of the 1997 AMS-IMS-MAA Annual Survey", *Notices of the AMS*, **45**, no. 9 (Oct 1998), 1163–1165.

Finally, a cautionary note is in order. Gathering massive amounts of data and then using it to support whatever arguments one proposes can be counterproductive. (A famous quote of Andrew Lang goes: "He uses statistics as a drunken man uses lamp posts—for support rather than illumination.") There are some vital aspects of a department's life that are not easily measured by numbers. Nonetheless, data can be an important part of understanding.

Chapter 22
A Digest of Some Reports

Index of Report Summaries

This book is only one of many attempts to address the issues of research, education, and the role of mathematics. While it is difficult to be knowledgeable about all such material, mathematicians can profit by knowing what has been said, even when they disagree with it.

This chapter contains descriptions of a sample of such reports, selected to represent the variety of material. The reports include:

- 1945 Science—The Endless Frontier (Vannevar Bush Report)
- 1984 Renewing U.S. Mathematics (David Report)
- 1991 Moving Beyond Myths (MSEB)
- 1992 Educating Mathematical Scientists (Douglas Report)
- 1994 Recognition and Rewards in the Mathematical Sciences (JPBM)
- 1994 Talking about Leaving
- 1995 SIAM Report on Mathematics in Industry
- 1996 Shaping the Future, New Expectations for Undergraduate Education
- 1998 Reinventing Undergraduate Education (Boyer Report)
- 1998 Senior Assessment Panel Report
- 1998 Unlocking Our Future (Ehlers Report)

The following chapter contains a more comprehensive bibliography, with brief annotations for much of the material.

Science, The Endless Frontier — A Report to the President on a Program for Postwar Scientific Research

- *By Vannevar Bush, Director Office of Scientific Research and Development, Washington, DC, 1945 (reprinted by the National Science Foundation in 1990).*

The Office of Scientific Research and Development was established in June 1941 to coordinate weapons development and related research during World War II. It was directed by Vannevar Bush, an electrical engineer. The OSRD oversaw the development of the atomic bomb, advances in microwave radar, and mass production of penicillin. Much of its scientific work was performed at universities under contract with the government. More than fifty universities received contracts of over a million dollars each. Such levels of government support of research were unprecedented. (The four or five largest university departments of physics, chemistry, and biology each spent thirty to forty thousand dollars annually on research before the war.)

In November of 1944, with the end of the war in sight, Roosevelt wrote a letter to Bush (at least in part at Bush's instigation), asking for his recommendations on the continuation of government involvement with science. He asked in particular about four points: first, the diffusion of scientific knowledge arising from the war effort; second, the continuation of medical research undertaken for the war; third, government aid to research by public and private organizations (primarily military laboratories and universities); and fourth, the discovery and development of scientific talent.

Bush's response, delivered to Truman in July 1945, is a very precise and personal vision, contained in less than forty pages. He appointed and consulted advisory committees for each of the four points, and their reports provide a hundred and fifty pages of appendices. The answer to the central question of continued government support for science was implicit in Roosevelt's letter: "The information, the techniques, and the research experience...should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living." Bush's report echoed this theme, with emphasis on how much remained to be done: "But without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world." The report was released to the public on July 19, three days after the Trinity test in Alamogordo.

The heart of Bush's vision was a National Research Foundation, to be controlled by a board of nine civilian scientists appointed for four-year terms by the president. The Foundation was to be organized into five divisions: Medical Research, Natural Sciences, National Defense, Scientific Personnel and Education, and Publications and Scientific Collaboration. This foundation would distribute all federal support in these fields. (The Division of National Defense was to be charged with "long-range scientific research on military matters." The military would retain direct control over "research on improvement of existing weapons.")

At the same time, Senator Harley Kilgore of West Virginia was proposing a slightly different vision: a National Science Foundation, structured more like other federal agencies and including more direct consideration both for the social sciences and for social goals. Kilgore, for example, wanted at least part of the federal support for research to be distributed on a geographic basis, and he wanted to include guarantees that small businesses could enjoy some of the benefits of technology developed with government support.

The political dispute between Bush's vision and Kilgore's lasted five years. In 1947 Congress passed a bill close to Bush's model. Truman vetoed it, saying that he could not approve an executive agency so far beyond the control of the chief executive. A compromise proposal was enacted in 1950, creating the National Science Foundation. By that time federal support for medical research was well established in the National Institutes of Health, and never moved to the NSF. Research in the natural sciences and military research were being (generously) supported by the Office of Naval Research and the Atomic Energy Commission, and both the military and the academic scientists they supported vehemently opposed any transfer to the NSF. For all of these reasons, the National Science Foundation did not become the unique center for federal support of research—the peacetime OSRD—that Bush envisioned.

Renewing U.S. Mathematics—Critical Resources for the Future

- *Report of the Ad Hoc Committee on Resources for the Mathematical Sciences, Edward E. David, Jr., Chairman, National Academy Press, Washington, DC, 1984*

In 1981 the National Research Council established the Ad Hoc Committee on Resources for the Mathematical Sciences and gave it the charge of reviewing the health and support of mathematics research in the U.S. The committee's report, widely identified as "The David Report", was published in 1984.

"The David Report" was a wakeup call to the mathematical sciences research community, professional organizations, universities, and federal agencies concerning fifteen years of deteriorating support for mathematics research. The problems were recognized earlier and, in fact, motivated the emphasis in the committee's charge on issues of support.

During the same timeframe that the Committee on Resources was working, other groups were also addressing aspects of the crisis in support for basic research. In 1982 the Committee on Science, Engineering, and Public Policy (COSEPUP) reported to the White House Office of Science and Technology Policy (OSTP) and to the Department of Defense (DoD) on research areas within mathematics that were likely to return the highest scientific dividends as a result of planned increases in federal research funding. The COSEPUP report also painted the grim picture of the status of federal support for mathematics in 1982.

"The David Report" is systematic and thorough in developing three topics:

- The strength of the mathematics research enterprise in the U.S. and the opportunities for new achievements.
- The status of federal support of the mathematical sciences and an analysis of how the crisis was allowed to happen.
- An estimate of the amounts needed for future support of research in the mathematical sciences and a plan for attaining the needed levels of support.

Appendices to the report provide data documenting the deterioration of support for mathematics and an essay by Arthur Jaffe amplifying the strength, achievements, and opportunities in mathematics perceived at the time.

The report's assessment of support in the early 1980s emphasizes how the impact of changing patterns of support over the preceding period had a more drastic impact on mathematics than on other disciplines.

"Since the late 1960s, support for mathematical sciences research in the United States has declined substantially in constant dollars, and has come to be markedly out of balance with support for related scientific and technological efforts.

"...We estimate the loss in federal mathematical funding to have been over 33% in constant dollars in the period 1968–73 alone; it was followed by nearly a decade of zero real growth, so that by FY 1982 federal support for mathematical sciences research stood at less than two thirds its FY 1968 level in constant dollars."

All sciences were affected by the changed federal policies for support of graduate students starting in the late 1960s and by the 1969 Mansfield Amendment. NSF graduate fellowships were sharply curtailed, and NDEA fellowships disappeared. The Mansfield Amendment to the FY 1970 Military Procurement Authorization limited research sponsored by the Defense Department to studies and projects that directly and apparently related to defense needs, or mission relevance. Before enactment of the amendment, the defense agencies provided substantial support for basic research in mathematics.

In 1971 and 1972 Congress increased NSF appropriations substantially to help provide for the shift from DoD to NSF of support for basic research. However, the $50 million increase for NSF did not help mathematics. At the time, as a matter of federal policy, there was greater emphasis on areas connected to industrial development such as chemistry and materials research. While the NSF budgets for support of both chemistry and physics increased at average annual rates of 20% from 1970 to 1972, the average annual increase for mathematics was a meager 4.7%.

Also in the early 1970s NSF worked to fill the void left by the shrinking or disappearance of the NSF and NDEA fellowship programs. Funds were made available through the research budgets for more research assistantships. The budgets for chemistry and physics show the positive effects of this funding.

However, mathematics did not garner the same increases. In part this resulted from inaction by the mathematics research community and its concern about a possible oversupply of new Ph.D.'s; the community did not make a strong case for the increase in NSF funding for research assistantships, and that support flowed in other directions.

By 1982 the NSF budget for support of mathematics research had actually declined in constant dollars from its 1968 level. Over the same period, the NSF budgets for chemistry and physics research had both grown on the order of 25% in constant dollars.

"The David Report" set goals for rectifying the support problems and recommended actions by the federal government, universities, and the research community. The goals included:

- support for 1,000 graduate students actively doing research for the Ph.D.,
- support of 200 new multiyear postdoctoral fellowships annually,
- support of 400 research grants for young investigators, and
- research funding for at least 2,600 established (senior) mathematical scientists.

Most significantly, the report captured the attention of the research community. The community as a whole, including professional organizations and federal agencies, worked toward its goals.

"The David Report" fifteen years later is still an important and timely document for the mathematics research community. The imbalances in support that developed between 1968 and 1982 have not been erased, even though significant progress has been made since the report. The forces that were felt in the 1970s recur, and the messages sent to the research community, professional societies, universities, and the federal agencies are worth remembering as we continue to address issues of the health and support of mathematics research.

Moving Beyond Myths—Revitalizing Undergraduate Mathematics

- *Committee on the Mathematical Sciences in the Year 2000, Board on Mathematical Sciences, Mathematical Sciences Education Board, National Research Council, National Academy Press, Washington, DC, 1991*

"Moving Beyond Myths" was written by the Committee on the Mathematical Sciences in the Year 2000, under the aegis of the Board on Mathematical Sciences, the Mathematical Sciences Education Board, and the National Research Council. It complements the booklets *Renewing U. S. Mathematics*, *Everybody Counts*, and *A Challenge of Numbers*.

“Moving Beyond Myths” is a 1991 critique of U.S. undergraduate mathematics education. It lists several myths pervading the public perception of mathematics. These myths include:

- Success in mathematics depends more on ability than on hard work.
- Women and members of certain ethnic groups are less capable in mathematics.
- Most jobs require little mathematics.
- All useful mathematics was discovered years ago.
- To do mathematics is to calculate answers.

Furthermore, MBM says the U.S. colleges and universities perpetuated, if not created, these myths with their attitude toward undergraduate teaching.

From 1970 to 1990 mathematics enrollments increased by more than 70%, while faculty size increased by less than 30%; and instead of forcefully articulating the need to maintain low student-faculty ratios, mathematics departments acquiesced to their increased workload by teaching ever larger classes and by putting less prepared graduate assistants and part-time teachers in the classrooms. By 1990 the system was “beset on all sides by inadequacies and deficiencies”:

- in the mathematical preparation of students,
- in rewards and support for teaching,
- in teaching innovations,
- in the use of computers in undergraduate mathematics,

and many others, such as a shortage in the number of mathematics students (graduate, undergraduate, women, and minority), and in the number of qualified school mathematics teachers.

“Moving Beyond Myths” also criticizes the large reliance on teaching via lectures, which “place students in a passive role,” the irreverence of mathematics courses to the majority of the students’ future needs, and the general effect upon students of a professional value system that rewards research more than teaching.

“Moving Beyond Myths” then challenges the mathematical community to “restructure fundamentally the culture content, and context of undergraduate mathematics education,” and lists four goals:

1. Effective undergraduate mathematics instruction for all students
2. Full utilization of the mathematical potential of women, minorities, and the disabled
3. Active engagement of college and university mathematicians with school mathematics, especially in the preparation of teachers

4. A culture for mathematicians that respects and rewards teaching, research, and scholarship

“Moving Beyond Myths” offers an Action Plan, with recommendations for faculty, mathematics departments, colleges and universities, professional societies, and the government. Recommendations for faculty include:

- Learn about learning; explore alternatives to “lecture and listen”.
- Involve students actively in their learning.
- Teach future teachers in the ways they will be expected to teach.
- Teach the students you have, not the ones you wish you had.

Recommendations for departments include:

- Assign the best teachers to introductory courses.
- Use knowledge gleaned from minority projects.
- Build a team of faculty to carry out experiments.
- Have a departmental seminar on issues of teaching and learning.
- Employ varied instructional approaches.

Written in 1991, “Moving Beyond Myths” is somewhat out of date (for example, with its call for computerization), but it remains a valuable guide for chairs, departments, and faculty. Articulately written, it contains several valuable examples.

Educating Mathematical Scientists: Doctoral Study and the Postdoctoral Experience in the United States

- *Committee on Doctoral and Postdoctoral Study in the United States, Board on Mathematical Sciences, Commission on Physical Sciences, Mathematics, and Applications, National Research Council, National Academy Press, Washington, DC, 1992.*

This 1992 report continues to be a highly valuable resource for any mathematics department looking for suggestions for enhancing its doctoral program. The report was prepared by the Committee on Doctoral and Postdoctoral Study in the United States of the NRC Board on the Mathematical Sciences. The chair of the committee and chief author of the report was Ron Douglas, now provost at Texas A&M. The committee based its findings on site visits to a diverse set of programs in ten universities, small and large, public and private, geographically diverse; four departments were ranked in the “Top 20”.

The report anticipates several subsequent NRC reports in arguing for broader doctoral and postdoctoral training to prepare Ph.D.’s for a variety of nonacademic jobs. It contains helpful suggestions about general issues, such as recruiting and retaining doctoral students, and specific issues, such as placing foreign students with weak language skills but advanced training in mathematics.

The report seeks to characterize the best practices of doctoral and postdoctoral education in the United States, a world leader in mathematical sciences research and in doctoral and postdoctoral education. The committee was looking for programs that accomplish the following two objectives.

- All students, especially the majority who will spend their careers in collegiate teaching, government laboratories, business, and industry, need to be well prepared by their doctoral and postdoctoral experience for their careers.
- Larger percentages of domestic students and, in particular, women and underrepresented minorities need to be attracted to the study of and careers in the mathematical sciences.

The committee's findings were meant to respond to growing concerns that many doctoral students are not prepared to meet undergraduate teaching needs, establish productive research careers, or apply what they have learned in business and industry. The inadequate preparation, high attrition, declining interest of domestic students, particularly women, and the near-absent interest of students from underrepresented minorities in doctoral study were problems in the early 1990s, and they are likely to remain problems into the next century.

The report suggests that even with limited resources, a successful doctoral program can flourish if, among other things, the mathematics department focuses its energies rather than trying to implement a "standard" or traditional program that covers too many areas of the mathematical sciences. It also notes that departments with the best faculty do not necessarily have the most successful doctoral and postdoctoral programs.

In its site visits, the committee conducted in-depth interviews with students, faculty, and administrators. It looked for features that were present in successful programs as well as for elements that were detrimental to quality education. The committee noted that successful programs possessed, in addition to the sine qua non of a quality faculty, the following three characteristics:

- A focused and realistic mission, with clearly defined goals and adequate "human and financial resources" to meet those goals;
- A positive learning environment, where students receive assistance, nurturing, feedback, and encouragement in a cordial atmosphere;
- Provision for relevant professional development, i.e., a program tailored to the career objectives of the students, whether undergraduate teaching, academic research, or work in government laboratories, industry, or business.

The committee identified two kinds of models for programs:

1. The standard model, which supports research in a broad range of areas, with depth in each one, and has as its goal the preparation of talented, well-motivated doctoral students and postdoctoral associates for careers as mathematical scientists at research universities.

2. The specialized models, such as the subdisciplinary model, the interdisciplinary model, the problem-based model, and the college-teachers model, which were seen to alleviate two large, human resource problems: difficulty in recruitment and replacement; and the desirability of clustering of faculty, postdoctoral associates, and students—a practice that helps create a positive learning environment and promotes relevant professional development.

Both standard and specialized programs can be successful. However, programs that do not have the human or financial resources to run a successful standard program should consider whether a specialized model might better fit their needs.

The Standard Model. The report describes the shortcomings of the American standard doctoral and postdoctoral programs. It suggests that most standard programs do well in preparing their best students and postdoctoral associates for the academic research job market, but very few prepare any of their students well for jobs in teaching, government, business, or industry. It also suggests that some of these programs struggle because they cannot attract the graduate students necessary to function as a standard-model program. The committee acknowledged the continuing need for well-established standard programs at a small number of centers and encouraged efforts to broaden the experience of students in those programs and to provide a more supportive learning environment.

The Subdisciplinary Model. For subdisciplinary models in both pure and applied areas, the department concentrates much of its faculty and resources in a few subdisciplines of the mathematical sciences. Recruiting strong, well-prepared students for subdisciplinary programs requires considerable effort to ensure a proper fit. The main advantage of the subdisciplinary model is that clustering of students and faculty working on related topics enables them to assist each other in their common goals. Some of the doctoral programs with the best reputations for research are subdisciplinary programs.

The Interdisciplinary Model. The interdisciplinary program is usually only one among several programs in a department of mathematics, statistics, or operations research. It utilizes department faculty with interdisciplinary interests and mathematically oriented faculty in cognate disciplines. The curriculum, which often involves course work in one or more other departments in science or engineering, trades depth in the mathematical sciences for greater breadth overall. Students can choose thesis advisers from the mathematical sciences department or one of the other departments. Faculty in both departments often adopt a cooperative approach to directing Ph.D. research. Graduates of interdisciplinary programs sometimes move into other disciplines or take positions in industry. These programs succeed in bringing mathematically well-trained students into fields in which they can effectively use their talents and at the same time promote the transfer of mathematical knowledge to these fields.

The Problem-Based Model. In a problem-based model, a specific application or set of applications is used as a unifying theme for courses and research. The program is concerned with the strictly mathematical aspects of an applied program, and mathematical modeling is a common focus. An attraction of such programs is that the students are immersed in research-related activities from the beginning. Student internships in regional industries are often an integral part of the program. Industrial researchers often visit the students and faculty of the program. Post-Ph.D. employment opportunities in industry are common, but graduates also obtain positions in academia.

The College-Teachers Model. Designed specifically to prepare teachers for two- and four-year college employment, this model is to be distinguished from a program that confers doctor of arts and doctor of education degrees. Breadth of course work, an emphasis on professional development in pedagogy, and a research apprenticeship are parts of the program. Most new Ph.D.'s from standard programs currently take jobs in college teaching but are often ill prepared for teaching. New Ph.D.'s from a college-teachers program are attractive candidates for employment because they are prepared to be teachers.

The committee noted the following common features of specialized models:

- Students in specialized programs find it easier to obtain appropriate jobs than do those in standard programs.
- A smaller department is more likely to be successful if it adopts one of the specialized models.
- Recruiting of domestic students, as well as women and minorities, is more effective for specialized programs than for standard programs.

The report has the following general recommendations.

- New Ph.D.'s with a broad academic background and communication skills appropriate for their future careers are better able to find jobs.
- Active recruiting increases the pool of quality students; it does not just reapportion the pool. It also increases the number of women and underrepresented minorities. Students with strong mathematical backgrounds have a choice of studying mathematical sciences, physical sciences, engineering, law, medicine, and other areas. More of them can be attracted to the mathematical sciences.
- Clustering faculty, postdoctoral associates, and doctoral students together in research areas is a major factor in creating a positive learning environment.
- A positive learning environment is important to all doctoral students, but is crucial for women and underrepresented minorities.
- All departments, including those characterized as elite and selective, need to provide a supportive learning environment.

- Doctoral students and postdoctoral fellows should receive broad academic preparation appropriate for their future careers in research universities, teaching universities, government laboratories, business, and industry.
- Doctoral students and postdoctoral fellows should learn teaching skills and other communication skills appropriate for their future careers.
- The number of postdoctoral fellowships in the mathematical sciences should be greatly increased so that such positions can be viewed as the logical next step after completion of the doctorate for the good student, not as a highly competitive prize for a select few. More postdoctoral fellowships should have applied, interdisciplinary, or pedagogical components. (Note: This report played a major role in changing the name used for initial visiting faculty positions for new Ph.D.'s in research mathematics departments from "instructor" to "postdoc".)

This summary draws heavily from text in the Executive Summary of this BMS report and the article about it by Ed Block appearing in the May 1992 *SIAM News*.

Recognition and Rewards in the Mathematical Sciences

- *Report of the Joint Policy Board for Mathematics, Committee on Professional Recognition and Rewards, American Mathematical Society, Providence, RI, 1994*

A committee of thirteen mathematical scientists, chaired by Calvin Moore, was charged with investigating the current reward systems at a wide variety of mathematical sciences departments, initiating dialogues about the issues raised, and making recommendations for improvements. The committee made site visits to twenty-six institutions of all types, convened focus group discussions at several professional meetings, and conducted a broad survey of opinion from faculty members and department chairs about key issues. This survey sampled opinion not only on what is current practice but also on what those surveyed felt "should be" the practice.

There are several categories of rewards and recognition: some are direct, such as salary, promotion, and tenure; some are more indirect, such as sabbaticals, awards for outstanding teaching, grants, course release for special projects, etc; and some are less tangible "quality-of-life" issues, such as collegiality within a department.

The committee found widespread dissatisfaction about the current reward systems, including a concern that research is overemphasized, a lack of flexibility to accommodate changing contributions throughout faculty careers, and much discomfort about the evaluation of teaching and service. The surveys also revealed a significant disparity between how chairs and faculty viewed certain issues, although this disparity was not observed during the site visits. For example, only 28% of faculty at the top-ranked 39 doctoral departments felt that salaries reflect differences between excellent and average teaching, while 55% of chairs felt this to be true.

The committee arrived at ten findings and three guiding principles, described below. Each finding is supported by data from the surveys and information from the site visits and focus groups. Although the committee did not reach any sweeping recommendations, in part because of the diversity of the institutions involved, it did suggest that "The recognition and rewards system in mathematical sciences departments must encompass the full array of faculty activity required to fulfill departmental and institutional missions." The report concludes with an appendix on "Defining Mathematical Scholarship".

Findings

1. There is a substantial gap between what faculty members think the rewards structure should be and what it actually is, as well as a desire for a broader and more flexible rewards structure.
2. During the last five to ten years there has been an evolution in mathematical sciences departments, with an increased emphasis on research and scholarship in the departments which traditionally emphasized their teaching roles, while at the same time there has been an increased emphasis on the teaching roles in departments which traditionally emphasized their research roles.
3. Survey results from questions about the importance of three different types of mathematical sciences research for the rewards structure indicate that "research in the discipline" was almost universally seen as very important and that it should be very important. Results also indicated that "interdisciplinary research involving new mathematics" and "applications of existing mathematics to other fields" were seen as important, but not as important as "research in the discipline".
4. There is ambiguity and uncertainty in the mathematical sciences community about what should be included in the definition of scholarship.
5. Lack of effective communication between various organizational levels is a major problem at many institutions.
6. A. The role of the chair is critical to the well-being of the department.
   B. There are marked discrepancies between the answers of the chairs and faculty on many questions in the survey.
7. There is general dissatisfaction with the methods of evaluating teaching, especially student evaluation questionnaires on teaching.
8. There is discomfort with the evaluation of faculty duties in general.
9. "Quality-of-life" issues are of major importance in any rewards structure.

10. Most faculty members favor a rewards system that includes a combination of across-the-board and merit increases.

Guiding Principles

1. Research in the mathematical sciences and its applications is fundamental to the existence and utility of the discipline and should continue to be among the primary factors of importance in the recognition and rewards systems.
2. Each department should ensure that contributions to teaching and related activities and to service are among the primary factors of importance in the recognition and rewards system.
3. Departments should develop policies that encourage faculty to allocate their efforts in ways that are as consistent as possible with their current interests and, at the same time, fit the needs of the department. The goal should be to create a department that meets all its obligations and aspirations with excellence, while at the same time engaging faculty in activities that they find personally rewarding. These activities should be recognized as valuable, and they should be rewarded when done well.

Talking about Leaving

- *Factors Contributing to High Attrition Rates among Science, Mathematics & Engineering Majors, Elaine Seymour and Nancy M. Hewitt, Bureau of Sociological Research, Westview Press, Boulder, CO, 1994, 1997*

Within two years after taking a college science, mathematics, or engineering class, 40%–60% of a group of above-average students have left majors in these disciplines. This report endeavors to document reasons that had been given with smaller, earlier studies. In the 1980s Treisman and Henkin wondered why so few African-American students succeeded in introductory calculus at Berkeley. They wrote a list of reasons they guessed for why students would not succeed. Their list was not very different from the one given in this book. Faculty believe the reasons students leave include:

- Some students choose the wrong area to begin with.
- Some students are underprepared.
- Some students lack interest, ability, competence, or capacity for hard work.
- Some students discover a passion for another discipline.

Treisman and Henkin discovered that the data at Berkeley did not support these reasons. Part of Treisman's work was to isolate more significant factors. This ethnographic study underscores the factors that seem to play a significant role. Factors that are part of the educational experience and the culture in science, mathematics, and engineering seem to be most significant. Students who leave and those who stay in these disciplines repeatedly mention the same factors.

Hewitt and Seymour describe two groups of students as "more pulled than pushed" and "more pushed than pulled" away from studying science, mathematics, or engineering. The students in the first group are often ambivalent about switching and may feel they will someday return. "They attribute their decision to leave almost exclusively to the poverty of the educational experience created by the weed-out system, and, by any measure, represent a loss to science, mathematics, and engineering of high-quality students."

The second group have the ability, are adequately prepared, and entered majors with interest. Poor teaching and a weed-out environment discourages these students. They enter other majors that they view as a poor compromise. These students are frequently angry, resentful, regretful, and frustrated because they feel science, mathematics, or engineering is the right choice for them. They believe they could succeed given the right support and a less competitive atmosphere. Many females and students of color fall into this group.

Seymour and Hewitt did encounter students leaving for the reasons stated at the outset. However, they hypothesize that "on every campus, there are substantial numbers of students who could be retained in S.M.E. majors if appropriate structural and cultural changes are made." Some of the case studies cited in the references support this hypothesis, at least for mathematics.

Seven different institutions of varying type and about 460 students participated in this study. The hypotheses of this study are not original, and the authors have thoroughly investigated, analyzed, and reported on earlier studies with smaller numbers of students.

The authors look at differences among institutions; choice of major; preparation for college study; difficulty of science, mathematics, and engineering majors; the competitive environment of these majors; the teaching and learning environment; issues of career, money, time, and lifestyle; gender issues; and issues of ethnicity. Mingled with statistics about student motivations are a very large number of quotations by students that accord with the statistics.

The SIAM Report on Mathematics in Industry,

- *Report prepared by the Society of Industrial and Applied Mathematics, Philadelphia, PA, 1995*

This can be found at http://www.siam.org/mii/index.htm.

The report presents the results of a survey of nonacademic mathematicians and their managers about the mathematics they use, the problems to which their mathematics is applied, the environment in which they work, and their assessment of the strengths and weaknesses of graduate training in mathematics. The report ends with suggestions for making graduate training in mathematics more responsive to the needs of nonacademic mathematicians. The study presents a substantial set of useful survey data.

The Role of Mathematics in Industry

Employment of Nonacademic Mathematicians by Degree and Field

	Ph.D.	*M.S.*
Government	28%	22%
Engineering research, computer software and services	19%	18%
Manufacturing (electronic, computers, aerospace, transportation)	17%	12%
Services (financial, communications, transportation)	13%	22%
Chemical, pharmaceutical, petroleum	6%	2%

The study found that many areas of pure mathematics as well as most all areas of applied mathematics found use in industry and government. For example, algebra and number theory were used in cryptography, formal systems and logic were used in computer security and verification, and geometry was used in computer-aided engineering and design. Nearly every manager interviewed cited particular problems where mathematics had made a significant contribution. The mathematical reasoning skills cited by managers as of greatest value were: modeling and simulation, mathematical formulation of problems, algorithm and software development, problem solving, statistical analysis, verifying correctness, and analysis of accuracy and reliability.

Both managers and mathematicians indicated that they saw substantial new opportunities for mathematicians in industry and government. Manufacturing, product development, and materials were listed as particularly promising areas.

The Working Environment

Some of the key findings about the role of mathematicians and the R&D context in which they work are:

- Mathematicians are part of the R&D infrastructure; mathematics cannot be viewed as an end in itself.
- Nonacademic research is often faulted for too much understanding with too little transfer. Even in groups with a research charter, examples of success with products or services are required to justify continued support.
- Mathematicians are typically scattered across an organization among engineers, physicists, and computer scientists, where they are supported by various mission-oriented groups.

- Nonacademic mathematicians need to be facile at working with a wide range of mathematical skills in support of projects. Even a single project will have many aspects requiring a variety of mathematical techniques. At the same time, it is desirable to have special expertise in some area. Further, nonacademic mathematicians need to have an interest and some knowledge in other technical areas. This is important for developing real solutions to real-world problems. The most frequent discipline cited was computer science.

Formulating problems was found to be an interactive and continuing process for mathematicians working on projects with other R&D scientific staff. Good communicating and listening skills, as well as general interpersonal skills, are critical. The hardest task for a mathematician is typically developing the real-problem requirements. The user does not usually know what the solution will look like in the end. Mathematicians cannot throw their solutions “over the wall” and be done with a project. Customers inside or outside one’s organization may express frustration with the current solution without communicating clearly what they really want. Indeed, a mathematician’s biggest contribution to a team is often the ability to pose the right question. In addition, nonacademic mathematicians can be expected to provide a “solution” even when no rigorous solution can be found or when there is not time to find one.

Interviews consistently found that mathematicians are valued most of all for two general attributes: highly developed skills in abstraction, analysis of underlying structures, and logical thinking; and expertise with the best tools for formulation and solving problems.

Well-trained, even pure, mathematicians were viewed as critically equipped to keep going when textbooks have to be left behind. Mathematicians are seen as better equipped than others in coming up with the correct definitions of problems and developing the right level of abstraction. Mathematicians were also cited for their ability to spot hidden gaps in the analysis of a problem and to identify connections.

Shortcomings of some mathematicians who did not fully understand the nature of the nonacademic environment were, according to managers: a tunnel vision (writing a paper and that’s the solution); a lack of concern for the real environment that requires realistic models, cost considerations, and implementation details; and the desire to continue investigations forever instead of recognizing when to stop.

Perceptions of Graduate Education

While a number of reports have voiced the concern that graduate education is only training students to be the clones of their professors, nonacademic mathematicians interviewed in this study mostly believed that their graduate education had helped them to obtain and perform well in their present positions. They felt that their graduate education had been very effective in developing facility in:

- logical thinking and the ability to deal with complexity,

- broadly applicable problem solving,
- conceptualizing and abstracting,
- formulating problems and modeling.

Many nonacademic mathematicians felt that their graduate preparation was wanting in aspects outside their core mathematical training. The areas where preparation was rated as less than good included:

- working well with colleagues,
- communicating at different levels,
- having broad scientific knowledge,
- effectively using computer software.

These problems were substantial enough that 90 percent of Ph.D.'s and M.S.'s interviewed said that it was important to make educational changes in graduate mathematics training.

Managers echoed the problem areas of their mathematical employees, saying that they felt improvement was needed in graduate mathematics training in the areas of applications of mathematics, knowledge of other disciplines, real-world problem solving, oral and written communication, computer skills, and teamwork.

Suggestions and Strategies

The suggestions in this study for changes in graduate mathematics education largely mirror the areas that nonacademic mathematicians and their employers cited in the previous section as in need of improvement: substantive exposure to applications of mathematics in the sciences and engineering; experience in formulation and solving real-world problems, preferably involving a variety of disciplines; computation; and communication and teamwork. For faculty the report recommends activities to enhance connections between mathematics faculty and researchers in other disciplines, inside and outside academia. For graduate students there are recommendations for taking the initiative in making contact with nonacademic mathematicians and researchers in other disciplines. For nonacademic organizations that use mathematicians there are recommendations for building various connections with university mathematicians and their students.

Shaping the Future—New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology

- *Advisory Committee to the National Science Foundation, Directorate for Education and Human Resources, National Science Foundation, Washington, DC, 1996*

In 1996 the National Science Foundation released “Shaping the Future”, a report of the Advisory Committee to the Directorate for Education and Human Resources. The report was created by the Advisory Committee’s Subcommittee on Undergraduate Education, under the leadership of Dr. Melvin D. George. Dr. George is a mathematician and a retired president of both St. Olaf College and the University of Missouri.

Dr. George’s committee was charged with conducting an intensive review of the state of undergraduate education in science, mathematics, engineering, and technology in America and to prepare a report that was “action oriented, recommending ways to improve undergraduate education in science, mathematics, engineering, and technology.”

The EHR Advisory Committee unanimously approved and endorsed the report. Since the release of the report, the NSF has co-sponsored a large number of “Shaping the Future” conferences at colleges and universities across the country. By their actions the EHR is demonstrating their strong support of the report. It is reasonable to assume that funding decisions made by EHR in coming years will be designed to further support the recommendations in the report.

The “Shaping the Future” report focused on recommendations to support one major goal:

> All students should have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students should learn these subjects by direct experience with the methods and processes of inquiry.

The report offered a variety of recommendations to institutions of higher education; business, industry, and the professional community; national and regional media; governments at the state and federal level; and the NSF. We reproduce here some of the recommendations that might most directly impact the professional lives of mathematicians in our colleges and universities.

- The president and the Congress: Establish, in consultation with the higher education community, a new social contract for higher education in America. What is needed may be a new act to reconnect the research base of these institutions to the learning of students and to service to the wider community.
- State governments: Ensure that funding formulas and state policies are modified, as necessary, to provide incentives and rewards for increased undergraduate student learning in science, mathematics, engineering, and technology (SME&T) at institutions in the state.
- University administrators:
  1. Reexamine institutional missions in light of needs in undergraduate SME&T-education.
  2. Hold accountable and develop reward systems for departments and programs, not just individuals, so that the entire group feels responsible for effective SME&T learning for all students.

3. Create or strengthen an institution-wide commitment to the preparation of K–12 teachers and principals, bringing together departments of education, SME&T and other departments, K–12 staff, and employers of teachers to design and implement improved teacher preparation programs having substantial SME&T content and stressing rigorous standards, along with emphasis on engaging students in learning.

- Departments:
  1. Encourage faculty to work toward the understanding of and resolution of serious educational issues, and reward those who most effectively help all students learn.
  2. Provide opportunities for graduate students to learn about effective teaching strategies as part of their graduate program.
- Professional societies: Work together to promote education as well as research, focus on student learning as well as teaching, and help departments in their disciplines find realistic ways to implement these recommendations.
- NSF:
  1. Lead the development of a common national agenda for improving undergraduate SME&T education in a collaborative way with other Federal agencies and foundations.
  2. Make clear to all colleges, universities, and other educational institutions receiving grants and contracts that the NSF expects its awards to contribute positively to the quality of undergraduate SME&T education.

In total, the Shaping the Future Report offers nearly 100 recommendations to every possible participant in the business of educating undergraduates in science, mathematics, engineering, and technology. Given the high visibility that NSF is giving to this report, mathematics departments are well advised to believe that the recommendations of this report will drive funding decisions at the Foundation.

Reinventing Undergraduate Education: A Blueprint for America's Research Universities

- *Boyer Commission for Educating Undergraduates at the Research University, Carnegie Foundation, Stony Brook, New York, 1998.*

This can be found on the Web at: http://notes.cc.sunysb.edu/Pres/boyer.nsf.

Background: This is a publication of the Boyer Commission on Educating Undergraduates in the Research University, which was funded by the Carnegie Foundation for the Advancement of Teaching. The Commission was named for

Ernest Boyer, president of the Carnegie Foundation until his death in 1995. Bruce Alberts, president of the NAS, was one of eleven members of the Commission.

This report is a fairly broad-sided attack on the quality of undergraduate education at America's research universities. While the 125 universities that are classified as Research I or II institutions comprise only 3% of the 3,500 institutions of higher education, they award 32% of the undergraduate degrees in America and 56% of the baccalaureates in science and engineering during the period 1991–95. In all science fields except chemistry, the majority of students who obtain a Ph.D. earned their bachelor's degree at a U.S. research university.

Mathematics is almost invisible in the report. It is mentioned only a couple of times and then in connection with remedial education or the teaching of freshmen by graduate students.

Basically, the report is a call for dramatic changes in how research universities teach undergraduates. The goal is to create an undergraduate experience (centered on inquiry learning and research experiences for undergraduates) that is not duplicated by the other types of institutions that award undergraduate degrees. The centerpiece of the report is an Academic Bill of Rights and a set of ten guiding principles for changing undergraduate education. Each principle is followed by a set of recommendations to implement the principle.

The Academic Bill of Rights asserts that by admitting a student, a college or university should commit to providing the following:

At all colleges and universities:

- ♦ Opportunity to learn through inquiry;
- ♦ Training in the skills necessary for oral and written communication;
- ♦ Appreciation of arts, humanities, sciences, and social sciences;
- ♦ Careful and comprehensive preparation for whatever may lie beyond graduation.

Additional rights for students at research universities:

- ♦ Expectation of and opportunity for work with talented senior researchers;
- ♦ Access to first-class facilities in which to pursue research;
- ♦ Many options among fields of study;
- ♦ Opportunities to interact with people of backgrounds, cultures, and experiences different from the student's own.

The ten guiding principles are:

1. Make research-based learning the standard.
2. Construct an inquiry-based freshman year.
3. Build on the freshman foundation.
4. Remove barriers to interdisciplinary education.
5. Link communication skills and course work.

6. Use information technology creatively.
7. Culminate with a capstone experience.
8. Educate graduate students as apprentice teachers.
9. Change faculty reward systems.
10. Cultivate a sense of community.

At present this report has received much criticism from the academic community. Indeed, one is led to conclude that it is unlikely that it will have as much impact as did "Scholarship Reconsidered" (an earlier report by the Carnegie Foundation in 1990; see p. 232.)

Report of the Senior Assessment Panel of the International Assessment of the U.S. Mathematical Sciences

- *A report commissioned by the National Science Foundation using a panel of mathematicians drawn largely from outside the United States as well as scientists from related disciplines, 1998.*

This report was prepared for the National Science Foundation (NSF) by a panel of individuals who had not received funding from the Foundation. It was prepared in response to the Government Performance and Results Act, which called for agencies to set strategic goals and evaluate their progress toward those goals. The panel was charged with making specific recommendations to the Foundation. A brief summary of the report can be found in the *Notices of the AMS* **45**, no. 7 (1998), 880-82. The report also contains the article by Gromov, which is included as Chapter 19 of this book. Appendix 2 of the report contains the panel's assessment of the health of various subdisciplines of mathematics in the United States.

The report points out the disparity between the percentage of scientists with federal support as a fraction of scientists active in research in the various disciplines: 69% in biological sciences, 67% in physical sciences, and 35% in mathematics.

The panel notes the ways in which mathematics research differs from research in the other sciences. It is small science, and much work is done by individuals working alone, with modest equipment needs. Mathematical research is long-lasting, which forces a need for good libraries. Mathematics is an international discipline; thus local events can lead to widespread migration of mathematicians, as from Europe before World War II or from Eastern Europe more recently.

The percent of Ph.D.'s going to noncitizens is 55% in the U.S., 33% in France, 40% in Japan, and 27% in England.

The panel did its benchmarking by considering the contributions of the U.S. mathematics community to fundamental mathematics by assessing interactions between mathematics and the users of mathematics and by assessing the quality of undergraduate, graduate, and postdoctoral education.

The comparisons involve data (the number of research papers by regions of the world, the number of speakers at the International Congress by region) which are not perfect (for example, there is no good measure of the number of Ph.D.'s in the regions).

The panel felt that communication between mathematical scientists and other scientists is poor the world over but that several countries were becoming more involved in promoting multidisciplinary research. They felt that the U.S. undergraduate programs offer less exposure to mathematics than programs in Europe and Asia.

U.S. graduate programs offer a wider range of specialization, but European programs offer better financial support to graduate students. Retention in U.S. graduate programs is lower than in Europe (particularly for U.S. students). Graduates of U.S. doctoral programs have higher expectations of an academic career than in Europe, while academic jobs are constant or decreasing. All of these observations may play a role in the fact that the percentage of U.S. students pursuing graduate degrees has declined in recent years (although a loss of interest in graduate work in mathematics has been seen in several nations).

The report contains an analysis of sources of federal support showing mathematics to be more heavily dependent on NSF funding (60% of 1997 federal funding for mathematics), to be more dependent on institutional support for graduate students, and to have only a small share of overall federal support for academic basic research. Nonfederal support is extremely limited.

The report contains the following overall assessment: The U.S. has the lead in many subdisciplines and is capable of responding to breakthroughs in all areas of mathematics. Yet U.S. mathematics suffers from isolation from the rest of science, a decline in the number of young people entering the field, and a low level of interaction with nonacademic fields, particularly in the private sector. The panel concludes that morale is low in the U.S. The European Union is expanding opportunities and funding for young mathematicians, while in the U.S. students are overly dependent on teaching, which extends their time to degree and decreases the attractiveness of mathematics to young people.

Specific findings of the panel are:

- **Finding 1:** The academic success of U.S. mathematics has been and remains distinguished. Although the U.S. is the strongest national community in the mathematical sciences, this strength is somewhat fragile. U.S. strength rests heavily on mathematicians who have come from outside the U.S. The lack of financial support thwarts the careers of many young mathematical scientists.
- **Finding 2:** Academic mathematics is insufficiently connected to mathematics outside the university. (The report makes it clear that each side could do a better job of reaching out to the other side.) Academic mathematics could interact fruitfully with other disciplines in ways that are often obscured by the inward focus of mathematics and science departments. The structure of universities mitigates against multidisciplin-

ary research. Scientific problems of the future will be extremely complex and will require collaborative mathematical modeling, simulation, and visualization. (The panel urges funding agencies to provide financial support that recognizes and rewards multidisciplinary activities and that recognizes the long time required to become competent in such work.)

- **Finding 3:** U.S. graduate programs in the mathematical sciences, especially the top 25, are considered to be among the very best in the world. Graduate applications in the mathematical sciences have declined, however. Careers in mathematics have become less attractive to U.S. students. The curriculum in U.S. institutions for undergraduates needs to be strengthened, broadened, and designed for more active participation by students in discovery. There are exciting mathematical science career opportunities outside the academy.

The panel recommends to the mathematical sciences community:

- Academic mathematical science must strike a better balance between theory and application.
- For U.S. mathematical sciences to thrive, the discipline must be made more attractive to young Americans with bright and inquisitive minds.

It recommends to NSF:

- NSF's specific objective should be to build and maintain an academic community in mathematics that is intellectually distinguished and relevant to society.
- NSF's broad objectives should be to build and maintain the mathematical sciences in the U.S. at the leading edge of the mathematical sciences and to strongly encourage it to be an active and effective collaborator with other disciplines and with industry.

The panel suggests some strategies to accomplish these objectives:

- Bring the number of active researchers supported to a level comparable to those in the physical and biological sciences and engineering.
- Encourage activities that connect mathematics to areas of application.
- Strengthen the connection between pure and applied mathematics.
- Broaden the exposure of mathematicians to problems in other fields.
- Maintain and strengthen abstract mathematics.

Unlocking Our Future: Toward a New National Science Policy

♦ *A report to Congress by the House Committee on Science, 1998. (The subcommittee writing the report was chaired by Congressman Vern Ehlers, who holds a Ph.D. in physics.)*

This report can be found at
http://www.house.gov/science/science_policy_study.htm

Overview

The growth of economies throughout the world since the industrial revolution began has been driven by continual technological innovation through the pursuit of scientific understanding and application of engineering solutions. America has been particularly successful in capturing the benefits of the scientific and engineering enterprise, but it will take continued investment in this enterprise if we hope to stay ahead of our economic competitors in the rest of the world. Many of those challengers have learned well the lessons of our employment of the research and technology enterprise for economic gain.

Americans must remain optimistic about the ability of science and engineering to help solve their problems and about their own ability to control the application of technological solutions. The United States of America must maintain and improve its preeminent position in science and technology in order to advance human understanding of the universe and all it contains and to improve the lives, health, and freedom of all peoples. The continued health of the scientific enterprise is a central component in reaching this vision. In this report, therefore, we have laid out our recommendations for keeping the enterprise sound and strengthening it further. There is no singular, sweeping plan for doing so. The fact that keeping the enterprise healthy requires numerous actions and multiple steps is indicative of the complexity of the enterprise. The fact that this report advocates not a major overhaul but rather a fine-tuning and rejuvenation is indicative of its present strength.

This report focuses on three major areas: (1) government's role in supporting the research enterprise; (2) the private sector's role in supporting the research enterprise; and (3) the collective responsibility of government, industry, and educators to strengthen science and mathematics education. In addition, the report discusses the need for science to play a greater role in public policy and international relations and the need for science to reforge its ties with the American people to gain their support and trust.

Recommendations of Interest to Mathematicians

Importance of Basic Research. It is in the country's interest for its scientists to continue pursuing fundamental, ground-breaking research. The experience with fifty years of government investment in basic research has demonstrated the economic benefits of this investment. To maintain the nation's economic strength and international competitiveness, Congress should provide stable and substantial federal funding for scientific research.

Basic Research Is a Federal Special Priority. Fiscal reality requires setting priorities for spending on science and engineering. Because the federal government has an irreplaceable role in funding basic research, priority for federal funding should be placed on fundamental research. Moreover, because innovation and creativity are essential to basic research, the federal government should consider allocating a certain fraction of grant monies specifically for creative, ground-breaking research.

Breadth of Federal Support to Basic Research. The practice of science is becoming increasingly interdisciplinary, and scientific progress in one discipline is often propelled by advances in other, seemingly unrelated fields. It is important that the federal government fund basic research in a broad spectrum of scientific disciplines, mathematics, and engineering and resist concentrating funds in a particular area.

Limited Role for Government in Applied Research. While the federal government may, in certain circumstances, fund applied research, there is a risk that using federal funds to bridge the mid-level research gap could lead to unwarranted market interventions and less funding for basic research. It is important, therefore, for companies to realize the contribution investments in mid-level research can make to their competitiveness. The private sector must recognize and take responsibility for the performance of research.

Partnerships in Research. Partnerships in the research enterprise can be a valuable means of getting the most out of the federal government's investment. Partnerships between university researchers and industries have become more prevalent, and should be encouraged, as a way for universities to leverage federal money and for industries to capture research results without building up in-house expertise. However, the independence of the institutions and their different missions need to be respected. International scientific collaborations form another important aspect of the research enterprise and are often essential for large-scale scientific projects like the international space station.

Partnerships for Economics Development. Partnerships that tie together the efforts of state governments, industries, and academia also show great promise in stimulating research and economic development. Indeed, states appear far better suited than the federal government to foster economic development through technology-based industry.

Partnerships for Strengthening Regional Research. The university community has a role in improving research capabilities throughout its ranks, especially in states or regions trying to attract more federal R&D funding and high-tech industries. Major research universities should cultivate working relationships with less well-established research universities and technical colleges in research areas where there is mutual interest and expertise, and consider submitting, where appropriate, joint grant proposals. Less research-intensive colleges and universities should consider developing scientific or technological expertise in niche areas that complement local expertise and contribute to local economic development strategies.

Scientific Partnerships with Policymakers. For science to play any real role in legal and policy decisions, the scientists performing the research need to be seen as honest brokers. To ensure that decision makers are getting sound analysis, all federal government agencies pursuing scientific research, particularly regulatory agencies, should develop and use standardized peer review procedures. In return, scientists should be required to divulge their credentials, provide a résumé, and indicate their funding sources and affiliations when formally offering expert advice to decision makers. In Congress and the executive branch, science policy and funding remain scattered piecemeal over a broad range of committees and departments. These diffusive arrangements make effective oversight and timely decision making extremely difficult.

The Critical Importance of Outstanding Science and Mathematics Education. No factor is more important in maintaining a sound R&D enterprise than education. Yet student performance on the recent Third International Math and Science Study highlights the shortcomings of current K–12 science and math education in the U.S. We must expect more from our nation's educators and students if we are to build on the accomplishments of previous generations. New modes of teaching math and science are required. Curricula for all elementary and secondary years that are rigorous in content, emphasize the mastery of fundamental scientific and mathematical concepts as well as the modes of scientific inquiry, and encourage the natural curiosity of children must be developed.

Attracting Qualified Teachers. It is necessary that a sufficient quantity of teachers well versed in math and science be available. Programs that encourage recruitment of qualified math and science teachers, such as flexible credential programs, must be encouraged. In general, future math and science teachers should be expected to have had at least one college course in the type of science or math they teach, and preferably at least a minor. Ongoing professional development for existing teachers also is important. Another disincentive to entry into the teaching profession for those with a technical degree is the relatively low salaries K–12 teaching jobs offer compared to alternative opportunities. To attract qualified science and math teachers, salaries that make the profession competitive may need to be offered. School districts should consider merit pay or other incentives as a way to reward and retain good K–12 science and math teachers.

Opportunities in Educational Technology. The revolution in information technology has brought with it exciting opportunities for innovative advances in education and learning. As promising as these new technologies are, however, their haphazard application has the potential to adversely affect learning. A greater fraction of the federal government's spending on education should be spent on research programs aimed at improving curricula and increasing the effectiveness of science and math teaching.

Challenges in Graduate Education. Graduate education in the sciences and engineering must strike a careful balance between continuing to produce the world's premier scientists and engineers and offering enough flexibility so that students with other ambitions are not discouraged from embarking on further education in math, science, or engineering. While continuing to train scientists and engineers of unsurpassed quality, higher education should also prepare students who plan to seek careers outside of academia by increasing flexibility in graduate training programs. Specifically, Ph.D. programs should allow students to pursue course work and gain relevant experience outside their specific area of research.

The length of time involved and the commensurate forfeiture of income and benefits in graduate training in the sciences and engineering is a clear disincentive to students deciding between graduate training in the sciences and other options. Universities should be encouraged to put controls on the length of time spent in graduate school and postdoctoral study and to recognize that they cannot attract talented young people without providing adequate compensation and benefits.

Increased support for master's programs is needed to allow students to pursue an interest in science without making the long commitment to obtaining a Ph.D., thus attracting greater numbers of students to careers in science and technology. More university science programs should institute specially designed master of science degree programs as an option for allowing graduate study that does not entail a commitment to the Ph.D.

Importance of Postdoctoral Training. The training of scientists and engineers in the U.S. occurs largely through an apprenticeship model, in which a student learns how to perform research through hands-on experience under the guidance of a thesis advisor. A result of this link between education and research is that students and postdoctoral researchers are responsible for actually performing much of the federally funded research done in universities. Mechanisms for direct federal funding of postdocs are already relatively common. Expansion of these programs to include greater numbers of graduate students in math, science, and engineering should be explored.

Communication Problems. Educating the general public about the benefits and grandeur of science is also needed to promote an informed citizenry and maintain support for science. Both journalists and scientists have responsibilities in communicating the achievements of science. However, the evidence suggests that the gap between scientists and journalists is wide and may be getting wider. Closing it will require that scientists and journalists gain a greater appreciation for how the other operates.

As important as bridging the gap between scientists and the media is, there is no substitute for scientists speaking directly to people about their work. In part because science must compete for discretionary funding with disparate interests, engaging the public's interest in science through direct interaction is crucial. Scientists and engineers should be encouraged to take time away from their research to educate the public about the nature and importance of their work.

Chapter 23
Where to Find Other Material

Reports about Mathematics Research

Renewing U.S. Mathematics, National Research Council, National Academy Press, 1984.

This is the famous "David Report", which documented exciting developments in the mathematical sciences and effectively made the case for increased NSF funding in the mathematical sciences. (Note that David was an eminent engineer from industry, not an academic mathematician.) For a full discussion, see Chapter 22.

Renewing U.S. Mathematics: A Plan for the 1990's, National Research Council, National Academy Press, 1991.

An update of the "David Report". Along with urging the government and university administrations to make more money available for mathematics, the report presents some challenges involving better career paths for young mathematicians and balancing teaching with research for faculty and graduate TAs. A broadened training at the doctoral level is also urged.

Report on the Senior Assessment Panel of the International Assessment of the U.S. Mathematical Sciences, National Science Foundation, 1998.

This Congressionally mandated "benchmarking" assessment of U.S. mathematics also contains an honest assessment of the strengths of the American mathematics research enterprise, both overall and in a field-by-field breakdown. The report also contains important recommendations for how NSF should support mathematics.

Mathematical Sciences, Technology and Economic Competitiveness, J. Glimm, ed., National Research Council, 1991.

This document provides a good foundation in industrial mathematics from the point of view of clients, presenting the priorities of industry and federal agencies. The report gives an overview of mathematical sciences-based technology transfer to the business and governmental sectors as it summarizes the opportunities and challenges.

SIAM Report on Mathematics in Industry, Society for Industrial and Applied Mathematics,1995.

This study examines the roles of mathematics outside academia as well as the skills and preparation needed by nonacademic mathematicians. The report suggests strategies for enhancing graduate education in mathematics and nonacademic career opportunities for mathematicians. For a full discussion, see Chapter 22.

Preserving Strength While Meeting Challenges, Board of Mathematical Sciences, National Science Council, 1997.

Proceedings of a BMS workshop with papers about how the public views science and mathematics, how scientists view the role of mathematicians, the challenges to NSF, the challenges in the education arena, and areas of new opportunities for the mathematical sciences.

General Reports about Research and Education in Universities

Renewing the Promise: Research-Intensive Universities and the Nation, President's Council of Advisors on Science and Technology, 1992.

Among the findings and recommendations are: challenges in adapting to a tighter resource environment; better collaboration between academia and industry; developing a better balance between research, teaching, and outreach; and developing an honest strategic-planning process. Universities and individual departments are encouraged to develop focused strengths.

In the National Interest: The Federal Government and Research-Intensive Universities, President's Council of Advisors on Science and Technology, 1995.

This report reinforces many of the findings in "Renewing the Promise: Research-Intensive Universities and the Nation" above. Among other recommendations, it calls for a change in the reward system to encourage senior faculty to be more involved in undergraduate teaching and student advisement; more outreach by research universities to two-year colleges, and more attention to training of preservice school science and mathematics teachers.

Reinventing Undergraduate Education: A Blueprint for America's Research Universities, Carnegie Foundation, Stony Brook, New York, 1998.

This report by the Boyer Commission for Educating Undergraduates at Research Universities is quoted in Chapter 1 of this book. The report has been controversial among academics for its opening criticism of how research universities are not giving undergraduates the attention they deserve. However, it goes on to give thoughtful advice on how research universities can exploit their strengths to infuse the spirit of research into undergraduate education. For a full discussion, see Chapter 22.

Beginning a Dialogue on the Changing Environment for the Physical and Mathematical Sciences, National Research Council, 1994.

The proceedings of an NRC workshop concerned with the need to effect significant changes in both the research and educational missions of universities. While much of this report focuses on concerns of laboratory sciences, it has some recommendations relevant to mathematicians. These include: (1) instead of focusing on resources, we need to think about how research can develop and thrive in a changing environment; and (2) institutional reform will probably be required if we are to get the most science possible out of the resources that are available.

Reports about Doctoral and Postdoctoral Training in Mathematics

Educating Mathematical Scientists: Doctoral Study and the Postdoctoral Experience in the United States, Ron Douglas, ed., Board of Mathematical Sciences, National Research Council, 1992.

This document thoughtfully dissects graduate training into a number of components and analyzes critical issues in each. The report summarizes practices of a number of successful doctoral programs in mathematics. It presents three models for a mathematics department. The most relevant one for most departments is the specialized model, in which a department has half or more of its faculty in one area for a focused strength. The report anticipates several subsequent NRC reports in arguing for broader doctoral and postdoctoral training to prepare Ph.D.'s for a variety of nonacademic jobs. There are helpful suggestions about general issues, like recruiting and retaining doctoral students, and specific issues, like placing foreign students with weak language skills but advanced training in mathematics. For a full discussion, see Chapter 22.

Graduate Education and Postdoctoral Training in the Mathematical Sciences. National Science Foundation, 1996.

Findings and recommendations emerging from this 1995 NSF workshop address: broadening the intellectual content and increasing the diversity of skills acquired during Ph.D. training, adjusting the balance between research and education in doctoral and postdoctoral training, shortening the time to completion of the Ph.D., increasing internships and other real-world experiences, and changing graduate student support mechanisms in the NSF.

Report about Mathematics Education at All Levels

Everybody Counts, Mathematical Sciences Education Board, National Research Council, 1989.

This famous document is a case statement for the growing importance of a strong mathematical education for all students. While aimed primarily at precollege instruction, the report provides excellent support for collegiate mathematics.

Reports about Undergraduate Mathematics Education and Its Recognition

Recognition and Rewards in the Mathematical Sciences, Joint Policy Board for Mathematics, American Mathematical Society, 1994.

The report presents an in-depth study involving site visits to twenty-six mathematics departments. An important observation is that faculty members' contributions to their departments are likely to change over their lifetimes. A key finding was that faculty and department chairs have different perceptions of the reward structure, with chairs believing that teaching carries more weight than faculty believe it carries. Communication problems and the importance of a strong department chair are other critical issues discussed. The report recommends that each department should develop a working definition of scholarship that is consistent with the departmental and institutional missions and is sufficiently encompassing and flexible to embrace the broad variety of intellectual activities in the discipline. For a full discussion, see Chapter 22.

Moving Beyond Myths, Mathematical Sciences Education Board, National Research Council, 1991.

This report's main recommendations are echoed in later reports; they include greater recognition for teaching and more involvement of university mathematicians in school mathematics. The report was vocally criticized in the research mathematics community for its negative assessment of current instructional practices, such as many faculty's alleged weak commitment to teaching. However, it is instructive to read this report as a reflection of troublesome perceptions—heard again in this Task Force's focus groups with deans (see Chapter 6)—about mathematicians that exist in campus administrations, across the sciences and outside of academia. For a full discussion, see Chapter 22.

Models That Work: Case Studies in Effective Undergraduate Mathematics Programs, A. Tucker, ed., MAA Notes #38, Mathematical Association of America, 1996.

This study, cited in Chapter 13, discusses common themes of effective undergraduate mathematics programs. Most of the report's findings build on site visits to ten successful mathematics programs, ranging from a two-year college to two Top 10 research universities. One theme is the encouragement of continual experimentation in individual faculty classes.

Assessing Calculus Reform Efforts, J. Leitzel and A. Tucker, Mathematical Association of America, 1995.

This report summarizes the impact of the NSF Calculus Reform Initiative up through 1994. It documents surprisingly widespread experimentation with calculus reform at research universities. A key finding is how satisfied most faculty teaching reformed courses were with the levels of interest and performance of their students.

Guidelines for Programs and Departments in Undergraduate Mathematics, Mathematical Association of America, 1993.

While this report is aimed primarily at the assessment of four-year college mathematics departments, it conveniently inventories many concerns that are applicable to university mathematics departments.

Recommendations for a General Mathematical Sciences Program, Mathematical Association of America, 1980. Reprinted in Reshaping College Mathematics, MAA Notes #13, 1989.

The last comprehensive CUPM report on the undergraduate major in mathematics. While almost twenty years old, this report presents an inclusive view of the mathematics major that is getting more and more currency today.

Mathematics Outside of Mathematics Departments: A Study of Mathematics Enrollment's in Non-Mathematics Departments, by S. Garfunkel and G. Young, Consortium for Mathematics and Its Applications, 1990 (summarized in the November 1990 AMS Notices).

This study documents that more upper-division mathematics instruction, primarily in applied mathematics, occurs outside mathematics departments than inside them.

Challenges for College Mathematics: An Agenda for the Next Decade, L. Steen, ed., Report of the American Association of Colleges, reprinted in FOCUS, November 1990, pp. 1–32.

A report focusing largely on noncurricular components of undergraduate mathematics instruction, such as hurdles and strategies for making mathematics classrooms more welcoming to students from underrepresented groups.

Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus, American Mathematical Association of Two-Year Colleges, 1995.

A companion document for two-year colleges to the "MAA Guidelines for Programs and Departments in Undergraduate Mathematics" above.

Twenty Questions that Deans Should Ask Their Mathematics Departments," by L. Steen, Bulletin of the American Association of Higher Education, May 1992.

While not a report, this article is similar to some of the preceding reports in its underlying concerns. It anticipates many of the findings and recommendations of this resource book. Along with the questions are principles to aid mathematics departments to be ready for the questions.

Reports of NSF Undergraduate Education Self-Assessments

Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology, National Science Foundation, 1996.

This review of the NSF's Division of Undergraduate Education makes recommendations to the NSF for future funding priorities in undergraduate education. There are also thoughtful suggestions to universities and faculty that rise above specific knowledge acquisition to address issues such as lifelong learning, critical thinking, and communication skills. For a full discussion, see Chapter 22.

Evaluation of the Division of Undergraduate Education's Course and Curriculum Development Program, National Science Foundation, 1997.

This external evaluation of the main NSF undergraduate education program (which has since been reorganized) points to what works and what are critical factors for success in undergraduate instructional projects. It also suggests to the NSF future directions for funding instructional innovation and dissemination.

Resources for Improving Mathematics Teaching

Report of the Task Force on Teaching Growth and Effectiveness, Mathematical Sciences Education Board, National Research Council, 1993.

This report is a companion to "Recognition and Rewards in the Mathematical Sciences", cited above. It gives thoughtful guidance for faculty wading into the "mare's nest" of assessing effective teaching. A major theme is that effective teaching and growth in teaching are a collective responsibility of the faculty in a department. The report encourages senior faculty to assume a leadership role in the teaching arena by participating fully in teaching introductory courses, in course development, and in mentoring junior and part-time faculty and teaching assistants. An interesting finding was that NSF Presidential Young Investigators had complained about the low priority given to teaching (and public service) in their departments.

A Source Book for College Mathematics Teaching, A. Schoenfeld, ed., Mathematical Association of America, 1990.

This book contains a variety of information about teaching strategies. It goes into greater depth in analyzing ways to teach mathematics to undergraduates than any other publication.

How to Teach Mathematics, by S. Krantz, 2nd edition, American Mathematical Society, 1998.

A balanced, to-the-point paperback of helpful suggestions about the various issues associated with teaching mathematics in colleges and universities.

You're the Professor, What Next? Ideas and Resources for Preparing College Teachers, B. Case, ed., MAA Notes #35, Mathematical Association of America, 1994.

This resource book, prepared by the AMS/MAA Committee on Preparation for College Teaching, provides lots of good material about training graduate students to be future college teachers, including extensive descriptions of successful mathematics TA training programs at several universities. The report's appendices gather together in one place many short essays and reprints (from sources such as *UME Trends*) on teaching that are relevant for all faculty, as well as graduate TAs.

A Practical Guide to Cooperative Learning in Collegiate Mathematics, Nancy L. Hagelgans, ed., and Barbara Reynolds, MAA Notes 37, Mathematical Association of America, Washington, DC, 1995.

The handbook, prepared by the MAA's Advisory Board for Cooperative Learning in Undergraduate Mathematics Education, gives practical methods and a discussion of effectiveness of cooperative learning methods in college mathematics classrooms. There is helpful advice to first-timers about unanticipated difficulties.

McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers, Wilbert J. McKeachie and Graham Gibbs, Houghton Mifflin, 1998.

This helpful book, which has gone through numerous editions, has advice about every aspect of collegiate teaching. Much of the book is about problems in non-quantitative courses, but its tips about generic issues, such as handling students who try to monopolize discussions and effective ways to discuss results of a test, make the book a valuable resource for new mathematics faculty.

Calculus: The Dynamics of Change, W. Roberts, ed., MAA Notes 39, Mathematical Association of America, 1996.

A summary of lessons learned in the ten years of calculus reform (since the 1986 Tulane Conference). This volume includes a helpful assessment of the resources required to undertake a major reworking of calculus instruction. There is also an article by Mort Brown describing the Michigan New Wave calculus in depth.

Resources for Calculus Collection: Volume 1: Learning by Discovery; Volume 2: Calculus Problems for a New Century; Volume 3: Applications of Calculus; Volume 4: Problems for Student Investigation, MAA Notes 27–30, Mathematical Association of America, 1994.

A helpful collection of calculus resource materials for enriching calculus instruction. The MAA Notes series has a number of additional calculus-enrichment volumes.

General Background on Undergraduate Education

How College Affects Students, E. Pascarella and P. Terenzini, Jossey-Bass, 1991.

This book presents findings and insights from twenty years of research on the subject. It attempts to distill a huge quantity of sometimes conflicting research.

Talking about Leaving: Why Undergraduates Leave the Sciences, Elaine Seymour and Gloria Hewitt, Westview Press, Boulder, CO, 1997.

A widely cited study interviewing students who did and did not drop out of science/math/engineering disciplines. Both groups complained about the way they were taught (including discouraging attitudes of faculty) more than problems with what they were taught. For a full discussion, see Chapter 22.

What Matters in College: Four Critical Years Revisited, A. Astin and G. Erlandson (eds.), Jossey-Bass, 1997.

A study of how students change and develop in college. The book shows how a range of variables—including academic programs, faculty, student peer groups, and much more—affect students' college experiences.

What Works: Building Natural Science Communities, Vols. I and II, The Independent Colleges Office, Project Kaleidoscope, Washington, DC, 1991, 1993.

These two volumes document practices in effective undergraduate programs in the natural sciences.

Department Leadership

Chairing a Mathematical Sciences Department in the 1990's, National Research Council, Washington, DC, 1990.

Proceedings of a BMS Mathematics Chairs Colloquium. Among the touchy topics covered are differential teaching loads, experimentation with new curriculum and teaching methods, and the role of applied mathematics within a mathematics department.

On Being a Department Head, John Conway, American Mathematical Society, Providence, RI, 1996.
A personalized account by a mathematics department chair at a research university.

The Academic Chairperson's Handbook, K. Beyer, N. Egly, A. Seagren, D. Wheeler, and J. Creswell, University of Nebraska Press, 1990.

A book of case studies describing successful department chairs in a variety of disciplines.

You Can Negotiate Anything, H. Cohen, Mass Market Paperback, 1989.
A text highly recommended in Doug Lind's essay (Chapter 16) for help in dealing with your dean.

Data Studies

Statistical Abstract of Undergraduate Programs in the Mathematical Sciences, Fall 1995 CBMS Survey, Mathematical Association of America, 1997.
The latest of the five-year CBMS surveys documents a surprising new trend in mathematics enrollments, namely, a 9% decline in the past five years.

A Challenge of Numbers, People in the Mathematical Sciences, B. Madison and T. Hart, eds., National Research Council, 1990.
This report is a compilation of data documenting the challenges facing the mathematical sciences community in educating students and attracting future faculty to the profession.

AMS-MAA Annual Surveys, published annually in the AMS Notices.
These reports give data about new Ph.D.'s and their employment, including starting salaries. Recent surveys have also collected data about course enrollments.

Graduate Students and Postdoctorates in Science and Engineering: Fall 1996, National Science Foundation, June 2, 1998.
This report has graduate enrollment data going back to 1966, broken down by degree program, type of institution, ethnicity, source of support, nationality, and more.

Characteristics of Recent Science and Engineering Graduates: 1995, National Science Foundation, February 28, 1998.
This report has a huge amount of information about B.S. and M.S. recipients, including continuing education data, forms of support for students, how many students hold second jobs, and more.

Characteristics of Recent Science and Engineering Graduates: 1995, National Science Foundation, February 28, 1998.
Data includes salaries and forms of employment.

Survey of Mathematics and Statistics Departments at Higher Education Institutions, National Science Foundation, December 1990.
A survey of enrollments and opinions about various problems facing mathematics and statistics departments. The sample size is considerably larger than the CBMS five-year surveys.

Undergraduate Origins of Recent (1991–95) Doctoral Recipients, National Science Foundation, April 3, 1997.
An interesting report about where recent Ph.D.'s have come from.

School Mathematics and the Training of School Mathematics Teachers

Professional Standards for Teaching Mathematics, National Council of Teachers of Mathematics, 1991.
This is the oft-cited NCTM Standards that launched the whole movement of curriculum standards in the schools. The document is intentionally vague on many details. Interpretations of what it advocates and what it downplays have been the source of considerable controversy. Note: A new set of Standards will appear in 2000.

A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics, J. Leitzel, ed., Mathematical Association of America, 1991.
Recommendations for the preservice education of school mathematics teachers that are meant to prepare prospective teachers to use the NCTM Standards.

Guidelines for the Mathematical Preparation of Prospective Elementary Teachers. Texas Statewide Systemic Initiative, The Charles A. Dana Center for Mathematics and Science Education, University of Texas, Austin, 1996.

Model Standards in Mathematics for Beginning Teacher Licensing and Development: A Resource for State Dialogue, Interstate New Teacher Assessment and Support Coalition (INTASC), Council of Chief State School Officers, Washington, DC, 1995.

The Preparation of Teachers of Mathematics: Considerations and Challenges (A Letter Report), Mathematical Sciences Education Board, National Research Council, March 1996.

Towards High and Rigorous Standards for the Teaching Profession, Second Edition, National Board for Professional Teaching Standards, 1990.

What Matters Most: Teaching for America's Future, National Commission on Teaching and America's Future, 1996.

The Changing Environment in Higher Education

The following references discuss difficult issues facing higher education, particularly at research universities. These include imbalance between research and teaching, calls for a greater economic payoff from academic research, improving schools, society's changing expectations for a college education, backlash from academic "cultural wars", the view of academic researchers as just another special interest group, and more.

Academic Duty, Donald Kennedy, Harvard University Press, 1998.

An Exploration of the Nature and Quality of Undergraduate Education in Science, Mathematics, and Engineering, Sigma Xi, 1990.

Contemporary Understandings of Liberal Education: The Academy in Transition, C. Schneider and R. Shoenberg, American Association of Colleges and Universities, 1998.

Drive-Thru U., by J. Traub, The New Yorker, Oct 20 & 27, 1997, pp. 114–123.

Equilibrium in the Research University, R. Atkinson and D. Tuzin, CHANGE, May–June 1992, pp. 20–27, 30–31 (cited in Chapter 14).

From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology, Center for Science, Mathematics, and Engineering Education, National Research Council, 1996.

Functions and Resources: The University of the Twenty-First Century, H. Shapiro, Proceedings of the University of Chicago Symposium, The University of the Twenty-First Century, 1995.

Organizing for Learning: A New Imperative, P. Ewell, American Association of Higher Education Bulletin, December 1997, pp. 3-6.

Scholarship Reconsidered: Priorities of the Professoriate, Ernest Boyer, Carnegie Foundation for the Advancement of Teaching, 1990.

Today's Academic Market Requires a New Taxonomy of Colleges, C. Finn, The Chronicle of Higher Education, 9 January 1998.

Changing the Culture: Mathematics Education in the Research Community, N. Fisher et al, eds., Conference Board of the Mathematical Sciences, Issues in Mathematics Education, Vol. 5, American Mathematical Society, 1995.