Section V:

Background Data and Information Influencing the Conclusions and Recommendations of *Shaping the Future*

by Staff of the Division of Undergraduate Education

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Numerous changes of some significance have occurred, since 1980, in the fabric of influences affecting higher education. The cumulative impact of these changes has important implications for undergraduate education. Attention has been focused on entering students, mission priorities, faculty practices, technology, and needed skills.

I. Overview of Developments

A number of key concerns and promising developments were identified in the first volume of this report, *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF 96-139), influencing its recommendations. In this overview, these are summarized briefly. In the following section, each of the points listed under A and B are discussed and some of the data and information are provided in summary form (often in charts and graphs).

A. Education Concerns

1. Over the past 20 years, evidence has mounted that public, K-12, mathematics and science education in the U.S. is far from the best in the world. (In particular, see the next three items.)
2. Too many K-12 teachers are inadequately prepared in mathematics and science to properly teach these subjects.
3. Measured educational progress of 8th grade and 12th grade students indicates a decline over the high school years in the fraction who can perform at least at basic levels of proficiency in mathematics and science. It also indicates that only a small fraction of 12th grade students are fully prepared to undertake college level studies in mathematics and science.
4. Measured educational progress, in mathematics and science, by underrepresented minority students in the 8th and 12th grades is often significantly below average.
5. Nevertheless, there has been a steadily rising percentage of high school graduates entering undergraduate programs; more than 60 percent of high school graduates were entering college in the early 1990s.
6. The situation described above has fueled a growing awareness of the importance and enormity of the task of recruiting and educating future K-12 teachers in mathematics and the sciences.
7. Focus groups have indicated that the majority of undergraduates in the early to mid 1990s were often dissatisfied with their experiences in lower division courses in the sciences, mathematics, engineering, and technology (SME&T).
8. Following the peak reached in 1986, a declining percentage (and number) of students were earning bachelor's degrees in many disciplines in the natural sciences, engineering, and technology.

The evidence also supports the claim that improvements have been achieved in our educational system. The following kinds of improvement were examined during the review of undergraduate education that preceded the drafting of Volume I of *Shaping the Future*.

Improvements at the K-12 Level

1. On average, more course work in grades 9-12 is now taking place in subjects that constitute important building blocks for college studies, including mathematics and science. Advanced placement courses have become increasingly widespread. These data were reviewed in Volume I of *Shaping the Future*.
2. Average student achievement levels in mathematics and science in the 4th, 8th, and 12th grade have been improving since the late 1970s, particularly among African American and Hispanic students.
3. A number of standards have been developed for mathematics and science learning during the K-12 years, including those of the National Council for Teachers of Mathematics, the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science. These help to focus attention on needed minimum levels of achievement and help guide educators in incorporating new course materials and laboratory approaches to meet those standards.
4. A growing number of states have instituted higher standards for high school graduation.
5. Within the U.S., some states were achieving high levels of performance on the National Assessment of Educational Progress in 1992 [on par with the best foreign nations]. This fact informs us that there are high achieving school systems to examine, replicate, or improve upon for implementation in other settings.
6. The inflation adjusted pay of teachers and faculty has been improving since 1980, thereby aiding the effort to attract good students to teaching careers.
7. Attention to needed improvements in the preparation of K-12 teachers of mathematics and science has grown considerably in the 1990s.

Improvements at the Undergraduate Level

1. A large portfolio of highly promising educational practices and materials has been developed for undergraduate education over the past decade. These practices and materials were discussed in a generic way in Volume I of *Shaping the Future.* Some of these approaches are now starting to spread into wider use.
2. Faculty and college and university administrators have become ever more aware that there are a variety of pedagogical practices that can yield improved student learning.
3. Federal agencies have increased their support of innovative activities aimed at improving undergraduate education in SME&T disciplines. They often play the role of "venture capitalists," financing new national models of learning that are too expensive for individual schools, school districts, colleges, and universities to develop.
4. Systemic efforts to improve K-12 school systems are helping us to understand the challenges and potential in adapting comprehensive approaches to reforming education in institutions of higher education. NSF is starting to assist model institutions to develop comprehensive improvements.
5. Educational technology promises to provide attractive learning dividends when it is developed and applied correctly.

B. Important Changes in the Social, Economic, Political, and Technical Environment

1. There are pressures on colleges and universities to reconsider their mission priorities following the declining military imperative for scientific research and the rising tide of criticism about the cost and quality of undergraduate education.
2. The status accorded to teaching and student advising by faculty at many colleges and universities is increasingly perceived as being low.

3. Because a college education now confers a major advantage in lifetime earnings, there are some public officials who think that public subsidies of higher education should not grow.
4. However, there is growing pressure on family budgets as a consequence of rising levels of tuition (in response to the rising costs of higher education).
5. Institutional differences in resource expenditures per undergraduate student have grown considerably in recent years.
6. Public higher education competes for funds with public K-12 education and other demands for state resources. The increased expenditure of state-level resources on K-12 education during the 1980s has tightly constrained most states' capacity to fund transitional resource needs in higher education to accelerate their adaptation of new practices and educational technology.
7. Federal funding for science and engineering education, research, and facilities are concentrated in the hands of a relatively small number of institutions, while the distributions of SME&T majors and other students taking SME&T courses are widely spread over a large number of institutions differentiated by size and type.
8. The type and size of SME&T classes appear to be influenced by type of institution and discipline, suggesting that there is a need for a variety of approaches to improved undergraduate instruction.
9. There are a variety of faculty practices that would assist students in mastering basic concepts and materials. However, the extent of their use is often far from universal, indicating that more needs to be done to encourage faculty to adopt or adapt improved teaching practices.
10. A number of large employers have voiced dissatisfaction, in recent years, about the lack of broad skills evidenced by many recent college graduates in certain key areas. Improvements in curriculum and pedagogy would help to develop many of these skills.
11. The rising tide of educational and learning technologies threatens legions of faculty and students who are not familiar with much of it.

II. A Look at Some Basic Data and Information

A. Education Concerns

1. Student Achievement - International Perspective. Some of the latest data on comparative achievement in mathematics and science in the U.S. (including the state level) and foreign nations can be found in *The Learning Curve; What We are Discovering About U.S. Science and Mathematics Education* (NSF 96-53, January, 1996). This report shows, for example, that the Plains states of Iowa, North Dakota, and Minnesota had mathematics achievement scores for eighth grade students, on the National Assessment of Educational Progress in 1992, on par with the 13-year olds in the highest scoring other nations (Taiwan, Korea, The Soviet Union, and Switzerland). (See page 9.) However, the U.S. as a whole ranked substantially below these four nations and nine others on this test of proficiency.

2. Teacher Preparation in Mathematics and Science. Secondary teachers active in teaching mathematics and science are under-prepared in these disciplines. Consider the education credentials in academic year 1990-91 of those public secondary school teachers whose main teaching assignment was mathematics or science. Only 52 percent of those teaching biology, 35 percent teaching chemistry, 26 percent of those teaching physics, and 23 percent teaching mathematics had earned a baccalaureate (or higher) in the **corresponding** science discipline. Minors in the same discipline were earned by another 13 percent teaching biology, 25 percent teaching chemistry, 15 percent teaching physics, and 7 percent teaching mathematics. [Source: *1990-91 Schools and Staffing Survey*, as reported in U.S. Department of Education, National

Center for Education Statistics, *The Condition of Education 1995,* NCES 95-273, pages 419-422.]

In 1993, 72 percent of the science teachers had science baccalaureates (or higher) as measured by the less strict credential of counting *any* field of science, including science education. Similarly, 63 percent of the mathematics teachers had baccalaureates (or higher) as measured by the standard of mathematics or mathematics education. [Source: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education,* Chapel Hill, NC: Horizon Research, Inc.] For elementary teachers with teaching assignments in science and mathematics, typical preparation is still overwhelmingly in pedagogy rather than subject fields. (The importance of this fact is discussed in number 5 below.) There has been modest improvement in teacher credentials during the past 10 years.

<u>3. Educational Progress in High School</u>. This progress has continued over the past decade, but evidence suggests that substantial additional progress is vital. One source of evidence for basic achievement in mathematics and science of 13-year olds (typically 8th grade students) and 17-year olds (typically 12th grade students) is the test known as the National Assessment of Educational Progress (NAEP). The "anchor point" of basic proficiency for 13-year olds is a NAEP score of 250. Proficiency at this level in mathematics means that students have an initial understanding of the four basic operations. They are able to add and subtract whole numbers in one-step word problems and money situations. They can find the multiplication product of a 2- and 1-digit number. They can also compare information from graphs and charts. [See: US Department of Education, National Center for Education Statistics, *National Assessment of Educational Progress, Trends in Academic Progress: Achievement of U.S. Students in Science, 1969 to1992; Mathematics, 1973 to 1992; Reading 1971 to 1992; Writing, 1984 to 1994*.] However, fully successful 13-year old achievement in mathematics would be reflected in a score of 300 or higher, the anchor point level of basic proficiency for 17-year olds.

At the 300 level, students can compute with decimals, fractions, and percents. They can identify geometric figures, measure angles, calculate areas of rectangles, interpret simple inequalities, and solve simple linear equations. However, students taking mathematics each year have been exposed to most of this knowledge by the 9th grade, and full mathematics proficiency for 17-year olds planning on earning baccalaureates and studying mathematics (and other quantitative subjects) for another year in college would be demonstrated by a NAEP score of 350 or higher. At this level, students can solve a variety of two-step problems using variables, identify equivalent algebraic expressions, and solve linear equations and inequalities. They are developing an understanding of functions and coordinate systems.

The achievement data in the table below indicates several trends. The good trend is that in all cases, the fraction of students demonstrating achievement at the 250, 300, or 350 level has been rising. The negative trend is a little more difficult to see. In both mathematics and science, the fraction of 17-year olds scoring 300 or higher (or 350 or higher) is less than the fraction of 13-year olds scoring 250 or higher (or 300 or higher) in the same discipline four years earlier. In this sense of maintaining measured progress, students appear to be losing ground during the high school years. The amount of ground lost appears to be greater in mathematics, where there is more ground to lose because the fractions of 13-year olds scoring 250 or higher is greater than the counterpart fraction in science.

Fractions of a National Sample of Students Scoring Above Key Anchor Points in Mathematics and Science on the National Assessment of Educational Progress [NAEP]

13-year Olds	Percent in 1986	Percent in 1990	Percent in 1992
250 or higher in math	73%	75%	78%
300 or higher in math	15%	17%	19%
250 or higher in science	53%	57%	61%
300 or higher in science	9%	11%	12%

17-year Olds	Percent in 1986	Percent in 1990	Percent in 1992
300 or higher in math	52%	56%	59%
350 or higher in math	6%	7%	7%
300 or higher in science	41%	43%	47%
350 or higher in science	8%	9%	10%

A key observation is that only small percentages of 12th grade students score 350 or higher (7 percent in mathematics and 10 percent in science in 1992). Yet more than one-half of these students will shortly enter college.

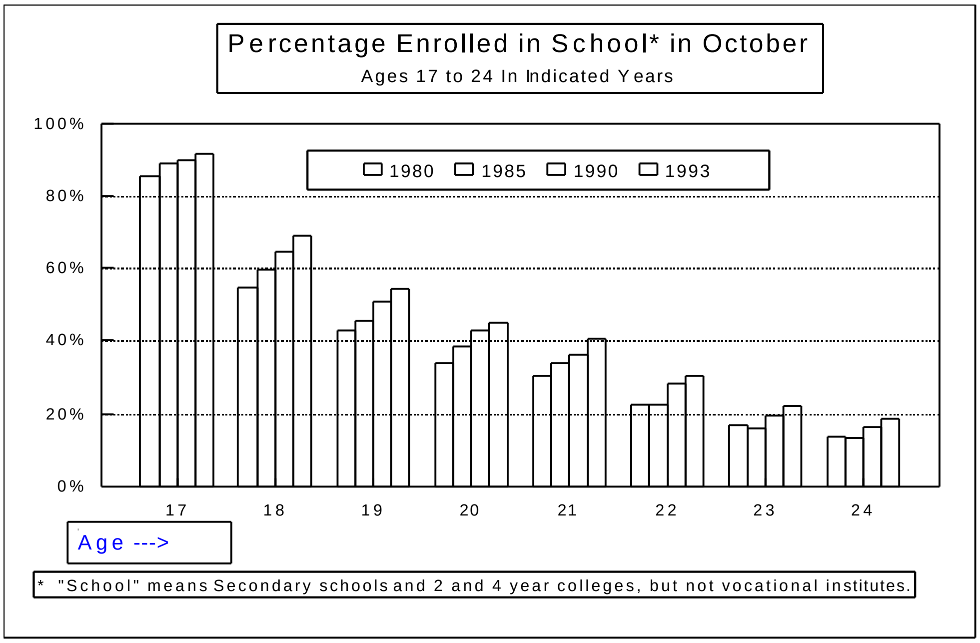
<u>4. Minority Achievement</u>. Although minority achievement has improved for years, it has far to go. Using the anchor points for basic achievement on the NAEP test in 1992, 85 percent of eighth grade white (non Hispanic) students scored 250 or higher in mathematics, compared to 63 percent of Hispanic and 51 percent of African American students. [US Dept. of Education, National Center for Education Statistics, *The Condition of Education 1995*, NCES 95-273, pages 216-218.]

At the 12th grade level, 66 percent of twelfth grade white students scored 300 or higher in mathematics, compared to 39 percent of Hispanic and 30 percent of African American students. In comparing basic achievement in mathematics in the 8th grade and 12th grade, we see not only the decline in the percentage of students in each demographic category able to achieve minimum basic proficiency for their age level, but also a growing **relative** gap on the basis of race and ethnicity. The fraction who demonstrated at least basic proficiency in mathematics declined from the 8th to the 12th grade by 22 percent for white (non Hispanic) students, 38 percent for Hispanic students, and 41 percent for African American students. The pattern of NAEP scores in science is similar.

<u>5. Rising Rate of College Attendance</u>. The percentage of students continuing their schooling after high school has risen steadily. Undergraduate enrollments rose throughout the 1980s, and continued to rise in the 1990s through 1992, along with the annual expenses paid by students to attend college, indicating a strong growth in demand for college education after 1980. One important indicator of this rising demand is the growing percentage of high school graduates entering four-year institutions without interruption (e.g., June graduates entering college in August or September). The percentage of female high school graduates attending four-year institutions within a few months of graduation rose from 33 percent in the early 1980s to 41 percent in early 1990s. Similarly, the percentage of male graduates rose from 31 percent in the first half of the 1980s to 38 percent in the second half of the 1980s, fluctuating slightly after 1990 in the 35 to 38 percent range. Including matriculation in two-year colleges, nearly 67 percent of female high school graduates and nearly 60 percent of male high school graduates entered post secondary education within a few months of graduation in 1992. Another 10 to 15 percent will enter college a

few years after graduating from high school, or after leaving high school and earning their general equivalency diploma. College attendance has become a nearly universal rite of passage into the workforce in the 1990s.

Another perspective is provided by the rise in percentage of U.S. residents of college age enrolled in school in October of selected years. As the following chart indicates, at each age in the span from 17 to 24 years old, this fraction has risen since 1980. This fact has had a large impact on undergraduate enrollments, which have continued to rise through 1992 despite a drop in the number of high school graduates after 1988.



Source: US Department of Commerce, Bureau of the Census, October Current Population Surveys.

6. Importance of Recruiting and Preparing K-12 Math & Science Teachers. Starting at least with *A Nation at Risk* (National Commission on Excellence in Education, 1983), educators and policy makers began to give teacher preparation high priority, particularly after the decline in the quality of K-12 schools was linked to declining economic productivity in *Time for Results* (National Governors' Association, 1986), and we collectively began to realize that school reform would not succeed without programs to improve the quality of teacher education. [See, for example, *The Preparation of Teachers: An Unstudied Problem in Education* (Sarason, Davidson, and Blatt, 1986).]

The evidence of need for improvement has grown considerably, and the total body of evidence now indicates that it would be hard to overstate the size of this problem. In his study, *Teachers for our Nations Schools* (1990), Goodlad measured the magnitude of the problem of achieving meaningful reform and explained the need and value of **systemic** approaches — an approach that is now embodied in NSF's State, Urban, and Rural Systemic Initiatives for K-12 education, Comprehensive Partnerships for Mathematics and Science Achievement, and the Collaboratives for Excellence in Teacher Preparation Program.

Researchers and educators believe the most effective teachers are those who (1) are lifelong learners who regularly update their subject and pedagogical knowledge; (2) are willing to learn from others, including students; (3) have a vision of how they want to change, spend time reflecting on their own teaching strategies, and devise strategies that are effective in addressing the diverse learning styles that their students exhibit (which they comprehend through skillful observation of student's learning processes).

Increasingly, we want that knowledge to include a knowledge of — and a comfort with — mathematics and science. Even though, as a nation, we are making progress, elementary teacher candidates can still receive a bachelor's degree without ever learning content approaching the depth of understanding expected of mathematics and science majors. Instead, subject matter knowledge is transmitted through mathematics and science courses tailored to education majors. Some states do not require elementary majors to have taken any mathematics or science content courses.

What does the evidence indicate about the value of subject matter training in mathematics and science? Evidence from the National Education Longitudinal Study of 1988 (NELS:88), a national study of 24,599 students in the eighth grade and their teachers, indicates that students of those teachers who majored or minored in science and mathematics performed significantly better on achievement tests. The following summary deals with direct effects only, leaving out indirect effects and associative effects (such as giving the best teachers the best students). The results are reproduced below in Panel A (mathematics teachers) and Panel B (science teachers).

Student achievement scores rise for each descending step in each column:

A. Mathematics

Teachers Mathematics Preparation
No courses in math (low frequency)
Math at calculus level or lower; no math education
Math at calculus level or lower and math education
Math above calculus level; no math education
Math above calculus level and math education

and

Teachers Math GPA
2.5 or lower
2.5+ to 3.0
Above 3.0

B. Science

Teachers Science Preparation
No science courses, or sci. ed. only (low frequency)
Science and sci. ed. courses (< 41 credits)
Science courses only (< 41 credits)
Science and sci. ed. courses (> 40 credits)
Science courses only (> 40 credits)

and

Teachers Science GPA
2.5 or lower
2.5+ to 3.0
Above 3.0

A brief summary of the impact of teacher preparation in subject area and pedagogy on student test scores indicates that:

- There is no pattern based on teachers' highest academic degrees.
- Mathematics scores are higher if teachers majored in mathematics.
- Science scores are higher if teachers majored or minored in science, and somewhat higher yet if teachers majored in science as graduate students.
- Training in pedagogy helped only if the teacher had training in subject area too.

7. Student Dissatisfaction with Lower Division SME&T Courses. Seymour and Hewitt's large study, *Talking About Leaving* (1994), produced findings that are very critical of faculty teaching practices. They conducted a large ethnographic study over a three-year period (1990-93) with 335 students, majoring in the natural sciences and engineering (NS&E), drawn from seven campuses that were among the most productive contributors to the nation's flow of new baccalaureates in these fields. Most data were gathered by personal interview. Some data were obtained in focus groups of three to five students. An additional 125 students took part in focus group discussions on six other campuses. One-half of the students were in the biological sciences, physical sciences, and mathematics. The other half were in engineering. All of the students had SAT mathematics scores above 649 and, thus, were prepared to undertake NS&E studies in college. The student sample was designed to include slightly more students leaving (55 percent, all juniors or seniors) than remaining in NS&E majors (45 percent, all of whom were seniors). Underrepresented groups were over sampled.

Generally poor teaching by the science and engineering faculty was by far the most common complaint of able students. Nine out of ten one-time NS&E majors who switched to a non-NS&E major, and three out of 4 who persevered, described the quality of teaching as poor overall. The next most frequent complaint of non-switchers was inadequate advising by the faculty, mentioned by more than one-half of these successful majors.

Students were very clear about what was wrong with the teaching they had experienced. They strongly believed that faculty do not like to teach (especially lower division courses), that faculty do not value teaching as a professional activity, and that they lack incentive to improve. In their explanations for the poor teaching they had experienced, students constantly referenced faculty preoccupation with research as the overt reason for the failure of faculty to pay serious attention to the teaching of undergraduates and for specific inadequacies in attitude or technique. (Student perceptions of faculty research activities changed considerably, however, when students were allowed to observe or participate in that research. The few students who had this experience were pleased with the pleasant and open way in which faculty treated undergraduates in a research relationship, compared with their apparent indifference to them in a teaching context.)

The perceived dislike displayed by the NS&E faculty for pedagogical contact with students cannot be simply explained by a greater interest in research, or by the bias of departmental rewards systems, according to Seymour and Hewitt. Students offered many examples of non-NS&E faculty who evidently enjoyed teaching, saw it as an integral part of their work, and took the trouble to do it well. Important elements in what students saw as good teaching were openness, respect for students, the encouragement of discussion, and the sense of discovering things together. Student comparisons of NS&E teaching styles with those in other classes are permeated with strong contrasts including:

- coldness versus warmth,
- elitism versus democracy,
- aloofness versus openness, and
- rejection versus support.

The distancing of the NS&E faculty from students was sometimes increased by sarcasm and ridicule, which created an atmosphere of intimidation and had the effect of discouraging voluntary student participation in classroom discussions.

The focus of student criticisms were the following:

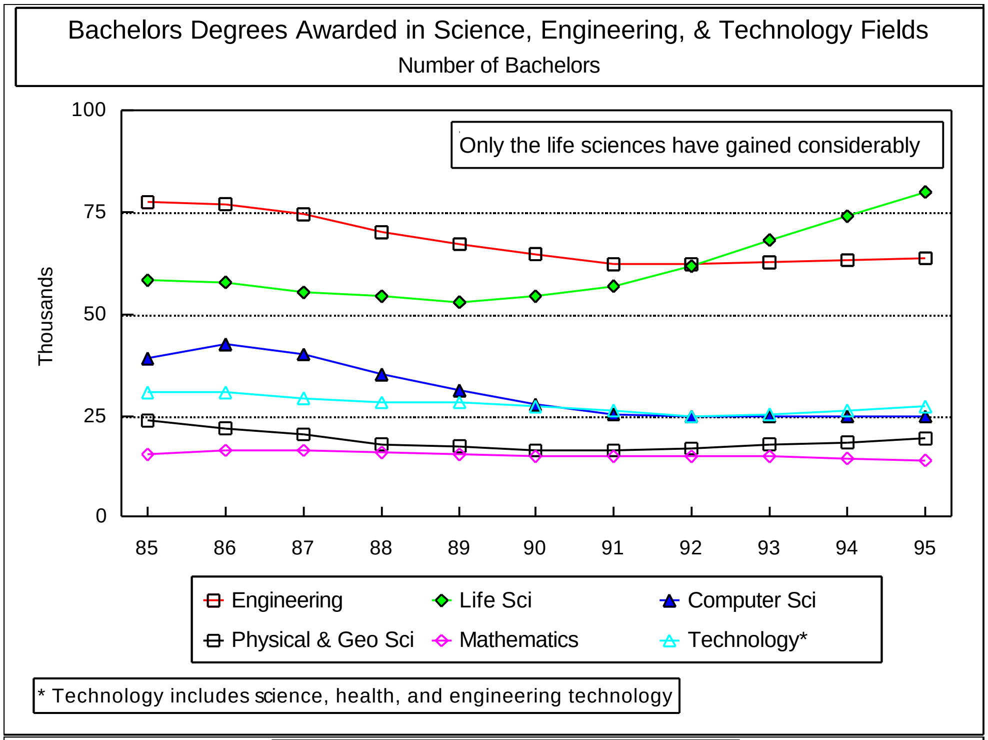
- There was a lack of student-teacher dialogue, which was also thought to reflect faculty indifference. Classes like this were one-way lectures and contrasted poorly to the high school experiences of many students, where there was considerable dialogue.
- Faculty were evidently poorly prepared for lectures, indicating to students that faculty were disinterested in student learning. Students were particularly frustrated by faculty who seemed unable to explain their ideas sequentially or coherently.
- Students also wanted (but typically did not find) many illustrations, applications, and discussions of implications. Nevertheless, students did not believe there was anything intrinsically dull about any NS&E class material, even though student interest in many classes began to flag when faculty failed to present material in a stimulating way. Many students made reference to the "monotone" voices and dry recitations of their instructors' lecturing.
- Class tedium grew in instances where faculty were "over-focused" on getting students to memorize material.

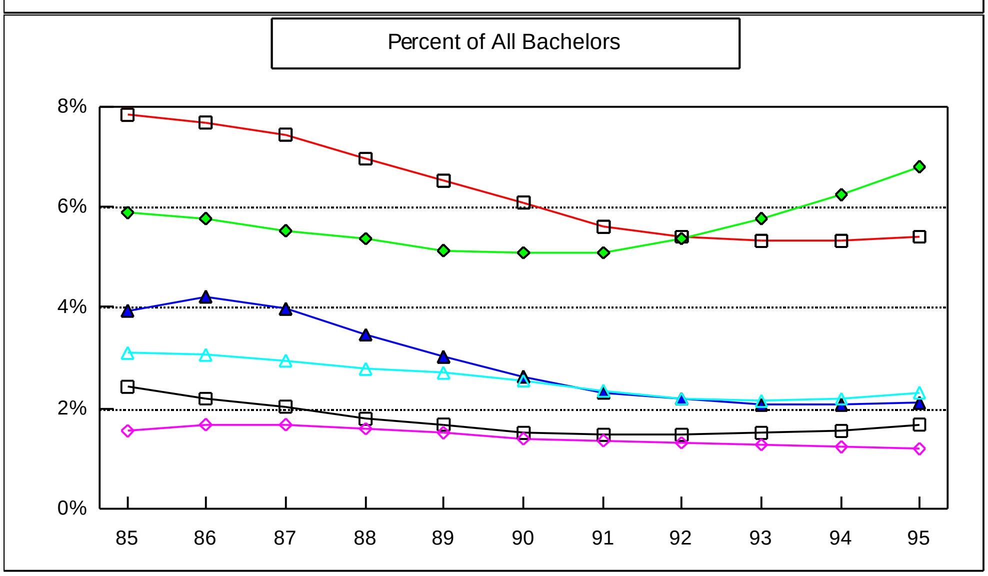
Turning briefly to the findings derived from focus groups of students convened for this study, covering a broader cross section of undergraduates than those participating in *Talking About Leaving*, it is noteworthy that the students' opinions about introductory courses are similar. (These findings are reviewed in substantially greater detail in Section IV of Volume II, pages 243 to 270.) In the focus groups for this study, students identified introductory SME&T courses as a major barrier. Many students majoring in other fields who were interested in improving their competence in SME&T fields were discouraged (or screened out) from pursuing further studies. SME&T majors found their introductory courses very challenging and often described them as "weed-out" courses.

All types of students objected to the large lecture format often used in these courses. Students from two-year colleges, Historically Black colleges, and comprehensive masters institutions were not as negative about these courses as those from research and doctoral universities, which have the largest classes. Even the recent graduates had no difficulty recalling the generally unpleasant experiences they had in introductory courses. In particular, students singled-out the practice in some large lecture classes of using television monitors in separate rooms to serve students who could not fit into the lecture hall as being very discouraging. The perception of many students was that the faculty did not want to teach these courses. In addition, a significant number of students objected to the competitive atmosphere in introductory SME&T courses, calling it a barrier to learning. Students also found considerable fault with introductory lab courses and sections. Some found them to be mechanical exercises that were seemingly unconnected to concepts of science. Lack of faculty or teaching assistant expertise on site in the labs was cited as another weakness.

<u>8. Declining Baccalaureate Degrees in SME&T Disciplines</u>. Starting pay for graduates in engineering, the computer sciences, the mathematical sciences, economics, and the physical and environmental sciences has remained higher than in the social and behavioral sciences, the biological sciences, and most other non-SME&T fields. (The exceptions are accounting, finance, and a few other fields.) Yet, students have tended increasingly to major and earn bachelor's degrees in these lower-paying fields. The higher-paying SME&T fields jointly accounted for 19 percent of all bachelors in 1985, but bachelor's degrees awarded in this group fell by nearly 20 percent during 1985-1993, while total bachelor's awarded in *all* fields rose by almost 20 percent (reducing the proportion of bachelor's in the high-paying fields to 13 percent during 1993 - 95).

In the more frequently used subtotal of NS&E, degree awards have declined from 215,000 in 1986 (21 percent of total bachelor's) to 175,000 in 1991 (15 percent of total bachelor's), recovering thereafter to 201,000 in 1995 (16.5 percent of total bachelor's) due to growing interest in the life sciences. Changing student interest in the life sciences accounted for only about 5 percent of the decline in NS&E bachelor's awards during 1986-91, but more than 90 percent of the rise in these awards during 1991-95. Associate of Arts degrees in these same disciplines exhibited the same pattern to a more limited extent. These trends are shown in the following charts.

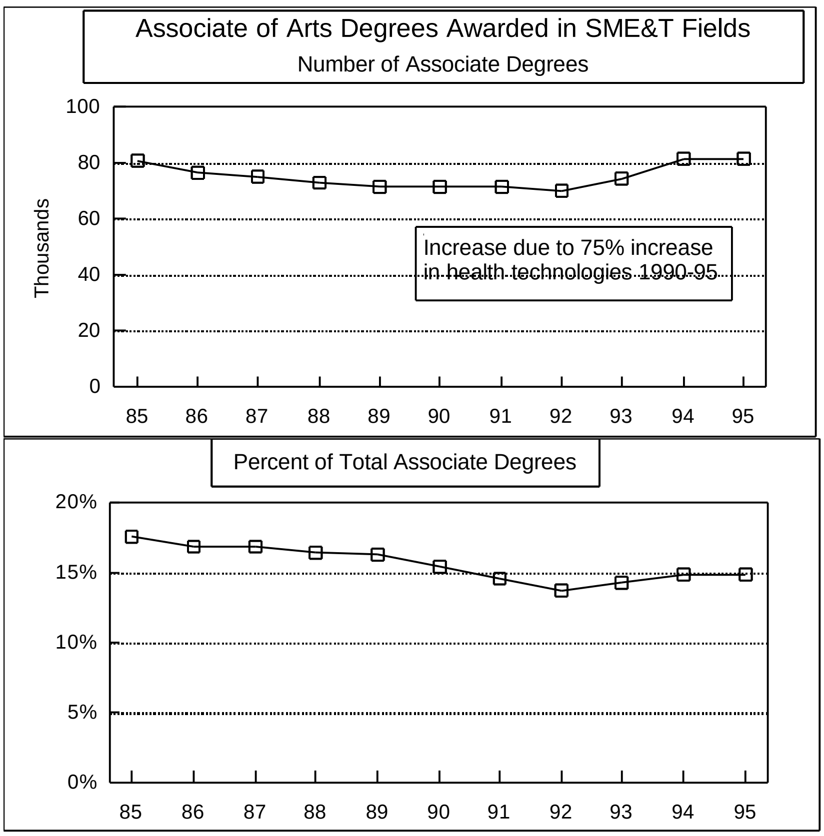




Source: U.S. Department of Education, National Center for Education Statistics, IPEDS (Integrated Postsecondary Education Data System) and HEGIS (Higher Education General Information Surveys) surveys of U.S. postsecondary institutions.

One concern that derives from these trends is that there may be similar declines at other levels of learning in the SME&T disciplines, such as a reduced number of minors elected in NS&E, or reduced percentages of students taking introductory courses in these fields. Unfortunately, national time series data to track these concerns are not available.

There are a variety of hypotheses for the decline in "popularity" of SME&T majors. One is the poor preparation of many high school graduates to succeed in NS&E courses. Although this is still a sizable problem, it is important to observe that, by all national quantitative measures, it has diminished during 1985-95.



<u>Source</u>: U.S. Department of Education, National Center for Education Statistics, IPEDS (Integrated Postsecondary Education Data System) and HEGIS (Higher Education General Information Surveys) surveys of U.S. postsecondary institutions.

It is possible that the growing number of older and part-time students include many whose mathematics skills and basic science preparation have become rusty from disuse, precluding the choice of an NS&E major. For example, data from the High School and Beyond panel surveys indicate that, from the perspective of 1993, nearly all of the baccalaureates in NS&E earned by students who were high school sophomores or seniors in 1980 were earned within six years by students who persisted with, at most, relatively short periods of absence from their studies.

<u>B. Important Changes in the Social, Political, and Technical Environment for Higher Education</u>

<u>1. Pressures on Public Institutions to Reexamine Their Priorities.</u> The Pew Higher Education Roundtable ("To Dance with Change," *Policy Perspectives*, Vol. 5, No. 3, Section A, April, 1994)

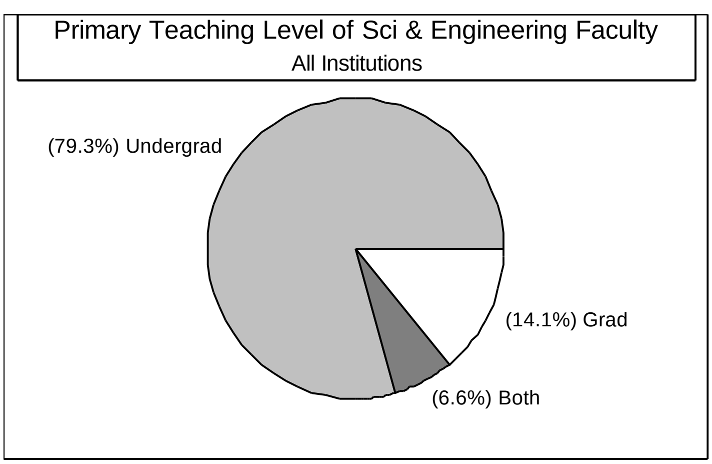
found that:

> *There is less inclination to trust government to establish public services or define public priorities. It is part and parcel of the general inclination to resist new taxes from the conviction that individual consumers make better and more appropriate choices than any government can* (page 5A); … *There is real anger at higher education ... from the makers and shapers of public policy — governors, legislators, regulators, heads of public agencies, and surprisingly, an increasing number from the world of private philanthropy. ... Many ... believe that colleges and universities have become too isolated from the economic pressures that are forcing most other American enterprises to rethink purpose and mission ...* (page 6A).

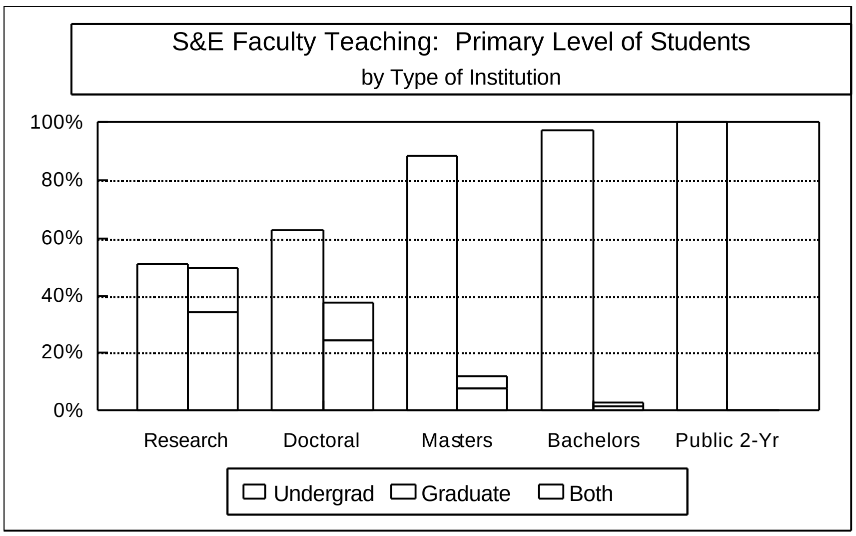
The Pew Roundtable traces this anger to two concerns, both of which are central to this Review. The first is the growing unease in recognizing that higher education has far to go before it fulfills the promises that have often been the implicit basis of its funding, namely the creation of a skilled citizenry, buttressed by the improved access of underrepresented minorities, leading the way to economic development for states and regions. The Roundtable claims that there is a growing sense that too many institutions frequently confer academic degrees on students who have not demonstrated sufficient skills to be effective workers or informed citizens. The best graduates are often seen as “exhibiting a self-centered aggressiveness rendering them incapable of working with others.” [Page 6A] This situation is seen as the consequence of excessive academic competition for the best students and competition within classes.

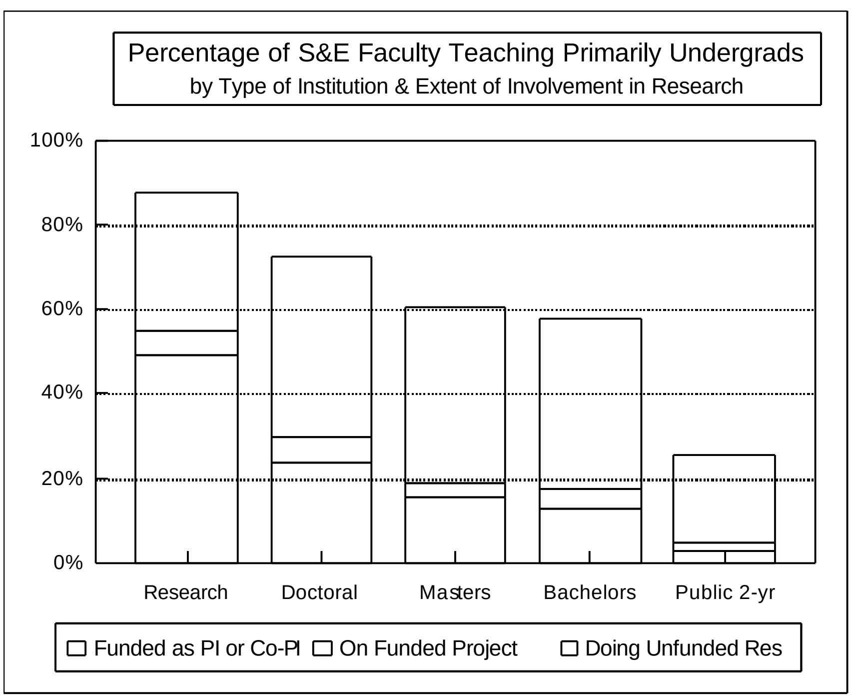
<u>2. Status of Faculty Teaching and Advising.</u> The Pew Roundtable (in the same 1994 publication) also reported a public perception that academic institutions “have become havens for a privileged class.” [Page 6A] Some states are actively pursuing (and others are considering) legislatively mandated requirements to increase faculty teaching. Statements, from state officials, that the principal job of the faculty is to teach students are increasingly common in the news media. Now, let us examine the faculty perspective.

Data on faculty teaching and research activities, taken from the *1993 National Survey of Postsecondary Faculty* (NSOPF-93; US Department of Education, National Center for Education Statistics), indicate that most faculty must teach. Nearly 80 percent of these taught primarily undergraduates in 1992, with another 6 percent teaching both undergraduates and graduate students. Even in Research Universities, 50 percent of the teaching faculty taught primarily undergraduates, with another 16 percent teaching at both the undergraduate and graduate level.

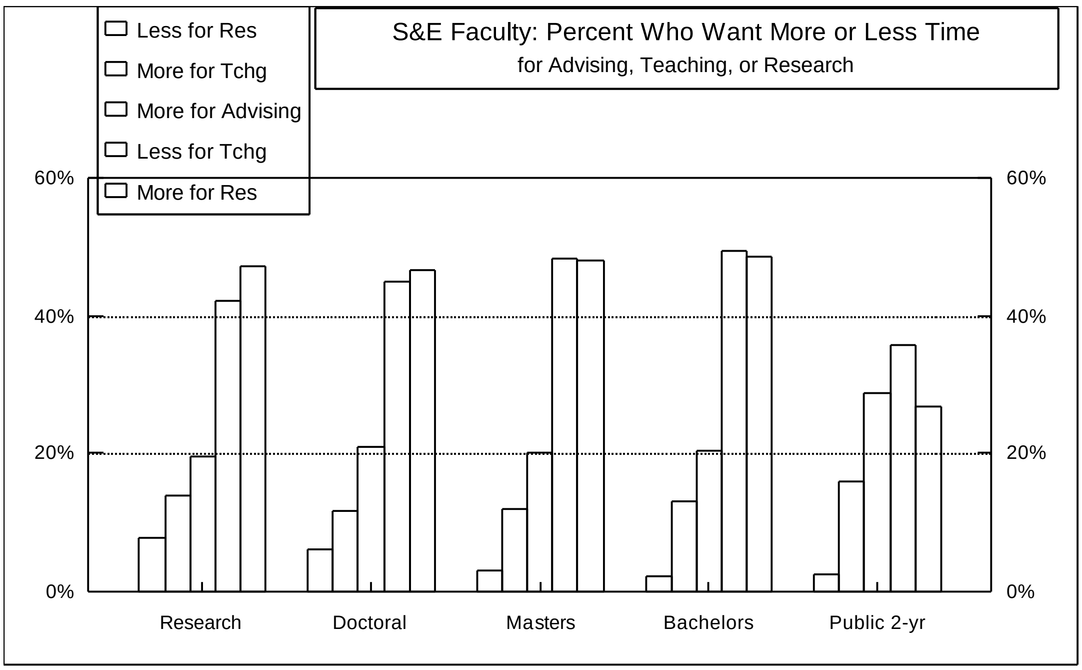


Not surprisingly, the fraction of faculty teaching primarily undergraduates rises as the research intensity of the institution drops. [See the following two charts.] A less obvious fact is that sizable proportions of the faculty who teach primarily undergraduates are also engaged in research. More than 50 percent of the "undergraduate" faculty in Research universities (and nearly 30 percent of the undergraduate faculty in Doctoral universities) are principal or co-principal investigators or included on externally funded research projects. These data suggest that student perceptions that faculty attention may often be focused on their research may be on target, but they also indicate the high potential for allowing students to observe or participate in faculty research.





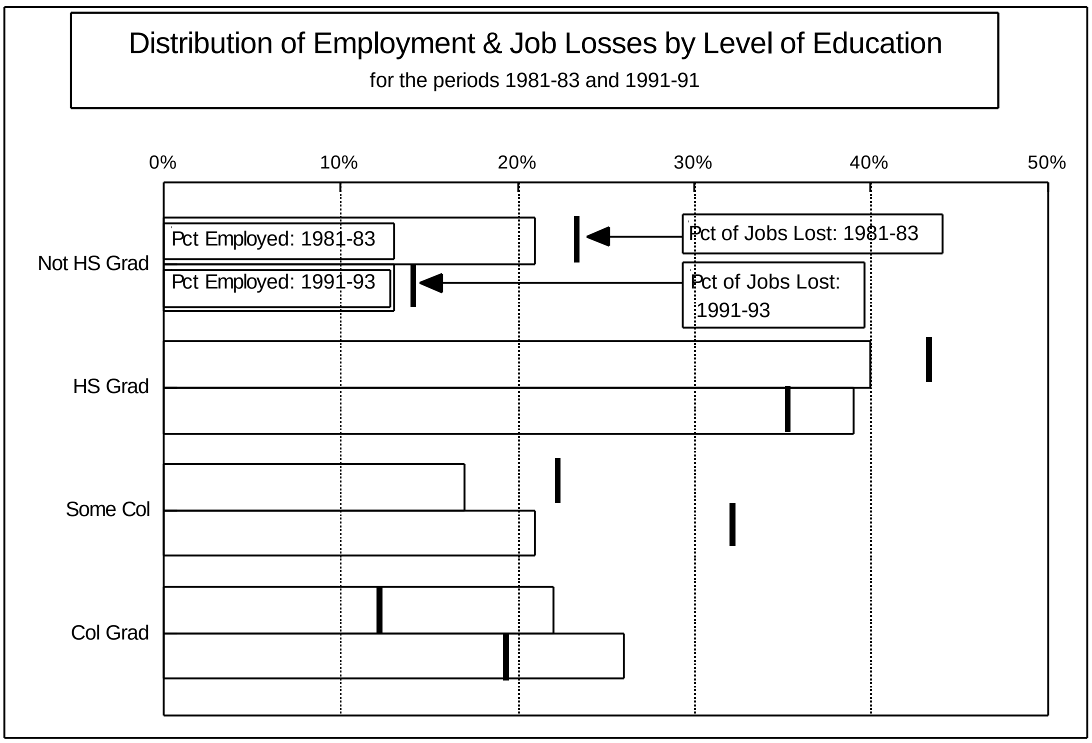
What were the faculty preferences for altering the distribution of their 1992 work efforts in teaching, student advising, and research? This is, in a sense, the faculty side of Seymour and Hewitt's profile of SME&T education. In every type of four-year institution, much greater percentages of faculty want to devote *less* time to teaching (40 to 50 percent) and *more* time to research (again, 40 to 50 percent) than would prefer spending more time engaged in teaching activities (10 to 15 percent) or less time doing research (8 percent or less). Despite widespread dissatisfaction of students with the quality of faculty advising, only 20 to 25 percent of the undergraduate faculty said they were somewhat or very dissatisfied with the (little) time available for student advising. The reasons faculty expressed these preferences are not available. One may speculate whether the reasons include a dislike for teaching by those who are not very good at it, ignorance of students' preferences due to inadequate contact between students and faculty, or a reward system that frequently favors successful research over successful teaching.



3. <u>Public Attitudes About Public Subsidies.</u> Among the sources of revenue for undergraduate education, public (chiefly state-level) sources have collectively been the most important. However, the share of total cost derived from this sector may be in long-term decline. According to the Pew Higher Education Roundtable (1994), a major force reshaping American higher education is the increased substitution of market revenues for public funds:

> *Having heard the message that a college degree translates into the higher earnings that come with a good job, the conclusion being drawn is that a college education in fact contributes more to individual advancement than to the nation's social fabric. The result is that students at public institutions everywhere are being asked to pay for an ever greater share of the costs of their higher education* (page 4A); ... *There are new adherents to the proposition that appropriations for public higher education, particularly at flagship institutions, amount to a public tax for the benefit of the economically advantaged, whose children neither need nor deserve such subsidy for their college education.* (page 5A)

Turning to data on the sources of employment growth and the effect of education on unemployment, there is ample evidence that college does confer important advantages on job holders and seekers. In the early 1980s, the following chart (based on employment data published on the Web Page of the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor) indicates that job losses were occurring disproportionately among those who were not college graduates (in each of three separate categories). By the early 1990s, employment of workers with less than high school diplomas had shrunk from 21 to 13 percent of the total, and employment of those with some college and a college degree each rose by 4 percentage points of the total. The growth in the pool of workers with "some college" and with college degrees was evidently large enough that job losses in the early 1990s were disproportionately higher among workers with *some* college than among those with less than a high school education. Workers with college degrees were still experiencing the lowest frequency of job losses.

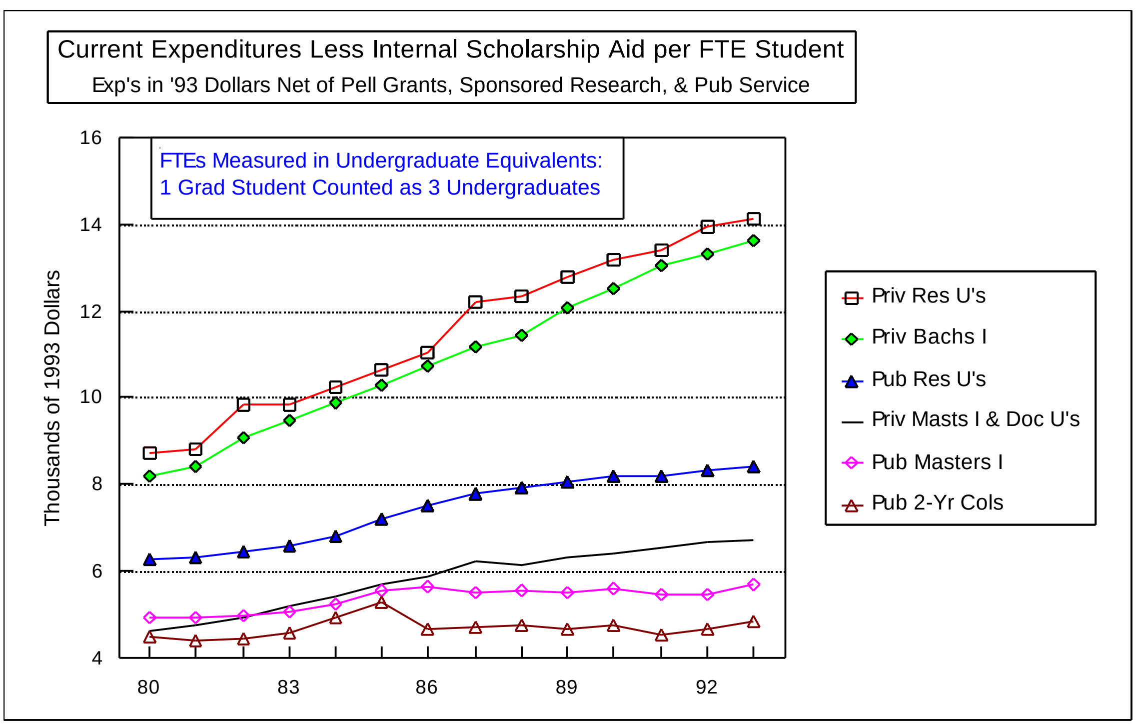


Source: U.S. Department of Labor, Bureau of Labor Statistics data reported in the *New York Times* on March 3, 1996, page 27.

4. Rising Per-Student Costs in Higher Education. Undergraduate education is part of the academic enterprise which spans graduate and professional education, research, and service to the community. Expenditures by this combined academic enterprise have grown rapidly for decades, funded by revenues from a variety of sources. Even though precise estimates of expenditures by type of activity (e.g., undergraduate education) are lacking because key resources (e.g., faculty) are shared by multiple activities, we can still infer valuable information from examining expenditures data. Because academic institutions are nonprofit organizations, trends in expenditures approximate trends in resource costs.

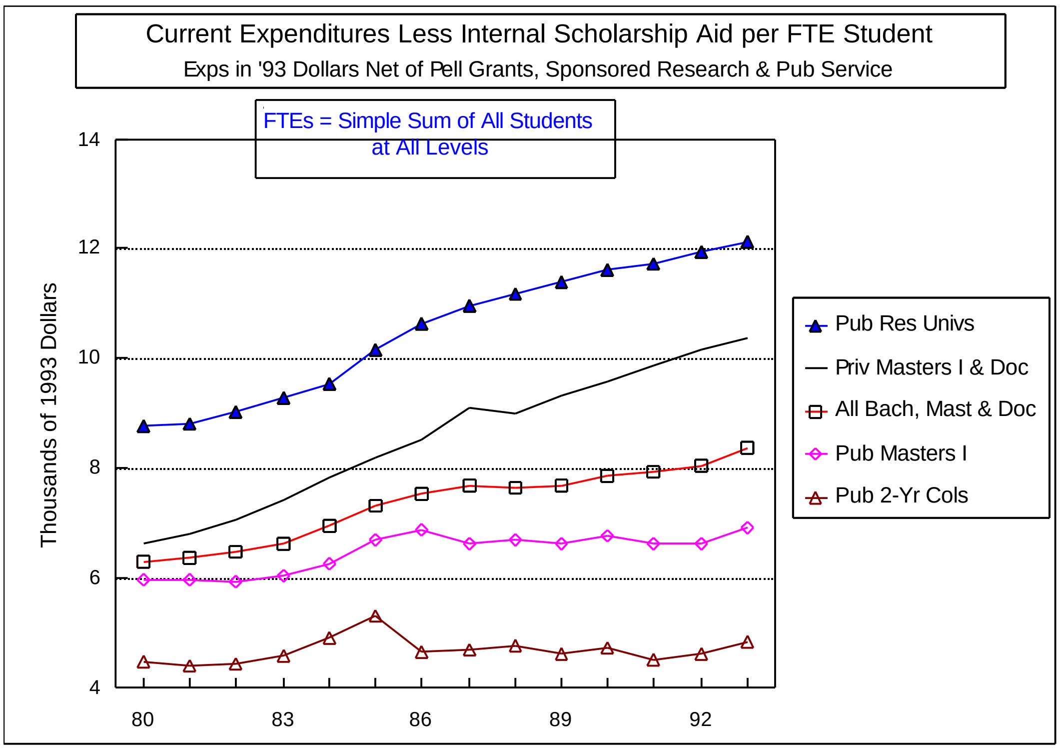
The unit costs of undergraduate education have been rising, at least since 1980, although it is hard to measure these costs with precision. An explanation is offered in the following text box. National estimates depend on financial data from the HEGIS and IPEDS surveys conducted by the U.S. Department of Education, National Center for Education Statistics. (Extensive documentation is available at http://www.ws.gov.edu/NCES/...) The following chart indicates that the unit costs of education rose during 1980-85 in each type of institution represented, but that thereafter they leveled off in public two-year colleges and public Masters I institutions. (This chart does not cover all types of institutions, but the included types cover the entire range of unit costs.) The high level of expenditure in the highly selective private Research I and Bachelors I — formerly known as Liberal Arts I — institutions is due in large measure to higher resource levels per student. These greater resources include substantially larger expenditures on "student services."

How do you measure the unit cost of undergraduate education? Estimates of the "educational and general expenditures" per undergraduate student full-time equivalent require some understanding of differences in education costs by level, because these expenditures are reported for undergraduate, graduate, and professional students combined. If all post-secondary education students are counted equally and total instructional costs are divided by the sum of all FTE students, the resulting calculated unit cost would overstate the *level* of expenditure per undergraduate in Research and Doctoral institutions and also the *increase* in this unit cost (because graduate and professional enrollments have been rising more rapidly than undergraduate enrollments). We do not know the exact nationwide "weights" to give graduate and professional students compared to undergraduates. However, specialized studies of individual institutions and programs have shown that graduate or professional students require at least twice (and often much more) the value of resources used to instruct undergraduates. In the fourth chart, unit undergraduate costs have been estimated, counting graduate and professional students as three times as costly to educate as undergraduates. This ratio was selected because it is representative of cost studies and brings the unit costs in private research universities into close proximity with unit costs in Bachelor's I institutions (formerly called selective Liberal Arts Institutions).



Also note that the rate of increase in unit costs in public Research and private Doctoral and Masters I universities slowed appreciably after 1986. Also a factor in explaining the higher level of unit costs in these two groups and in public Research universities ("flagship public institutions") is the much higher average compensation of their faculty. In fact, growing faculty compensation during the 1980s is the most important cause of growth in resources expenditures per student in academic institutions during that period. For example, according to Getz & Siegfried (1991, page 300), the rapidly rising prices of instructional inputs accounted for about 75 percent of the 2.7 percent per year increase in academic "education and general" expenditures per student *over and above* the general rate of price increase of GNP during the 1980s.

The values in the previous chart should be compared to those in the chart below to illustrate the point that the rise in costs per student (unadjusted for the mix of student types) was partly a consequence of growing proportions of graduate students in research and doctoral institutions. In particular, the large and growing difference in unit student costs by type of institution is partly a result of the growing proportions of graduate students.



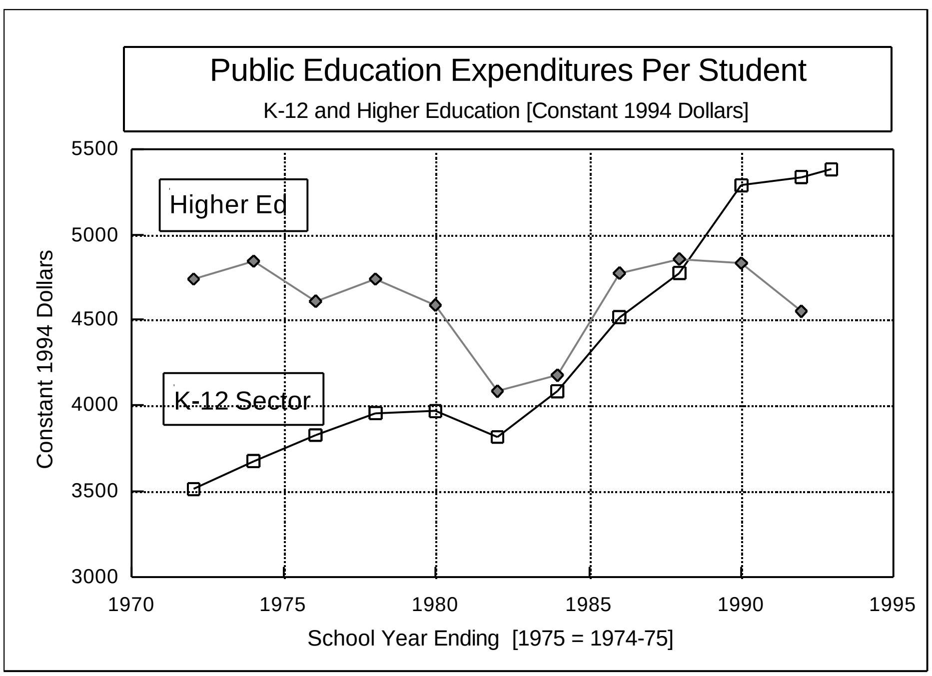
These estimated costs per student, unadjusted for the mix of undergraduate and graduate students, indicate a widening of unit costs in different types of institutions that took place during the 1980s and the early 1990s.

<u>5. Impact of Growing Differences in Per-Student Costs.</u> The cessation of growth in externally sponsored support, in combination with reduced or tightening state budgetary support (which is discussed in the next section) has likely had some impact on lower-division courses in NS&E within universities with externally supported research faculty and doctoral students. The replacement of retiring faculty has not been complete during the 1990s. Faculty retirements are often being used as a source of academic downsizing, which puts increasing pressure on existing

faculty to raise external grant funds and teach more students. These reductions in faculty resources for instruction have created pressures within undergraduate courses — larger classes, less variety, more incentive for hiring inexpensive teaching assistants or part-time adjunct faculty. Average class size rose throughout the 1980s (Getz & Siegfried, 1991, page 391). These developments may have reduced the opportunity to try innovative approaches to offering courses and curricula in these institutions at the same time that it has increased the need for productivity enhancing improvements.

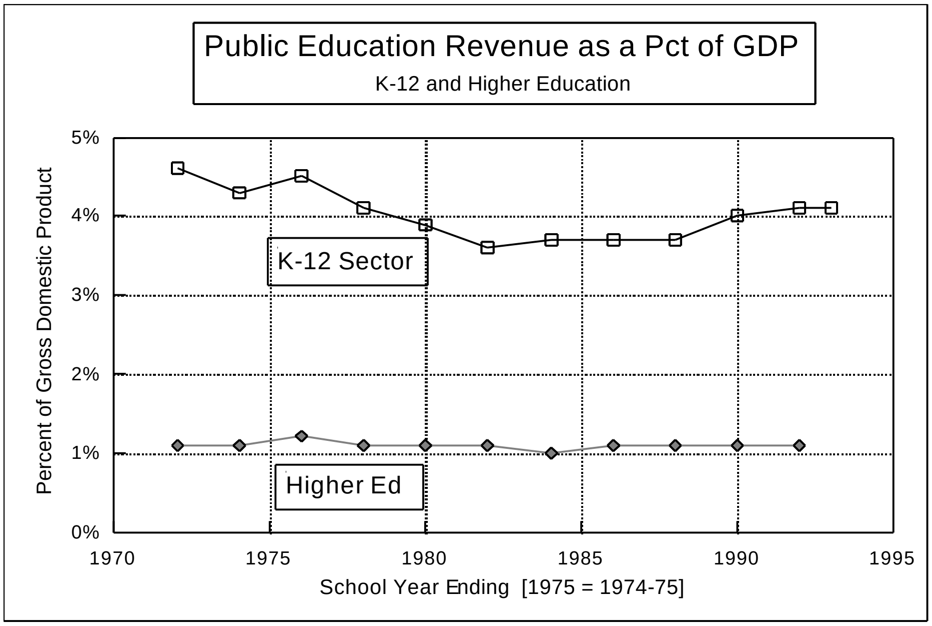
However, it is also important to realize that these data indicate a wide difference in institutional capacity to finance faculty release time. Such release time is valuable because it allows older faculty to engage in teaching enhancement workshops and seminars and to retool their teaching skills by studying the growing body of material and approaches to successful undergraduate education (and adapting those that best fit their needs). For national programs focused on improving the quality of undergraduate education, such as those found in NSF's Directorate for Education and Human Resources or in the Department of Education's Fund for the Improvement of Postsecondary Education (FIPSE), the challenge and need are to ensure that all types of institutions participate in these programs.

<u>6. Pressures on Sources of Revenues.</u> Public expenditures per pupil in grades K-12 began to rise shortly after the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1983). This increase is likely to have resulted from a growing awareness generated by this and other studies of the need for substantial improvements in quality — a conscious parallelism of action by many groups. The following chart indicates that the cumulative rise during 1983-1993 was large.

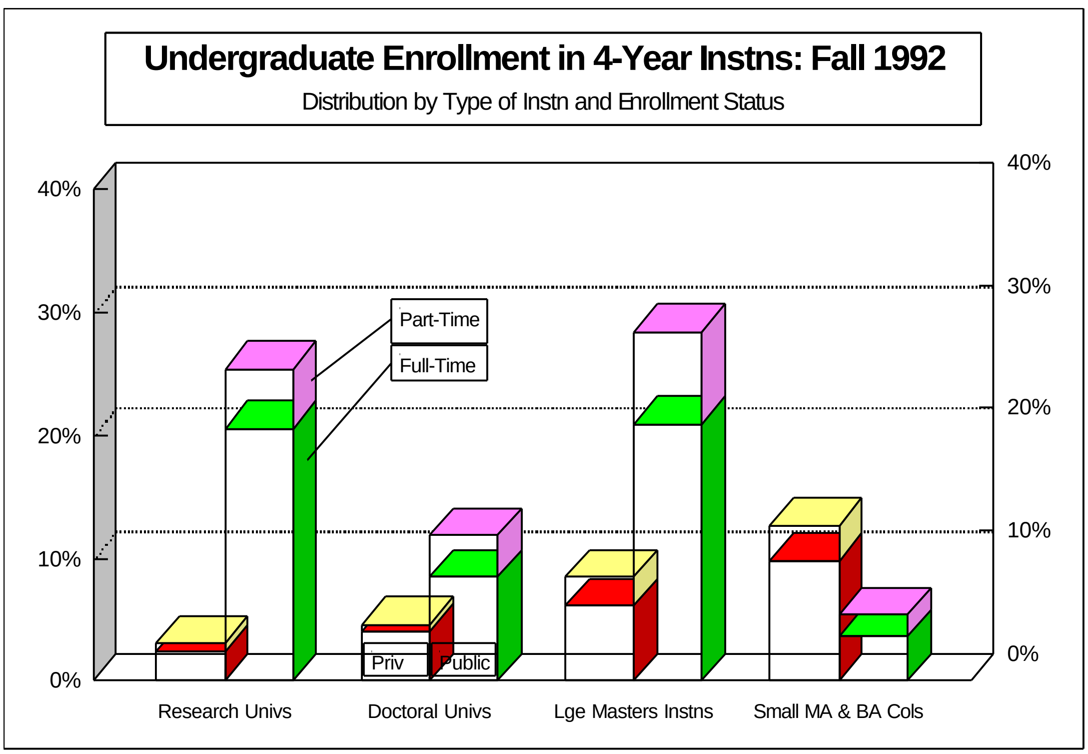


Source: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 1994*, NCES 94-149 pp. 148, 149, 325 - 328.

There has been a growing fiscal reliance on state governments to fund public education in grades K-12 during 1970-1990, as real expenditures per pupil were rising. This has constrained state-level funds for higher education. States provided 40 percent of public revenues for K-12 in 1970, 47 percent in 1980, and nearly 50 percent in the second half of the 1980s. During this period, public expenditure per student in the higher education sector did not grow in real dollars, although it has remained a constant 1 percent of Gross Domestic Product (GDP). (See the following chart.)



Source: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 1994*, NCES 94-149 pp. 148, 149, 325-328.

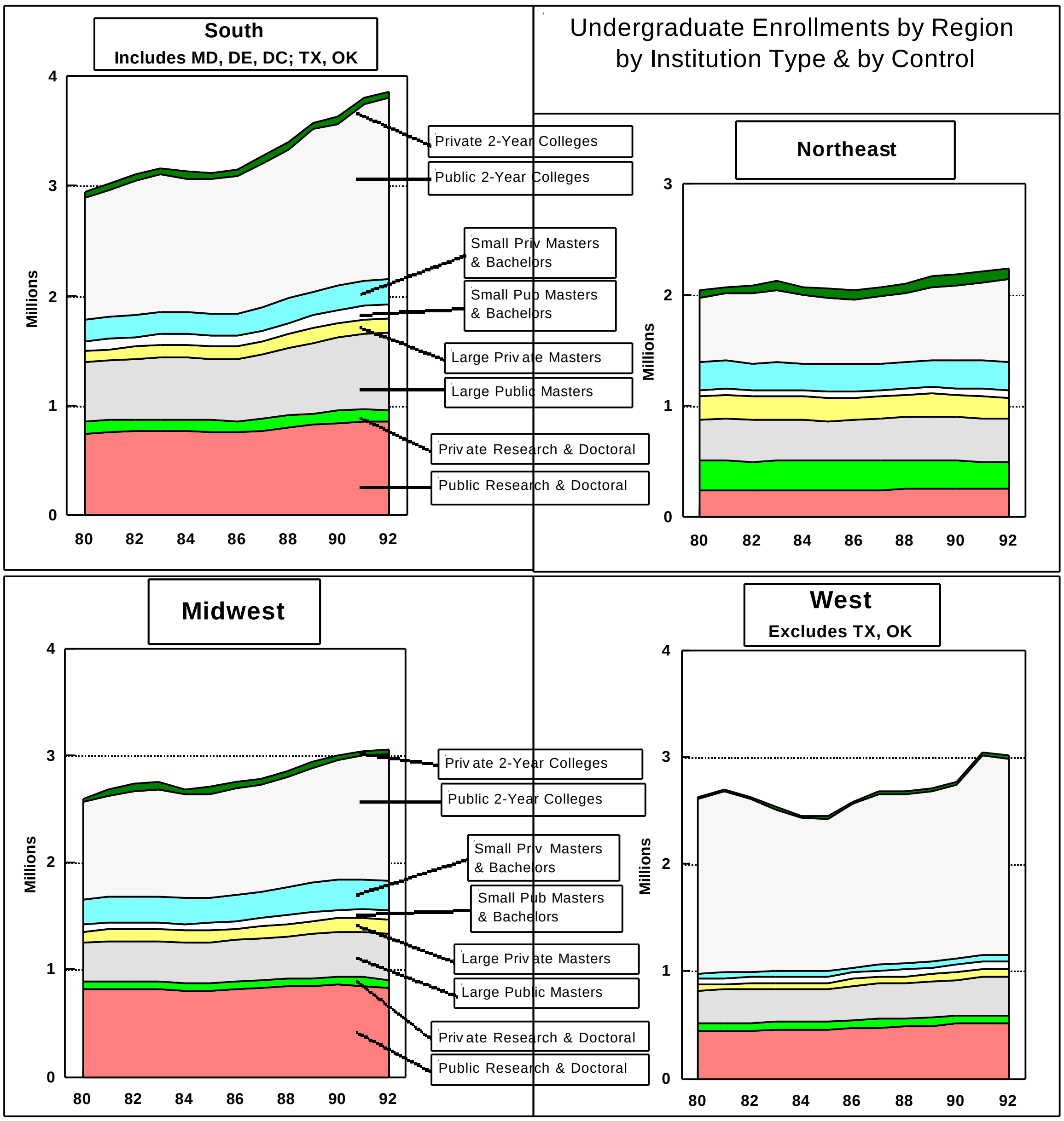


Source: U.S. Department of Education, National Center for Education Statistics, *Enrollment in Higher Education:*

Fall 1994, NCES 96-440 and detailed data runs using the NSF CASPAR data system. Enrollment data are collected as part of the IPEDS and HEGIS surveys.

And, as was discussed in Sections 4 and 5 above, graduate student enrollment in Research and Doctoral universities was increasing more rapidly than total undergraduate enrollment during this period, so public funds available for undergraduate students were declining in real dollars.

Public expenditure per undergraduate and graduate student dropped briefly during the 1978-1983 period as the rate of growth in undergraduate enrollments finally dropped after several decades of high levels. As it increased once again, it coincided with (and helped to cause) an increase in the inflation-adjusted compensation of the faculty, noted above in section 4, which experienced a cumulative growth of about 25 percent during 1980-1992.



7a. Distribution of Undergraduates and SME&T Courses. In this section, we examine the distribution of undergraduate students and SME&T courses and the headcount of undergraduates enrolled in those SME&T courses. Undergraduates are found in a large variety of institutions. Within four-year institutions in 1992, about 37 percent were enrolled in Large Masters Institutions (more than 2,000 undergraduates), compared to 29 percent in Research universities, 18 percent in small Masters and Bachelors colleges, and 16 percent in Doctoral universities. This distribution does not include other four-year institutions, such as Religious colleges, Business schools, and Art institutes, which were excluded from the chart because they do not have science and engineering degree programs.

Two-year institutions accounted for 46 percent of all undergraduates, counting part-time and full-time students equally, and the excluded four-year institutions would add about another 5 percent to the 4-year total. As the set of four regional enrollment charts indicates, community colleges are even more important as educators of high school graduates in the West and South. Large public Masters institutions are well-represented in all four regions, but most prominently in the Northeast. Large private Masters enroll considerably more students in the Northeast than in any other region. And, in general, all types of private institutions are proportionately most prominent in the Northeast and least prominent in the West. Finally, public Research and Doctoral universities enroll more undergraduates in the Midwest and the South.

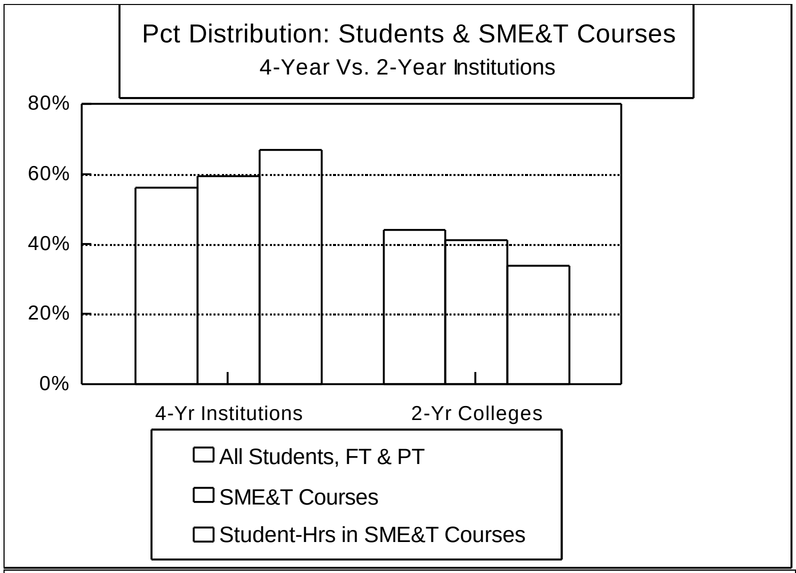
[These data were obtained from the NSF CASPAR data system, now available to the general public from a web site supported by the NSF: http://caspar.qrc.com. This system obtains its data from the U.S. Department of Education surveys known as HEGIS (or Higher Education General Information Surveys) and its successor IPEDS (Integrated Postsecondary Education Data System). Special tabulations were made because the standard tabulations available in *Enrollment in Higher Education: Fall 1994*, NCES 96-440 do not use the same institutional categories.]

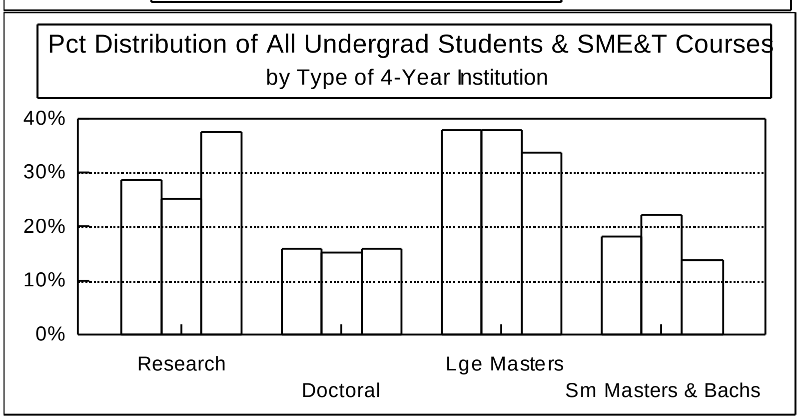
Compared to two-year institutions, four-year institutions have a larger share of SME&T courses than total undergraduates. [The information about SME&T courses was derived from data collected through the *1993 National Survey of Postsecondary Faculty*, NSOPF-93; US Department of Education, National Center for Education Statistics.] (See the charts on the following page.) But within four-year institutions, the distribution of SME&T courses is moderately less concentrated in Research and Doctoral universities than the distribution of undergraduate enrollment. Compared to these distributions of SME&T courses by type of institution, the distribution of students enrolled in SME&T courses is moderately more concentrated in four-year institutions than in two-year colleges, and — within 4-year institution groups — more concentrated in Research universities than in Masters and Bachelors institutions.

Overall, about 500,000 SME&T courses were taught for credit and about 17,000,000 students were enrolled in these courses. (Many students were enrolled in two or more courses.) On average, the enrollment in SME&T courses averaged 1.3 courses per undergraduate student.

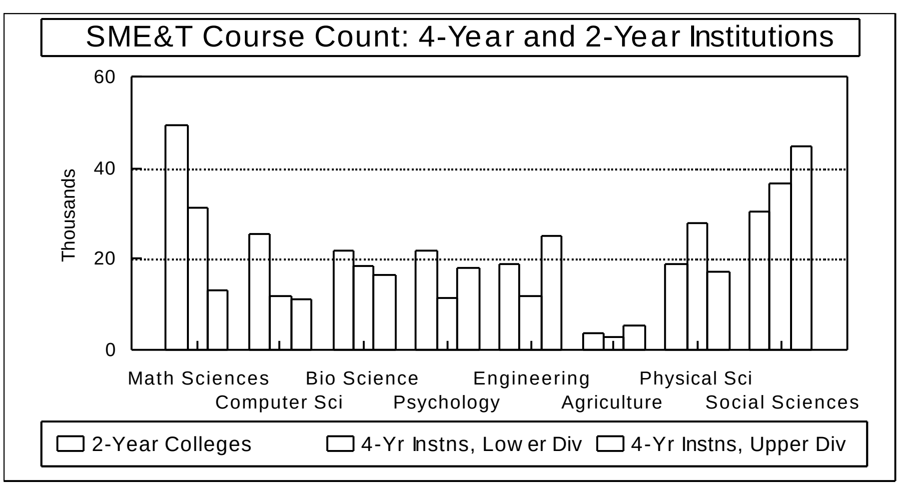
In a number of disciplines at the lower-division level (freshman and sophomore level), more courses were taught in two-year colleges than in four-year institutions. In descending order, these disciplines were the mathematical sciences, computer and information sciences, engineering (including engineering technologies), psychology, agriculture, and the biological sciences. In mathematics, computer science, and psychology, there were also a larger number of enrolled students in two-year colleges compared to lower-division students in four-year institutions.

In the aggregate, including all disciplines and institutions, there were more than twice as many lower-division courses as upper-division courses, and almost three times the number of students

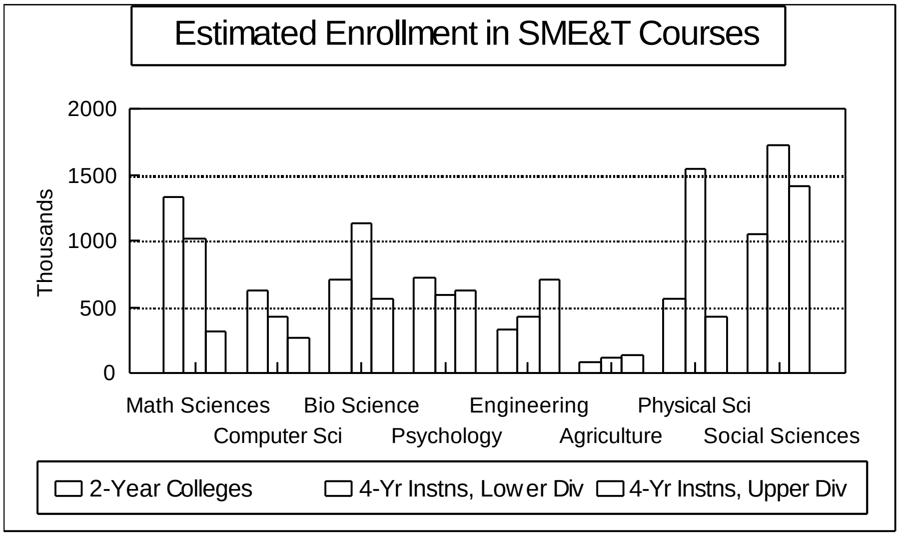




enrolled for credit in the lower-division courses. Mathematics is the discipline most oriented towards lower-division courses and students, followed by the physical sciences and the biological

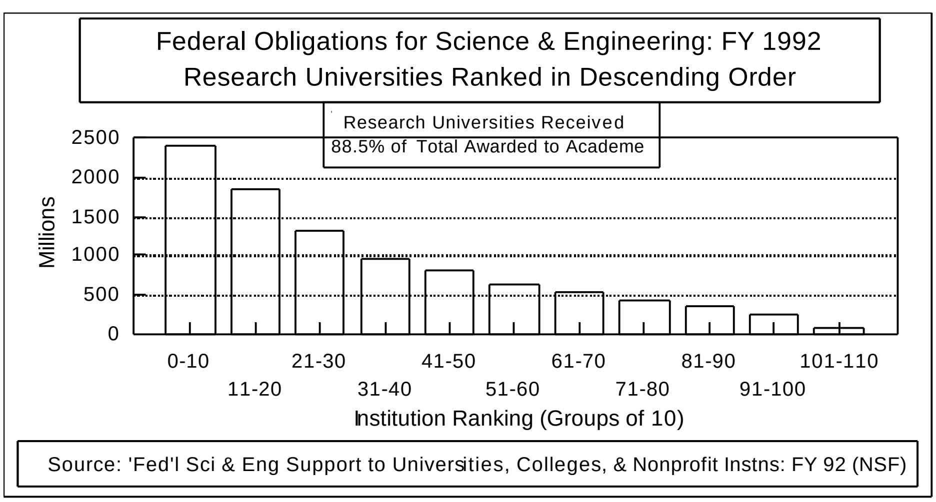


sciences. Engineering is the most oriented towards upper-division courses. This pattern of enrollment indicates the importance and strategic value of ensuring that students in lower-division courses are served with effective course designs and good teaching practices and ensuring that two-year colleges are included whenever possible in efforts to improve student learning in SME&T.



Finally, we turn to the distribution of Federal funds for Science and Engineering (S&E) in academic institutions, a category of Federal support that includes research and development (the largest category), equipment and facilities for S&E (the second largest), and education and training in S&E (the smallest). The Federal Government (which includes NSF) is by far the largest external sponsor of academic S&E.

<u>7b. Distribution of Federal Obligations for Science and Engineering</u>. Federal funds are highly concentrated in a number of ways. First, within each institutional category, research funds are highly concentrated. Second, funds are also highly concentrated across classes of institutions. The following chart shows the distribution of S&E funds among all 125 Research universities. (The



distribution in other classes of institutions was similar.) Research universities received 88.5 percent of total Federal obligations for science and engineering in FY 1992 and are clearly in a class of their own. In contrast, all 111 Doctoral universities received only 6.2 percent of total Federal S&E obligations. The top 10 Doctoral universities received slightly less than the ten Research universities ranked 91-100. Other categories receiving significant funds include the top 200 Masters I institutions (with 4.2 percent of the total), the top 100 Bachelors colleges (with 0.7 percent of the total), and the top 50 two-year colleges (with 0.2 percent). Funding is also very highly concentrated within the Doctoral and Masters subgroups: the top 12 Doctorals and 25 Masters received more than 50 percent of the funds in their subgroups.

The following table shows a ranking of these 575 institutions. They are shown in groups of 50 (except for the third group of 25 of Research universities) in descending order based on Federal S&E funding received in 1992. The table demonstrates the highly concentrated nature of these

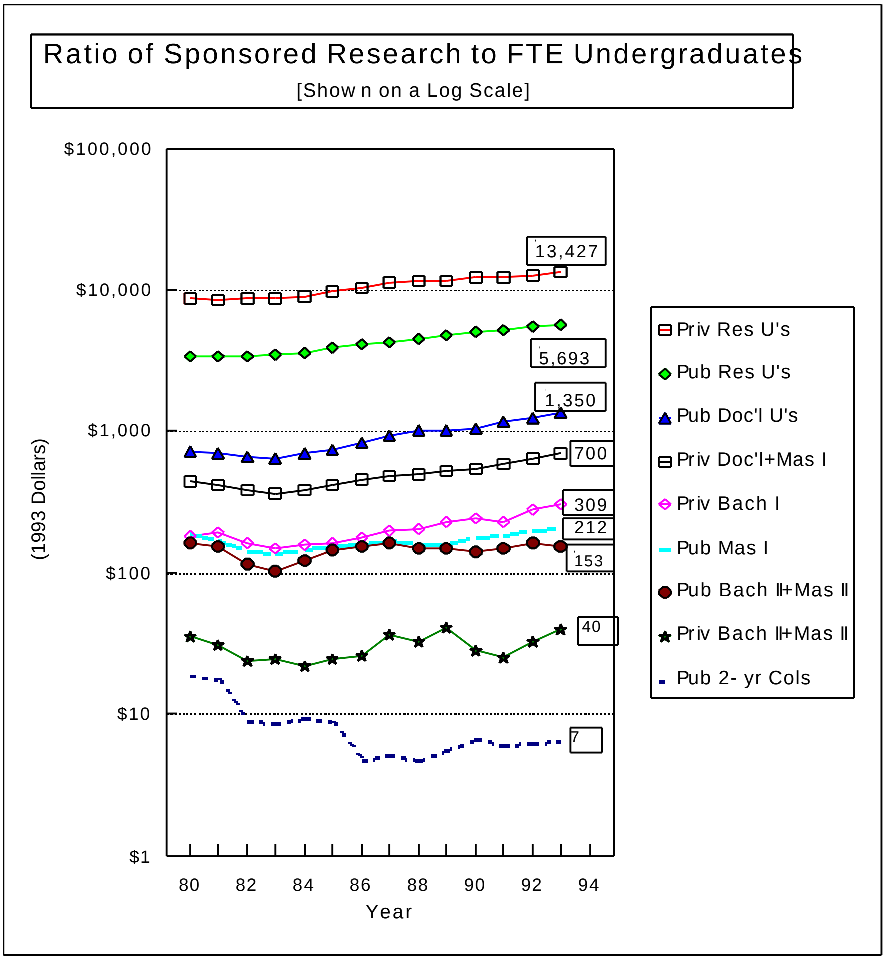
Distribution of Federal Funds for Science & Engineering in FY 1992

Categories of Institutions in Descending Order:	Federal S&E *Per Institution*	FTE Undergrads *Per Institution*
Research Univs Ranked 1-50	147,835,000	15,620
Research Univs Ranked 51-100	46,148,000	14,028
Research Univs Ranked 101-125	15,867,000	12,754
Doctoral Univs Ranked 1- 50	11,784,000	8,330
Masters Instns Ranked 1- 50	7,126,000	6,230
Doctoral Univs Ranked 51- 100	2,131,000	7,606
Masters Instns Ranked 51- 100	1,540,000	7,867
Bachelors Cols Ranked 1- 50	1,160,000	2,186
Masters Instns Ranked 101- 150	645,000	5,318
Masters Instns Ranked 151- 200	355,000	5,010
Bachelors Cols Ranked 51- 100	339,000	1,929

Source: *Federal Science & Engineering Support to Universities, Colleges, and Nonprofit Institutions: FY 1992* (NSF, Division of Science Resources Studies), and U.S. Department of Education, NCES, the IPEDS/ HEGIS surveys of students enrolled. FTE (=full-time equivalent) enrollment was calculated as full-time + 40% of part-time enrollment.

funds. The average enrollment level is provided to give a sense of difference in average size among these groups of institutions. The next chart provides additional perspective, illustrating institutional differences in the ratio of Federal S&E funds per FTE undergraduate, and how these have changed (primarily risen) since 1980.

Within NSF, the distribution of S&E funds is less concentrated than overall Federal funds, partly because of the broad base of institutions participating in the programs of its Directorate for Education and Human Resources (EHR). The awards made by EHR have both expanded the number of institutions receiving NSF funds (from 578 to 828 in FY 1994) and reduced the concentration of funds in the hands of the top 20, 50, 100 (etc.) institutions. It is still the case that institutions receiving the most funds from NSF *research* programs also tend to receive the largest amounts of *education* funds. As the next table indicates, it is also the case that about one-half of all undergraduates were enrolled in institutions that received no NSF funds in FY 1992.



Source: These data were calculated from data obtained from the U.S. Department of Education, National Center for Education Statistics surveys: HEGIS (Higher Education General Information Surveys) and the replacement IPEDS (Integrated Postsecondary Education Data System). Extensive documentation is available at http://www.ws.gov.edu /NCES/. FTE (=full-time equivalent) enrollment was calculated as full-time + 40% of part-time enrollment.

Distribution of Undergraduate Students in 4- and 2-year Institutions by Level of NSF Funding in FY 1992 (Each Row Sums to 100%)

NSF funds = f:	f=$0	f<$100K	$99<f<$250K	$249<f<$500K	f>$499K
1. Undergraduates Counted on an FTE Basis.					
4-Yr Institutions	23%	14%	9%	7%	47%
2-Yr Colleges	87%	10%	2.3%	0.3%	0.3%
All Institutions	49%	13%	6%	4%	28%
2. Full-Time & Part-Time Undergraduates Counted Equally.					
4-Yr Institutions	24%	14%	9%	7%	46%
2-Yr Colleges	87%	10%	2.3%	0.3%	0.3%
All Institutions	53%	12%	6%	4%	25%

Source: NSF funding for all science and engineering was taken from *Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions: FY 1992* (NSF, Division of Science Resources Studies). Enrollment data were taken from the IPEDS/ HEGIS surveys of the U.S. Department of Education, NCES.

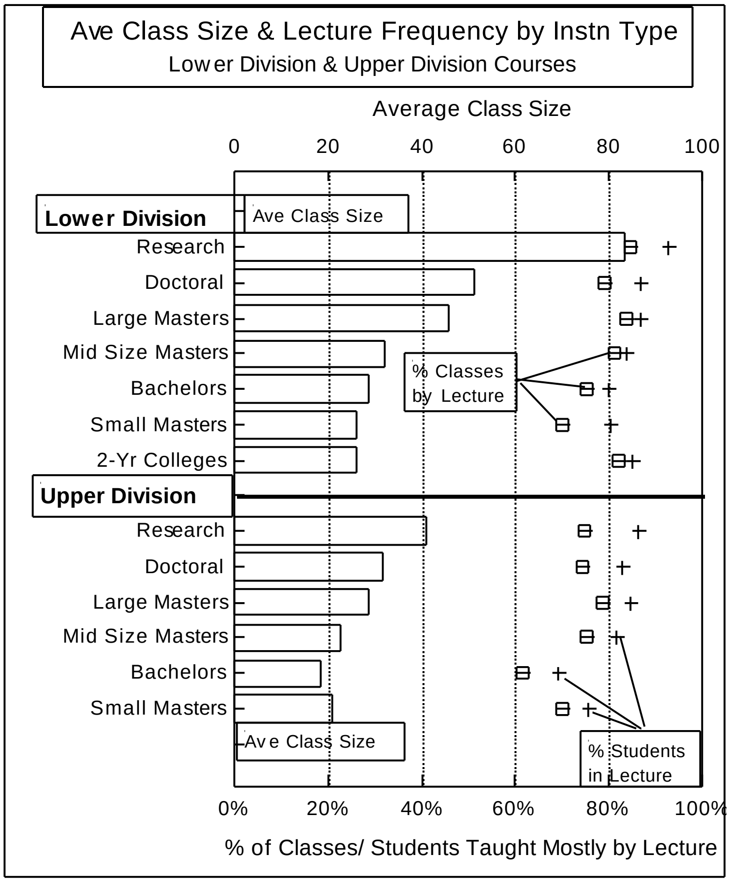
These patterns suggest that we will often find faculty in research intensive institutions developing innovative approaches to teaching and learning in a variety of SME&T disciplines, but that NSF has also helped increase the pace of innovation in undergraduate education by making education awards to a larger base of institutions. In order to maximize the impact of NSF funding, it is important to ensure that promising innovations used initially only by their developers are made accessible to other faculty in other institutions. Making NSF program funds accessible to faculty (in institutions where there is little current award activity) in order to adopt and adapt innovations developed elsewhere is one direct way to accomplish this.

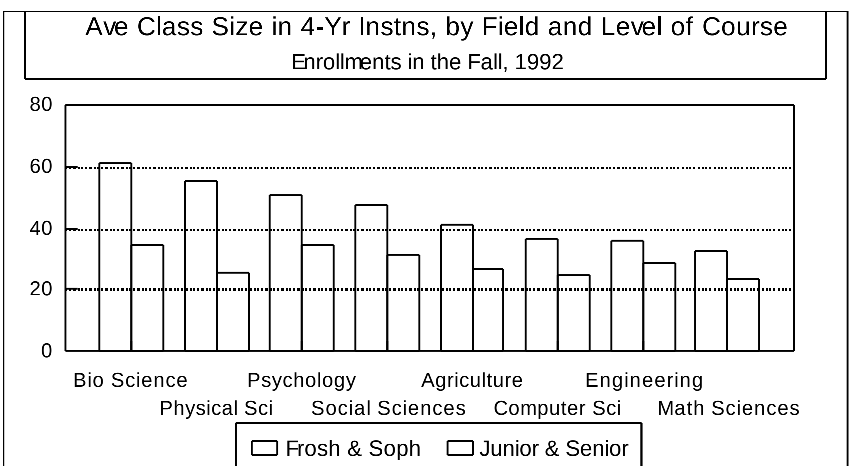
8. Institution Type, Class Size, and Choice of Teaching Methods. The information in this section and the following Section 9 was derived from data collected through the *1993 National Survey of Postsecondary Faculty* (NSOPF-92; U.S. Department of Education, National Center for Education Statistics). There are both institutional and disciplinary differences in average class size. These differences are shown in the next pair of charts, which reflect average teaching practice in the Fall of 1992. Lower-division SME&T courses tended to be the largest (by a considerable margin) in Research universities, and the smallest in Bachelors, small Masters, and two-year colleges. (They averaged 83 in Research universities and 26 in small Masters institutions.) The same ordering was also found in upper-division courses, but the differences were less pronounced. In four-year institutions, the average size of lower-division SME&T classes appears to have had some influence on the percentage of those courses and students taught primarily by lectures. (This influence is also apparent in upper-division courses.)

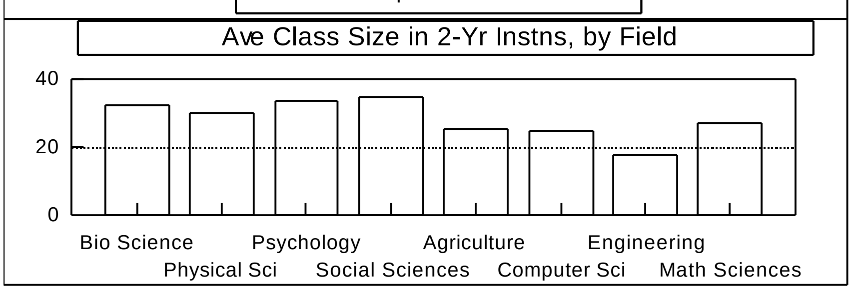
The much larger class sizes in lower-division courses in Research and Doctoral universities were supported in part by a much heavier reliance on teaching assistants. Lower-division classes averaged 1.5 teaching assistants per course in Research universities, and 0.5 in Doctoral universities, but no higher than 0.25 in other institutions. Upper-division classes averaged 0.6 teaching assistants per class in Research universities, but under 0.3 in Doctoral universities and well under 0.2 in other institutions.

Recall that estimated costs per FTE undergraduate (in all fields) were highest in research universities and next highest in doctoral universities despite the larger class sizes and greater reliance on teaching assistants. Clearly, the higher costs in these universities were due to other factors and held partially in check by resorting to large class sizes.

The reliance on lectures is striking. About 80 percent of lower-division courses in large four-year institutions and all two-year colleges were taught primarily by lecture, and about 70 percent of classes in small four-year colleges relied on lectures. Large enrollment courses tend more often to be taught by lecture, with the consequence that about 93 percent of students enrolled in lower-division SME&T courses in Research universities were taught by lecture (87 percent in Doctoral and large Masters universities, and 80 percent in small four-year colleges). The situation was somewhat better in upper-division SME&T courses, but even there more than 80 percent of enrolled students from large institutions were in lecture courses. Only in Bachelors colleges were less than 70 percent of students taking SME&T courses in those taught primarily by lecture.


Ave Class Size & Lecture Frequency by Instn Type
Lower Division & Upper Division Courses
Average Class Size
0
20
40
60
80
100
Lower Division
Ave Class Size
Research
Doctoral
Large Masters
Mid Size Masters
Bachelors
Small Masters
2-Yr Colleges
% Classes by Lecture
Upper Division
Research
Doctoral
Large Masters
Mid Size Masters
Bachelors
Small Masters
Ave Class Size
% Students in Lecture
0%
20%
40%
60%
80%
100%
% of Classes/ Students Taught Mostly by Lecture

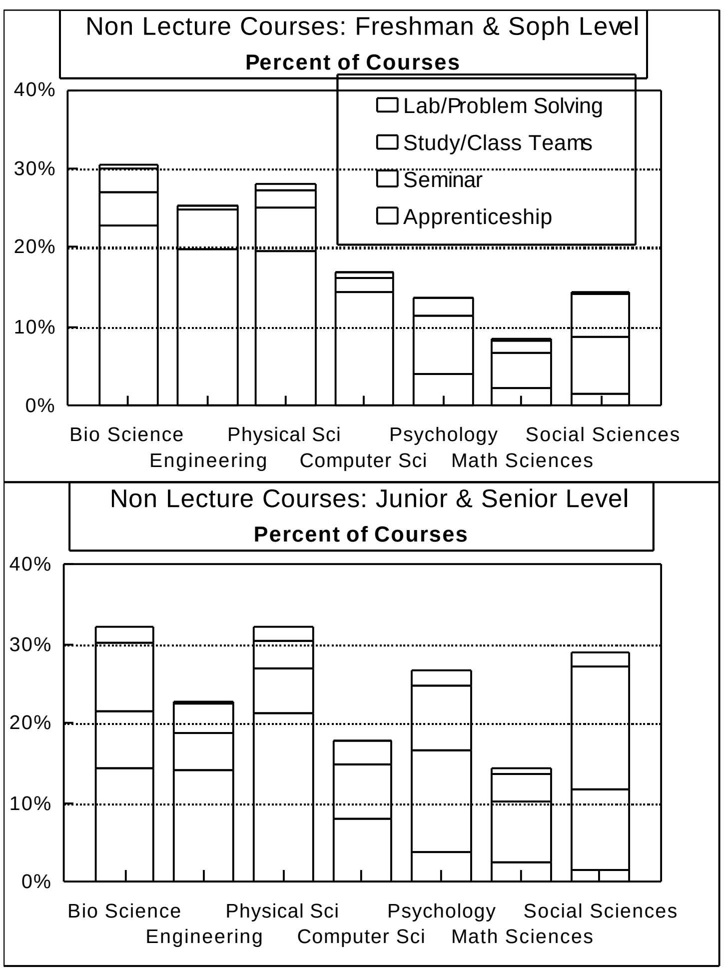

Ave Class Size in 4-Yr Instns, by Field and Level of Course
Enrollments in the Fall, 1992
80
60
40
20
0
Bio Science
Psychology
Agriculture
Engineering
Physical Sci
Social Sciences
Computer Sci
Math Sciences
Frosh & Soph
Junior & Senior


Ave Class Size in 2-Yr Instns, by Field
40
20
0
Bio Science
Psychology
Agriculture
Engineering
Physical Sci
Social Sciences
Computer Sci
Math Sciences

In four-year institutions, average class size at the lower-division level in different fields varied considerably, ranging from over 61 in the biological sciences to 33 in the mathematical sciences. At the discipline level, average class size seems to have had only a small effect on the choice of the lecture method of instruction. In two-year institutions, in every discipline, the average class size was smaller than in four-year institutions. And, although the ordering of size by discipline is not the same (see the last bar graph on the previous page), average class in the first four disciplines was higher (with a range of 30 to 34) than in the last four disciplines (with a range of 18 to 27).

In those courses not relying on lectures, the second most common instructional method used was a laboratory (problemsolving or clinical) approach, followed by “group” approaches to learning (i.e., cooperative learning groups, group projects, class discussion groups, class presentations, and role playing and simulation in class). The frequency of these approaches is illustrated in the two charts at the bottom of this page. A few courses were essentially apprenticeships or internships. These were much more common at the upper-division level.

These more active and interactive modes of instruction were more typically used in small classes, with the result that the percentage of students enrolled in these courses was considerably less than the percentage of courses employing these methods as their primary instructional technique. The high reliance on lectures has been addressed in a number of studies as well as in many published opinions. Consider, for example, the informed opinion published recently by the president of a



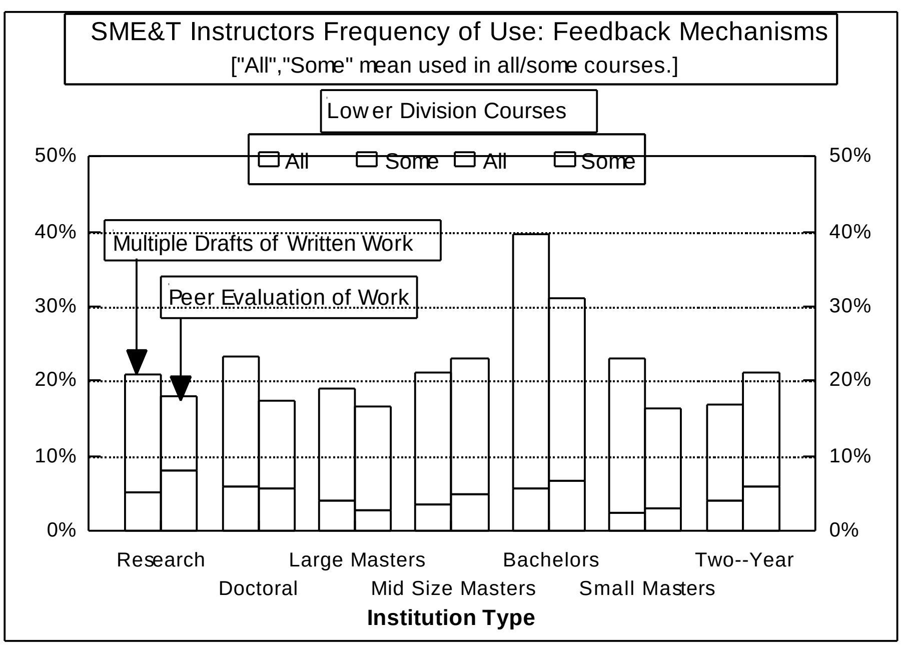
community college, observing that the "instruction paradigm" is still the dominant model for community colleges (Boggs, 1995/96, page 26):

> *Under the instruction paradigm, community colleges are responsible only for providing instruction, not for student learning. Responsibility for learning is the student's. ... Under [this] paradigm, faculty are primarily lecturers. Students are often competitive and individualistic. Faculty members carry out their functions independently of one another. Teachers classify, sort, and grade students.*

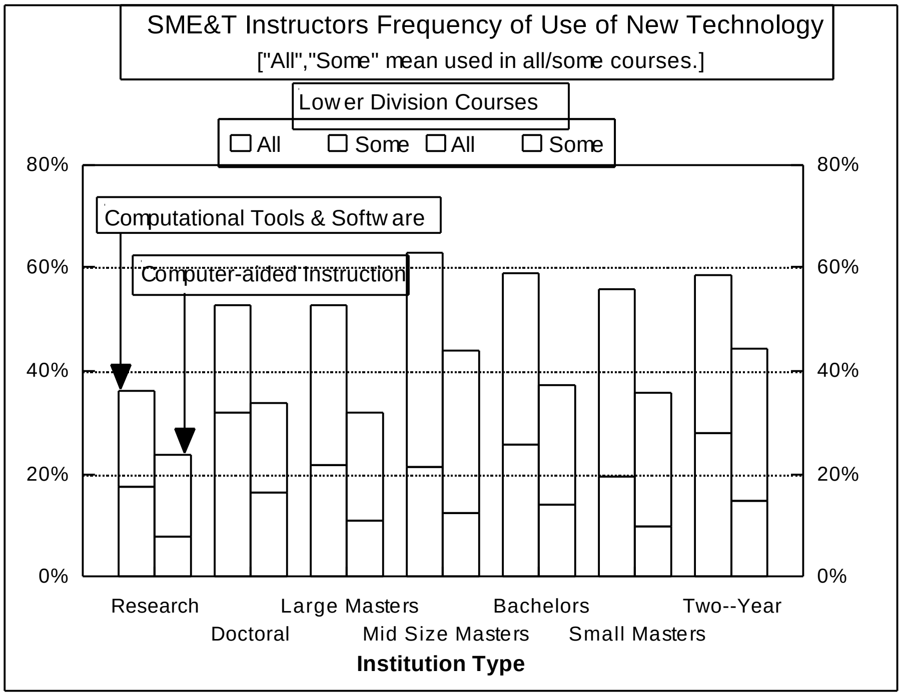
Data obtained from ethnographic studies and from focus groups of students support the hypothesis that most students learn most when reliance on lecturing is reduced. Boggs' careful statement is that he prefers "the learning paradigm," where colleges, as well as students, are responsible for student learning. In this paradigm:

> *...faculty are primarily designers of learning methods and environments. They are ... facilitators of student learning in much the same way as a coach facilitates the best performance of an athlete. They and their students work in teams with each other and with other college staff. ... The learning paradigm does not automatically define the lecture method as bad, ... [but it] will require that lectures prove their value in promoting student learning against other methods. ... Already there is a lot of research to indicate that more active methods of learning are usually more effective.*

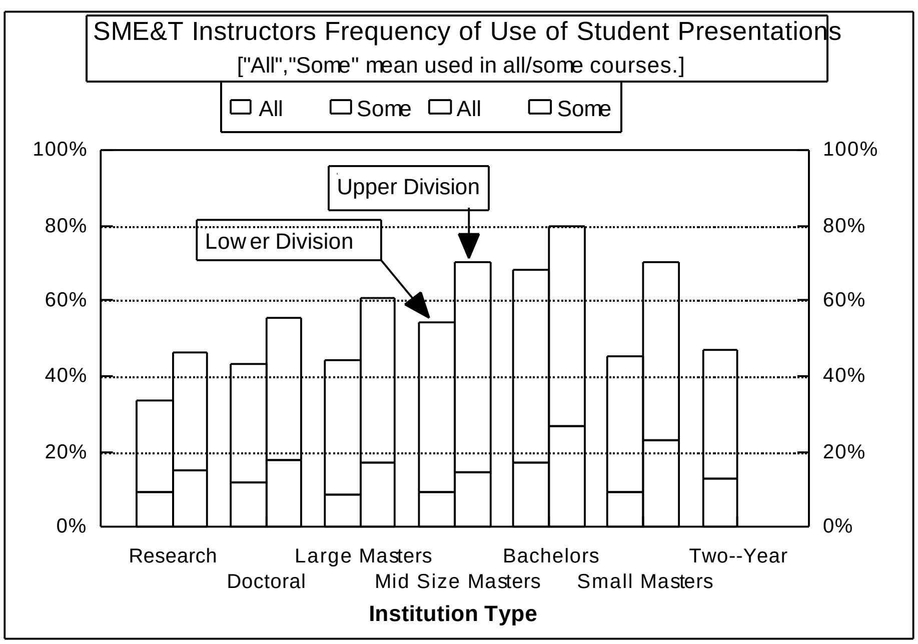
<u>9. Faculty Practices that May Influence SME&T Course-Taking and Student Learning.</u> The ethnographic studies of Seymour and our own focus groups indicate the importance of student access to teachers, teaching assistants, and themselves as peer learners. Even though the lecture format predominates in undergraduate education, it is still possible to improve the learning



environment considerably by employing techniques that ensure more frequent and helpful feedback on student learning. In the first two charts, the reported frequency of some such techniques in

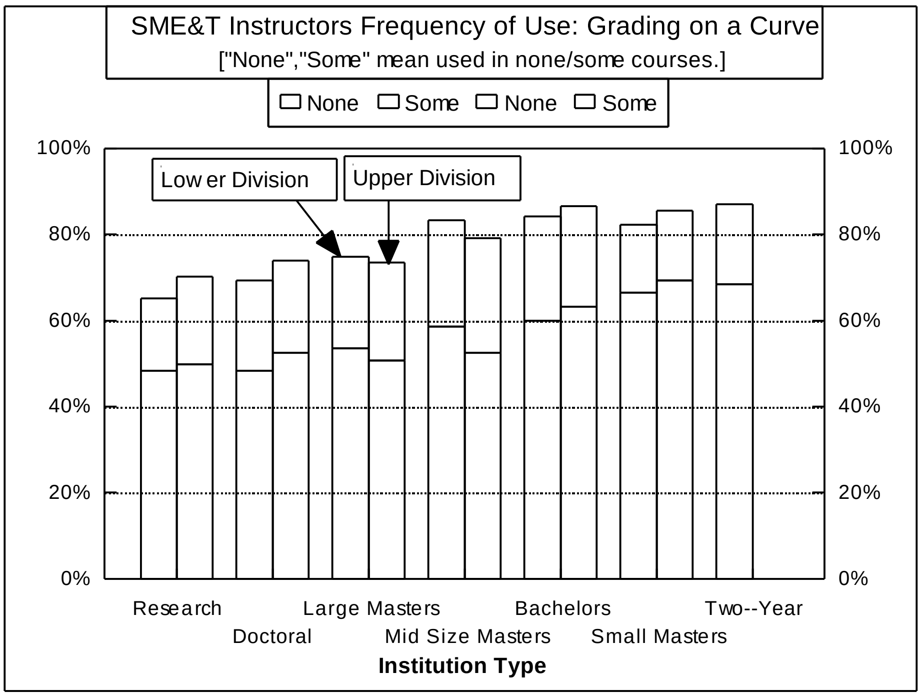


lower-division courses are illustrated from the 1993 Survey of Post-secondary Faculty. These charts illustrate that these techniques were used widely enough during the Fall of 1992 to be familiar at some level of detail to most SME&T faculty. However, teaching practices in SME&T courses taught during that Fall semester more frequently did not employ these methods.



This was particularly true in Research Universities, and also to a large extent in Doctoral and large Masters institutions. Only the use of computational tools and software could be called widespread.

The final two charts examine other good practices in both lower-division and upper-division courses taught by the SME&T faculty. The use of student presentations was most widespread in Bachelors colleges and was also found more frequently in upper-division than in lower-division courses. Grading on the curve, a practice associated with so called "weed-out" courses, is now absent in the majority of SME&T courses. So is the practice of basing grades on multiple choice examinations, particularly in Research universities and Bachelors colleges. This suggests that faculty practices are beginning to change for the better.



<u>10. Employer Perspectives on Desirable Outcomes from Undergraduate Study.</u> Employers today are seeking entry-level employees at the associate or baccalaureate degree level who can demonstrate solid basic (disciplinary) skills *and* a full complement of other skills. These other skills make the recently acquired specialized knowledge more valuable to the organization, which increasingly seeks to combine diverse areas of expertise embodied in individual employees by bringing them together to work in teams. Private firms have become more demanding and cautious in screening potential new employees, and increasingly require a full complement of skills in their new hires.

Statements made by employers about their needs and preferences have been growing in number during the 1990s. Yet these show a remarkable degree of consistency in identifying the skills sought from college educated, entry-level employees. (These skills are described in a subsection below.) Employers' preferences have also had a noticeable influence on undergraduates' strengthened sense of purpose.

Many employers also agree that the *growth* in skills needed to fulfill many jobs — including many professional occupations — has been rapid, and seems to have outstripped the capacity of many undergraduate institutions and their programs to keep pace. This is because most undergraduate programs are not specifically designed to help students develop these skills directly.

The deficits in skills identified most frequently by employers are usually not defined in terms of the disciplinary knowledge of recent graduates. In fact, employers of SME&T graduates have often indicated their basic satisfaction about the specific knowledge that recent graduates with good grades bring from most academic institutions to entry-level positions. However, while many academic SME&T departments are thought to produce able college graduates from able high school graduates, the bulk of them are often seen as not serving the needs of the remaining students to achieve a desirable level of SME&T competence or literacy, and there is growing concern about the breadth of learning of high-achieving SME&T graduates (as there is at the graduate student level).

There is also some concern about the low numbers of able graduates. Metaphors abound to convey this judgment of limited success. Faculty are advised to switch from playing the role of "filter" to being a "pump" (Steen, 1991, page 19). Departments are disparaged for conducting "weed-out" courses and employing excessively competitive grading practices (Seymour and Hewitt, 1994). Undergraduate SME&T education during the past three decades is described by Goodstein (1993) as:

> *... a mining and sorting operation, designed to cast aside most of the mass of common human debris, but at the same time to discover and rescue diamonds in the rough, that are capable of being cleaned and cut and polished into glittering gems, just like us, the existing scientists. ... [This] explains why we have the best scientists and the most poorly educated students in the world. It is because our entire system of education is designed to produce precisely that result.*

Employers are articulate in describing in general terms the types of skills that enhance the value of their employees, but they are not comfortable prescribing either methods for bringing undergraduate programs into better alignment with their stated needs or specifying actual levels of knowledge that recent graduates should have mastered in various disciplines. (See, for example, Bikson (1995), Verville (1995), Pew Higher Education Roundtable (1994), Wingspread Group on Higher Education (1993), and the National Center on Education and the Economy (1990). See also the written testimony of employers participating in a hearing at NSF on November 1, 1995, particularly the statements of Israel Galvan (GHG Corporation), Roberts Jones (National Alliance of Business), John McMasters (Boeing), Alfred Moye (HP), John Sisler (Shell Oil), and Patrick White (Bell Atlantic).

There are sound reasons for this reluctance to prescribe specific features of improved college programs. One is that the overarching need is for employees that can continuously adapt, adjust, and re-educate themselves to remain productive in a changing environment. As one employer commented to the National Academy of Sciences, "we may place a new employee in a position which exploits any special expertise [learned] in order to provide 'a soft landing,' but he or she will eventually be called upon to handle a wide range of problems that go far beyond the [formal course work] received during the completion of the Ph.D." (National Academy of Sciences, *Reshaping the Graduate Education of Scientists and Engineers*, 1995).

Another reason is that competence in mathematics, science, engineering, and technology serves a broad range of objectives, and needs vary by student major and intended career (for example, consider the literacy needs of a chemistry major, a mathematics major, and an English major). This broad range of needs is often a difficult issue for academic departments seeking to redesign their curricula. A representative minimum level of literacy was recommended by Lynne Cheney when she was Chair of the National Endowment for the Humanities (1989). She suggested a core 50-credit-hour curriculum for college students comprised of three civilization courses, a foreign language course, and a year of mathematics and science that is more than most undergraduates typically are required or elect to take. The study of mathematics would examine mathematics as a field of inquiry. The science course would cover the physical and life sciences, focusing broadly on how scientists have historically developed and validated new concepts and past concepts of matter, energy, and life.

<u>A Brief Look at Desired Workforce Competencies.</u> Jobs increasingly require basic knowledge of SME&T, as does the capability of individuals to engage in lifelong learning in broad directions. There is a growing expectation that successful students must acquire those skills that will allow them to be lifelong learners, often in non-academic settings. We are increasingly told that change itself is the *status quo*. Broadly speaking, a minimum requirement for lifelong learning is a basic grasp of mathematics and its uses, science and its methods, and technology and its effects. The expected need for this knowledge in the future is widespread among professional jobs and is spreading rapidly in so-called blue-collar occupations. Verville (1995) notes that about 65 percent of all workers in the U.S. use some type of information technology in their jobs, and this figure is anticipated to be 95 percent by the year 2000. (Recall from Section 3, Public Attitudes About Subsidies, that most of the job growth in the past decade has occurred in government, personal, and business services.)

A college graduate seeking employment must currently demonstrate the following skills in order to successfully compete for professional positions in a number of manufacturing or service firms with national or international operations. [These are borrowed from Bikson (1995).] The job seeker's academic major and associated transcript and grades open the door to job interviews, but the following skills are sought by employers to justify offers of employment:

Generic cognitive skills
- Problem solving skills
- Learning how to learn
- Decisionmaking skills

Social skills
- Communications skills
- Interpersonal skills (teamwork)

Personal traits
- Adaptability and flexibility
- Openness to new ideas, empathy for ideas of others
- Strong work ethic
- Innovative and entrepreneurial outlook

Many of these skills are seen as important because employees are more typically working together in teams comprised of demographically and functionally more diverse coworkers. Many firms are employing greater numbers of women, minority males, and employees from foreign countries, whose specialized training spans R&D, engineering, manufacturing, marketing, sales, and legal services. Compounding the challenges of diversity is the pace of technological change. Products and services are being changed rapidly under intense competitive pressure to accommodate regional preferences and to incorporate quality improvements.

Among recent baccalaureates who have demonstrated some mastery of their coursework in a college or university whose academic program is known to the potential employer, each of the above competencies was considered more important than academic achievement in predicting a job candidate's performance on the job. Some employers expect colleges and universities to inculcate these skills and traits more deliberately as part of the undergraduate learning experience. Such skills cannot be expected to develop in passive learning environments where the dominant pedagogical approach is lecturing by the faculty and note taking by the students, punctuated by cookbook laboratory exercises or, in some courses, recitation sections devoted to unimaginative sets of problems to be solved (designed to develop familiarity in using tools through repetitive practice).

These skills needs of employers can be developed as part of undergraduate studies to a much greater extent through the choice of sound pedagogical (learning-enhancing) practices and the increasing use of curricular improvements in SME&T courses. Many of these practices have been clearly identified by many contributors to this Review as more effective than traditional methods for most learners. In essence, this crucial finding is described by the following set of points:

1. Students acquire SME&T knowledge and retain it years later far more effectively when courses are designed with learning effectiveness as the highest priority, as opposed to covering a fixed body of "material."
2. Pedagogical techniques that teach teamwork and communication, sharpen cognitive skills, and help to develop openness to new ideas, adaptability, and flexibility are known to also enhance subject matter learning.
3. There should be a focus on concepts that apply across fields, and on connections across the disciplines and between science and technology, especially in basic introductory courses. At advanced levels of education, this translates as a recommendation for breadth as well as depth of learning. This is perhaps the most prescriptive recommendation for SME&T courses identified by contributors to this Review.
4. A much higher percentage of students from a given pool would be drawn to SME&T if curricular and pedagogical "best practices" were more widely employed.

<u>11. Electronic Technology and Systemic Reform</u>. The realization is growing that academic institutions no longer have a collective monopoly on knowledge, and access to that knowledge (which traditionally has been located in libraries, textbooks, and the brains of faculty). [See, for example, Noam (1995), Duderstadt (1995), Denning (October 23, 1995 NSF Hearing Testimony), Ward (October 25, 1995 NSF Hearing Testimony), and Massy and Zemsky (1995).] Noting that there are numerous examples of applications of new technology, Massy and Zemsky predict that, in most institutions, the demand for using information technology to assist teaching and learning will grow exponentially over the foreseeable future and "will change teaching and learning profoundly, no matter what the response of traditional higher education institutions." Competition from nontraditional providers of education will pressure colleges and universities to exploit these new technologies, a theme echoed by many others.

However, it is also realized that there is a lot of exploratory work to do before we can exploit the full potential of new technology (e.g., Noam, 1995, and Vest, 1996). For example, Vest (1996, page 4) warns us that we do not yet know how best to use the new information technology for many education objectives. Massy and Zemsky agree, stating:

> *Across American higher education the lure of the new information technologies remains as uncertain as it is unsettling. While few doubt that information technology has the potential to enhance teaching and learning, there is no agreement on how that technology should be used to boost academic productivity — or whether such an increase is in itself a valid goal if its enhancement means substituting technology for the more traditional, labor intensive rhythms of higher education.*

Many believe that the opportunity to become an effective lifelong learner outside of academic settings has been improved immensely by technological improvements in personal computers, the Internet (and other computer networks), the World Wide Web, and numerous software tools. We are making increasingly sophisticated use of video and audio technology in connection with these other advances, which "softens" this technology, making it more "personable." We are on the threshold of widespread access to digital libraries, with the promise of powerful tools becoming available to individuals, which will assist them to find, extract, understand, and connect information from a variety of sources. This will form a building block for the development of "virtual universities." The opinions of many who have discussed using these technologies in undergraduate settings agree that we have only started to exploit its potential. Faculty are increasingly expected to become knowledge guides rather than center-stage actors. As the National Academy of Science stated about the future of education, the promise of these related technologies is that:

> *... all students will be held to far higher standards of learning because everyone will have to be prepared to think for a living and everyone will have to be capable of learning many new skills over the course of a lifetime. ... The timing and location of education will be more flexible ... The distinction between learning inside of school and outside of school will blur.* (*Reinventing Schools...*, 1993).