DOCUMENT RESUME

ED 313 214 SE 050 872

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TITLE Where Have All the Young Men (and Women) Gone?
PUB DATE 89
NOTE 26p.; Paper presented at the Harvard University Symposium, "The Coming Revolution in Science Education" (Cambridge, MA, May 13, 1989).
PUB TYPE Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *College Science; Engineers; Higher Education; *Minority Groups; Science Careers; Science Education; *Science Interests; *Science Teachers; *Scientific Personnel; Scientists; Secondary Education; *Secondary School Science

ABSTRACT

The results of the Second International Science Study and the National Assessment of Educational Progress (NAEP) science assessments are cited and future job openings in natural sciences and engineering areas are projected. Technology is ever increasing in complexity, yet ninth-grade U.S. students scored second from the bottom on international comparisons of science achievement. There is an unprecedented crisis in the United States, and in order to resolve it, there is a need to: (1) place greater emphasis on middle school science education; (2) increase the quality of science teachers; and (3) increase the emphasis on science education and the teaching of science at the university level. Leadership is needed to meet these needs. The paper recommends greater commitment to science program and teaching by colleges and universities and greater support by the National Science Foundation. (YP)

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WHERE HAVE ALL THE YOUNG MEN (AND WOMEN) GONE?

presented by
Jerry A. Bell
Department of Chemistry
Simmons College

at the
Harvard University Symposium
"The Coming Revolution in Science Education"
May 13, 1989

to honor
Leonard K. Nash
on the occasion of his retirement

It is a singular pleasure for me to take part in this symposium honoring Leonard Nash. Thirty five years ago, Len Nash was my first college chemistry teacher. In the years since, my admiration has grown, as we have become colleagues and friends. My only regret on this occasion is that my son, John Leonard (a deliberately chosen middle name) is out of town and cannot be here this evening. He sends his best, Len, and I am sure you will be pleased to know that he is now an assistant editor at Addison-Wesley, a publisher to which you and Ava also have a few ties.

I not only admire Len, but stand in awe of the man. My awe increases with each instance that I try in my own teaching to catch the flavor of his. It's hard work and, only when you try it yourself, do you realize how hard Len worked before and during his classes. I want to return later to this theme of the difficulty of good teaching, but first need to set the stage a bit more.

In 1975, when Len received the James Flack Norris Award for "Outstanding Achievement in the Teaching of Chemistry," he began his acceptance address in what seemed a most uncharacteristic way. He said that the award was being presented several years too late. He went on, more characteristically, to say that several years before he thought he knew a great deal about teaching that he could have passed on to us, but that more recently he had found that he knew very little.

Those remarks could have formed a sub-theme for much of today's symposium. Most of us teach by the seat of our pants, more or less informed by our acquaintance with outstanding practitioners like Len Nash. Our knowledge of the teaching and learning processes and their interaction is primitive. Today we have heard about some of the halting steps that research is making toward a better understanding of teaching and learning. And, we have heard suggestions for ways they should or could be put into practice.

Research on learning and teaching and dissemination of the results into practice are vital for more effective teaching. And, as I shall argue in a moment, we face an unprecedented educational crisis in this country, which makes more effective teaching crucially necessary at all educational levels. Teaching that is consciously informed and relies explicitly on the best ideas that research has to offer is more effective and will undergird the "coming revolution in science education."

However, I do not wish, this evening, to extend the analysis of this revolution. My immediate concern is not for the revolution but for the revolutionaries or, more accurately, for the lack of revolutionaries. Where are all the teachers who are going to carry out the revolution? Or, to refer to the title of this presentation, "Where have all the young men (and women) gone?" They do not seem to have gone, or be going, into teaching, even in so-called "academic" careers.

Why is this such a cause for concern? Let me rehearse with you briefly the dismal situation we face. [Figure 1] This first slide reminds you that on international comparisons of science achievement, students in the fifth grade in the United States scored about in the middle among the fifteen countries in the study. Not a great record, but not an unmitigated disaster. The disaster occurs later. [Figure 2] When the comparison is done at the ninth grade level, students from the United States end up second from the bottom.

These comparisons are for all students at each level and you might argue that our more poorly motivated and less scholastically inclined student population is dragging the average down. Surely, however, we don't have a larger proportion of students who are intrinsically less able than in all the other countries in the study. These data support statements by Patricia Graham, Dean of the Harvard Graduate School of Education, and others that "this is absolutely the first time in our history that we have had to worry about science and math training for the bottom half" and we are ill-prepared for the task (quoted in the Boston Globe, May 8, 1989).

Perhaps we do better with the more motivated students who take chemistry courses in high school. [Figure 3] These data are doubly depressing. Not only does the United States rank close to the bottom, but our average student is unable to get even forty percent of the chemistry test items correct.

So far, the data I have shown are based on achievement tests. I am sure, however, that we are all much more concerned with a student's ability to use information than simply to store it. Such ability is not easy to measure, but the National Assessment of Educational Progress, "The Nation's Report Card," does try to assess different proficiency levels related to the use of information. [Figure 4] This figure simply summarizes the proficiencies that NAEP tries to assess. The taxonomy is apparent as one progresses from simple recall to analysis and interpretation.

The results of the two most recent NAEP science assessments [Figure 5] indicate that most young students do know age-appropriate science facts, such as the shape of the Earth and classification schemes (animal, vegetable, mineral). However, fewer than ten percent of seventeen-year olds are able to integrate a new piece of scientific information into the mental construct that their achievement suggests they have. A large number of the students in our beginning college science courses, therefore, lack such proficiency.

The situation I have outlined would be distressing, but not necessarily a crisis, if the United States had manpower to waste. But, we do not. On May 2, 1989, the MIT Commission on Industrial Productivity released its report "Made in America" that stresses the need for new kind of workforce managed in ways which United States business is unaccustomed and even opposed to using. This workforce will have to be much more technically competent and able to make more independent decisions. Our educational system is not prepared to meet this challenge; it's the "bottom-half" problem again.

The crisis is not confined to the ranks of those who provide the likes of us, in this room, the goods and services we have come to expect. A quick look at some demographics, and projections based upon them, provides the evidence that we face an unparalleled crisis that threatens to cripple our technological society. [Figure 6] This figure shows the number of twenty-two-year olds in the United States through the year 2011. Some proportion of this population will be graduating with baccalaureate degrees in natural science or engineering each year and going into the technical workforce or on to graduate study. Note that this figure is not a projection; all the persons represented on this curve are alive today.

One projection, based on these demographics is shown in the next figure. [Figure 7] Represented here are the cumulative number of jobs for natural science and engineering BS graduates for which there will be no graduates available. This projection is based on the very conservative assumption that the proportion of the workforce that will need technical degrees will not increase. The result of this shortfall, by the year 2004, will be about five hundred thousand jobs unfilled or filled by persons not fully competent to handle them.

The problems at the Ph.D. level are just as grave. [Figure 8] This figure projects available positions for Ph.D.'s in natural sciences and engineering to the year 2004 when about eighteen thousand openings will be available. [Figure 9] This figure shows the number of Ph.D.'s granted each year, projected through the year 2004. The shaded portion labelled "Shortfall" is the difference between production and available postions from the previous figure. Note the steady decline in numbers of US students projected to get Ph.D.'s and, even including foreign students, the decline in overall number of graduates. Are you worried at all about where your replacements might come from?

Why is more effective teaching at all levels so critical to finding solutions to the problems that are explicit and implicit in the data I have been showing you? A bit more demographic data will help provide a partial answer. [Figure 10] Fewer than twenty percent of high school sophomores are, by interest, potential candidates for natural science or engineering degrees at the college and graduate level. Thus the "pipeline," those students perhaps heading for science careers, is already severely constricted at the tenth grade and you can see how it narrows further at each succeeding stage.

It is the pipeline shown here that is the basis for the projections shown in the previous figures. The projections assume that the ratios will remain constant. Indeed, such ratios have been fairly constant. The challenge is to change them, that is, to get a higher proportion of students at each stage to go on in natural sciences and engineering -- or at least to go on far enough to provide the new workforce the MIT Commission says will be required to keep the United States strong and competitive. Equally important is to maintain an interest in science among those who will become our business leaders, lawyers, politicians, and voters. We want them to have enough interest to take science enrichment or science-for-the-non-scientist courses and become more aware of scientific issues, values, and methods for resolving problems. In a technological society, science literacy for the majority of people is crucial to long-term survival.

Where should efforts be targetted to change this diagram and increase the persistence in interest in science? At least one obvious point is before the students reach high school, in order to increase the proportion of those interested in science when they reach high school. There are obvious target populations for such efforts, as we can see from this breakdown of the pipeline by gender. [Figure 11] Tenth grade girls show about one-third the interest in science as tenth grade boys. Yet, at the elementary level, girls' <u>interest</u> in science is as great as boys'.

What is it in our culture, including our teaching, that turns the girls off? If their interest could be maintained as well as the boys', we would increase the potential pool of natural sciantists and engineers by a factor of one point five, one hundred and fifty percent. Similarly, we are squandering the talents of our minority students. [Figure 12] The major underrepresented pools from which we can draw the technical workforce we need are women and minorities.

The crisis in science education I have sketched cannot be solved by one institution or one approach alone. We require a wide variety of responses and new strategies, all of which will have teachers and more effective teaching at their core. We also require creative leadership. In the United States their are several institutions that others look to for leadership. Two of these leadership institutions are the National Science Foundation and Harvard University.

Institutional leadership is almost entirely a matter of what an institution does or does not do rather than what its spokespersons, however eloquent and well-intentioned, say or don't say. Since I have had some personal experience with them, I would like to look at a few bits of the history of the National Science Foundation and the Harvard Chemistry Department to see what insights might be gained about the sources of our present predicament and what pointers to the future they might provide.

As a backdrop for our look at the National Science Foundation, consider the NSF budget over the years. [Figure 13] This figure gives, in constant 1988 dollars, the amount NSF has awarded in grants each year. That portion of the budget targeted for education is labelled "SEE" for "Science and Engineering Education," and is shown as the unshaded portion at the bottom of the figure. It is easy to trace the Nation's response to perrceived crises in science education.

In the aftermath of Sputnik in 1957, the science education budget rose immediately and dramatically. The data suggest that our crisis mentality lasts for about a decade and then its memory fades away. The education budget begins to decline in about 1968 and goes effectively to zero in 1982-83 when the NSF science education directorate was disestablished. The new crisis was discovered in a landslide of reports and studies in the early eighties and accounts for the establishment of the present Directorate for Science and Engineering Education in 1983 and the steady increase in funding for science education since then.

Another look at these same data [Figure 14] is in the form of pie charts that present five-year "snapshots" of the budget. When the NSF science education budget is twenty-five to forty percent of the total, a strong leadership message is sent to the scientific community. The message says that science education and its practitioners, the teachers, are valued. Efforts expended in science education are supportable and encouraged. During the fifties and sixties, many scientists, including some of the very best, listened to this message and there was an enormous ferment in science education.

The great majority of us who have focussed our careers in science education were "born" professionally during this period. We are getting older and there is no younger cadre to replace us. Why not? A message is sent by the existence of funds to support science education; the opposite message is sent when they become much less important or disappear, as we see has happened. Young men and women entering the sciences are not likely to consider focussing any of their efforts in education when the premier science funding institution is telling them that education projects are unimportant and unfundable.

A parallel history can be traced in the Harvard Chemistry Department. When I was a student here thirty years ago, essentially all the responsibilty for both lecture and laboratory work was in the hands of faculty. Admittedly, most of the laboratory responsibilities were in the hands of Instructors and Assistant Professors, who were well known, by the students, to be on a three to five year sojourn on their way to someplace else. However, these were Ph.D.'s who were considered good enough to be worth at least a look as possible Harvard faculty. We thought that meant that our instruction was important enough to be getting faculty attention in all parts of the courses.

Len Nash was a master lecturer in the accelerated, one-semester general chemistry course I took. He had also crafted a great laboratory experience for us and Frank Harris was the Instructor charged with seeing that it ran well and that the Teaching Fellows performed well. I remember several of those experiments, but the one that is most important to me was the nine-solution problem: nine numbered test tubes whose contents you were to determine solely by intermixing aliquots of the solutions in the tubes. I have always liked puzzles and what I learned from Nash was that one could create intriguing chemical puzzles. What I learned further, due to a contest devised by Frank Harris, was that one could create diabolically clever chemical puzzles. That was a formative semester in my professional life.

My second semester was also exceptional. Undaunted by my loss of the nine-solution problem contest, I took the first half of analytical chemistry. Since this was the off-semester, J. J. Lingane was not in charge of the course. Rather, we had two Instructors who shared the lecture and laboratory responsibilities, Frank Harris and Bill Klemperer. That may have been the only time either has ever taught analytical chemistry. We got a chance to see them working it out as they went along, which is a reasonable teaching strategy for good, highly motivated students. I learned that physical chemists can teach anything, a lesson that has stood me, as a physical chemist, in good stead since.

There was another aspect of Len Nash's teaching that was remarkable to us as undergraduates. In addition to the accelerated general chemistry course for would-be scientists, he also taught a Natural Science course designed for non-science students. The contrast between the two audiences and, therefore, the very different teaching approaches required of one man seemed quite amazing at the time and still does. We were impressed that faculty like Nash, Gerrald Holton, and George Wald would give such effort to courses for students who had no intention of going on in the sciences. It was important to learn that these scientists thought that an understanding of science was accessible to everyone and were trying to provide that access.

When I was a graduate student, I had the opportunity to be associated with the physical chemistry course when Gus Maki, John Baldeschwieler, and Martin Gouterman (one summer) were developing new experiments. It was great to be part of such projects, because it translated into immediately useful approaches when I began teaching and developing my own labs.

I have indulged in this bit of personal reminiscence to make two points: (1), that teachers who interact most directly with students are very influential (even if the influence isn't immediately apparent) and (2), that my classmates and I felt priveleged to have faculty of this caliber in charge of everything. We thought teaching was taken very seriously, even though we knew that the highest priority for most of these young men was their research.

It is distressing to see how much of this has changed in the past thirty years. I am not aware of any chemistry faculty member who is teaching a core course in science for non-science students. This is a critical need in our increasingly technological society, but evidently not a priority here. Further, no longer do faculty have direct responsibility for undergraduate laboratories. The experienced Teaching Fellows who are charged with this responsibility are generally very good and very conscientious, but they are not Ph.D.'s with faculty appointments. That distinction is not lost on the students, unless their perceptiveness has markedly decreased since my own undergraduate days. The message, like that conveyed by the NSF budget, is that teaching is not important enough to occupy a faculty member more than the time put into presenting lectures. However conscientious one is in lecture preparation, most students perceive that lecturing takes three hours a week.

Apparently, this situation is not limited to the Chemistry Department. The most recent accreditation report on the University singled out the delegation of too much undergraduate teaching responsibility to Teaching Fellows as a problem for the institution. You can't deny accreditation to Harvard because it doesn't have all its faculty arrayed in undergraduate classrooms and laboratories. Sadly, however, it means you can't look to Harvard for leadership in effective teaching and preparation of effective teachers either.

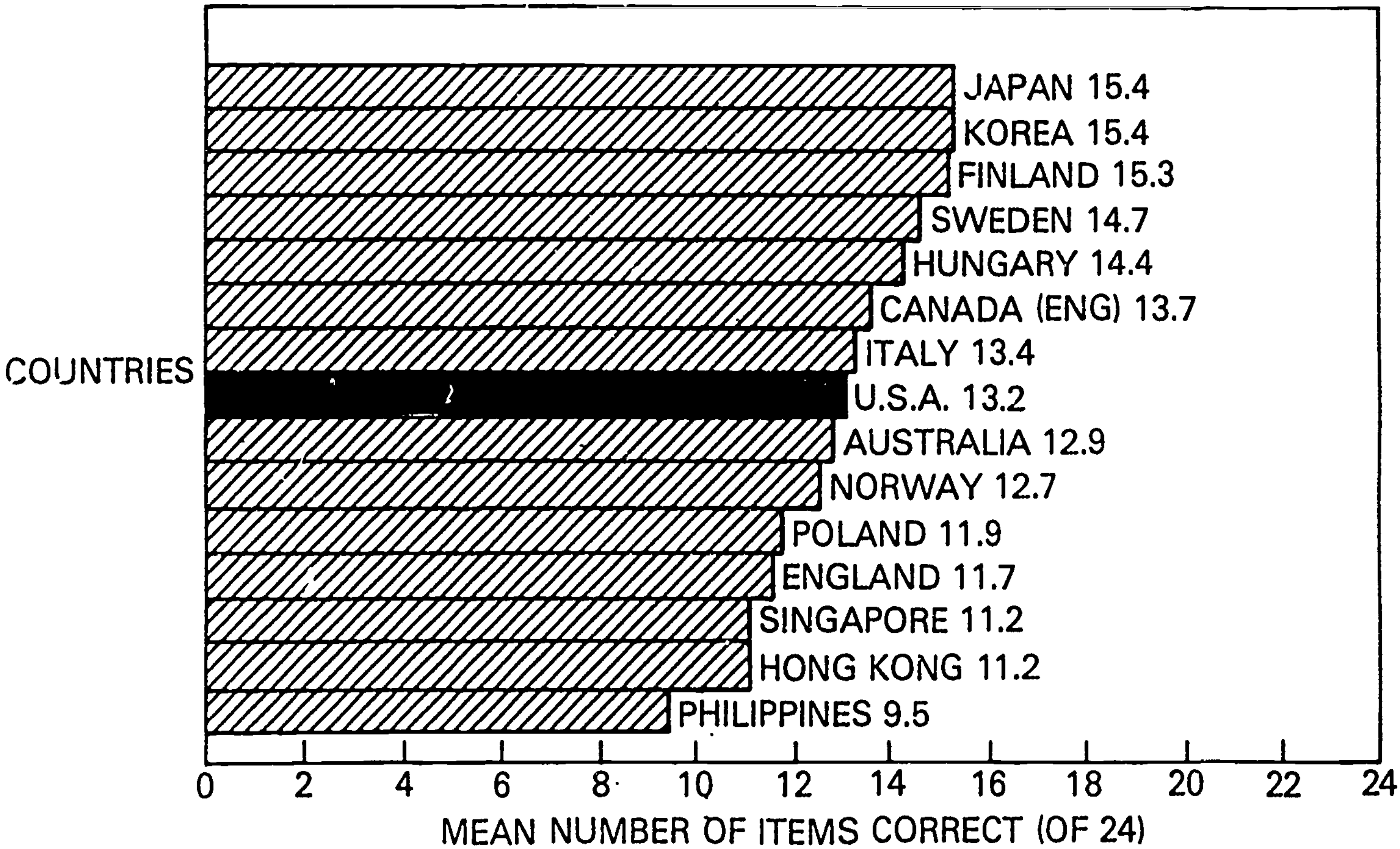
Effective and excellent teaching is extraordinarily challenging. Excellent teaching is as difficult as devising the total synthesis of a complex natural product. Excellent teaching is as subtle as the determination of the mechanism and stereochemistry of a phosphate group rearrangement in an enzymatic reaction. Excellent teaching is as important as understanding the atmospheric chemistry and dynamics responsible for the maintenance of life, as we know it. Encouraging talented young men and women to strive for excellence in teaching as well as research requires strong reinforcement and support for the teaching component. Also required are role models, faculty members who are taken seriously and respected for their contributions in the challenging teaching arena.

Where are all the young men (and women) going who could foment the coming revolution in science education? Where are tomorrow's (or even today's) Len Nashes? The present crisis in science education requires our leadership institutions to lead and lead boldly. Undoubtedly, Harvard has the <u>resources</u> to take a leadership role. It could mount programs and hire faculty who would attract and entice the best and brightest undergraduates and graduate students into teaching. The question is, "Has it the <u>will</u> to do so?"

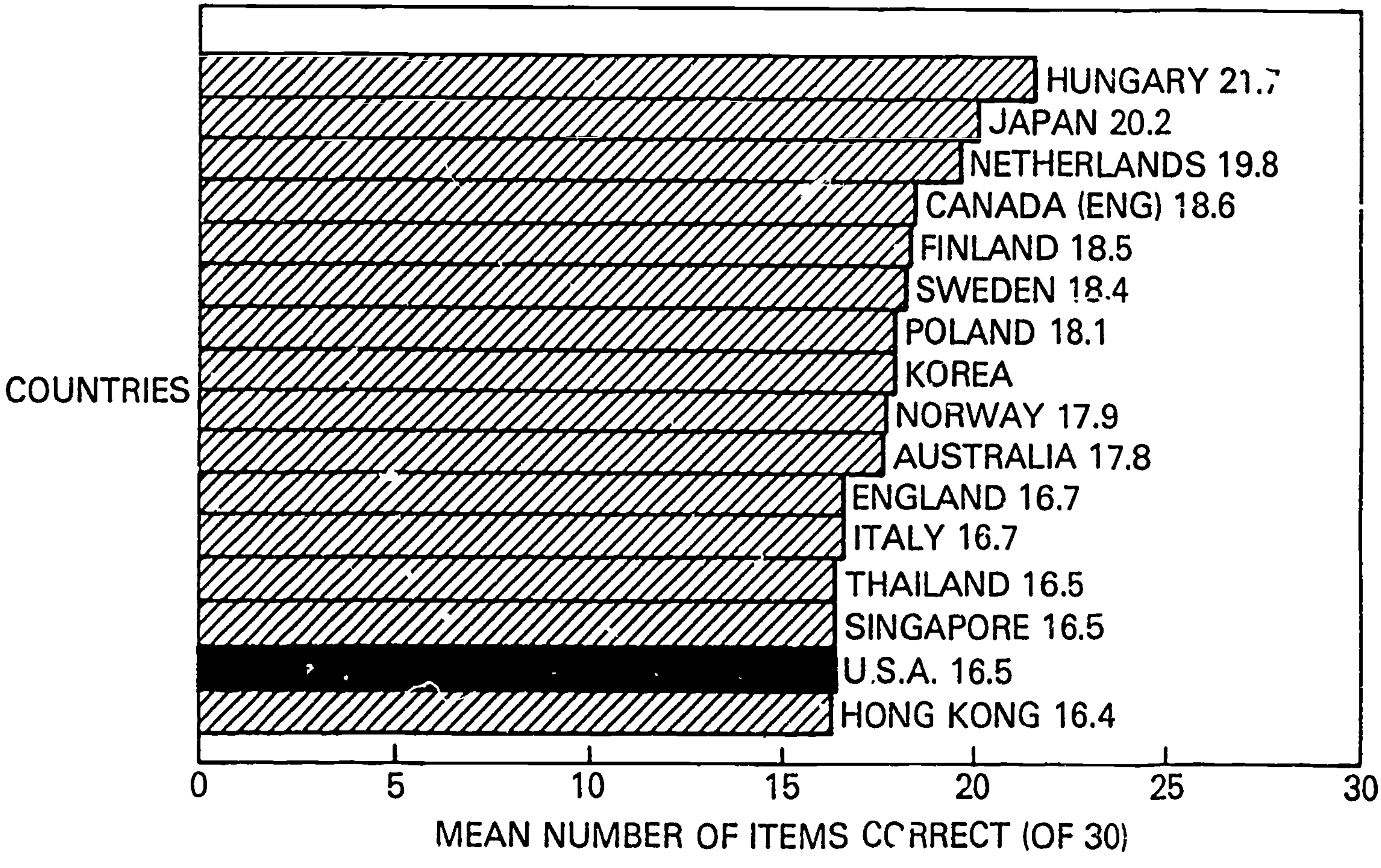
Faced with an impasse, when a lecture topic seemed not to be penetrating our minds, one of Nash's favorite phrases was, "How can I get some sex into it?" Len usually followed with a wonderful anthropomorphic analogy. The same question is relevant in the present science education crisis. Rephrased, we might say, "How can we make effective teaching more glamorous and attractive?" The human part of the response is to have more highly visible and creative faculty engaged in the enterprise.

Len, you will be sorely missed by an institution and a society that need leadership and creativity in science education. Thanks for what you have given so many of us for the past four decades.

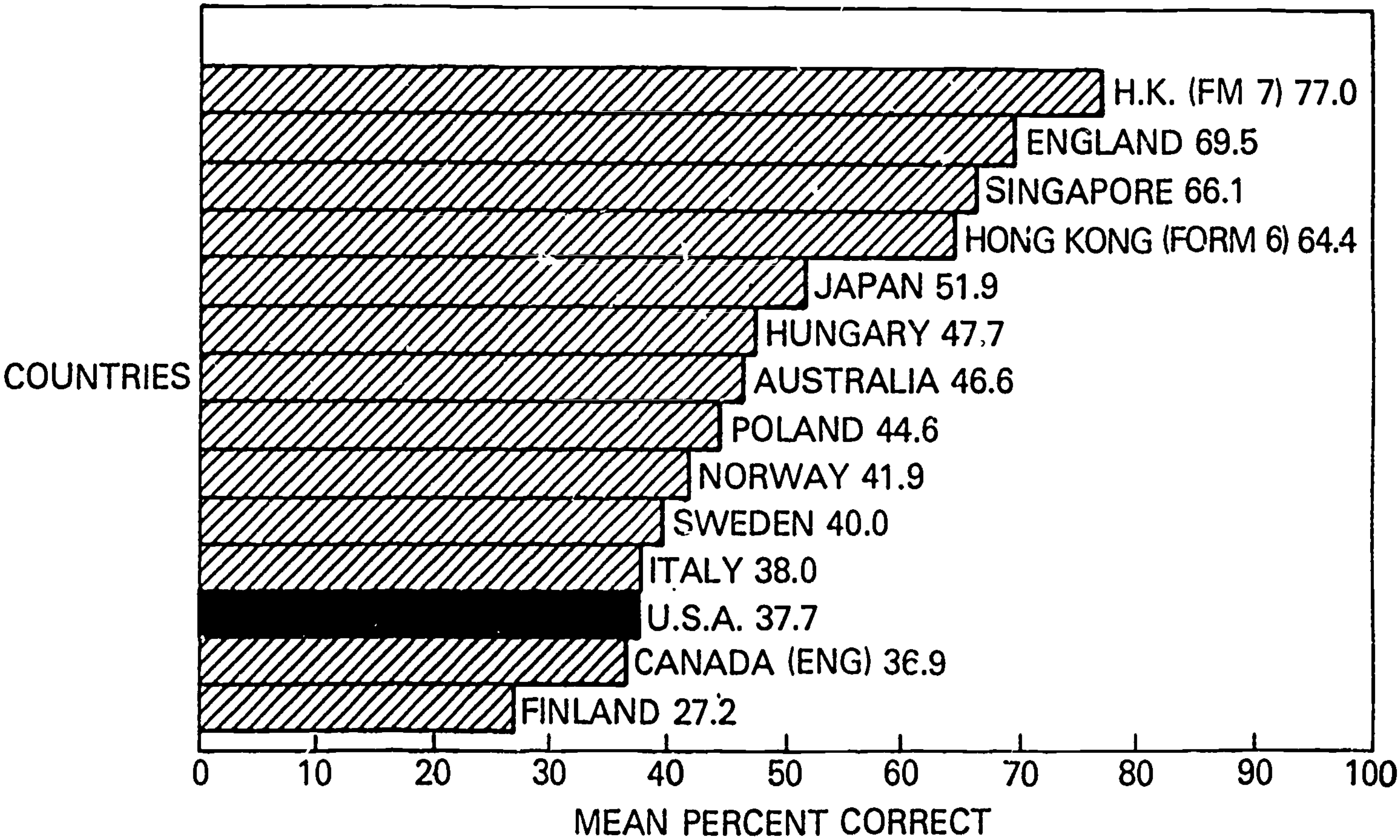
GRADE 5 SCIENCE ACHIEVEMENT IN 15 COUNTRIES



GRADE 9 SCIENCE ACHIEVEMENT IN 16 COUNTRIES



CHEMISTRY SPECIALISTS (MEAN PERCENT CORRECT)



PROFICIENCY LEVELS

LEVEL 150 — KNOWS EVERYDAY SCIENCE FACTS

LEVEL 200 — UNDERSTANDS SIMPLE SCIENTIFIC PRINCIPLES

LEVEL 250 — APPLIES BASIC SCIENTIFIC INFORMATION

LEVEL 300 — ANALYZES SCIENTIFIC PROCEDURES AND DATA

LEVEL 350 — INTEGRATES SPECIALIZED SCIENTIFIC INFORMATION

THE NATION'S REPORT CARD naep

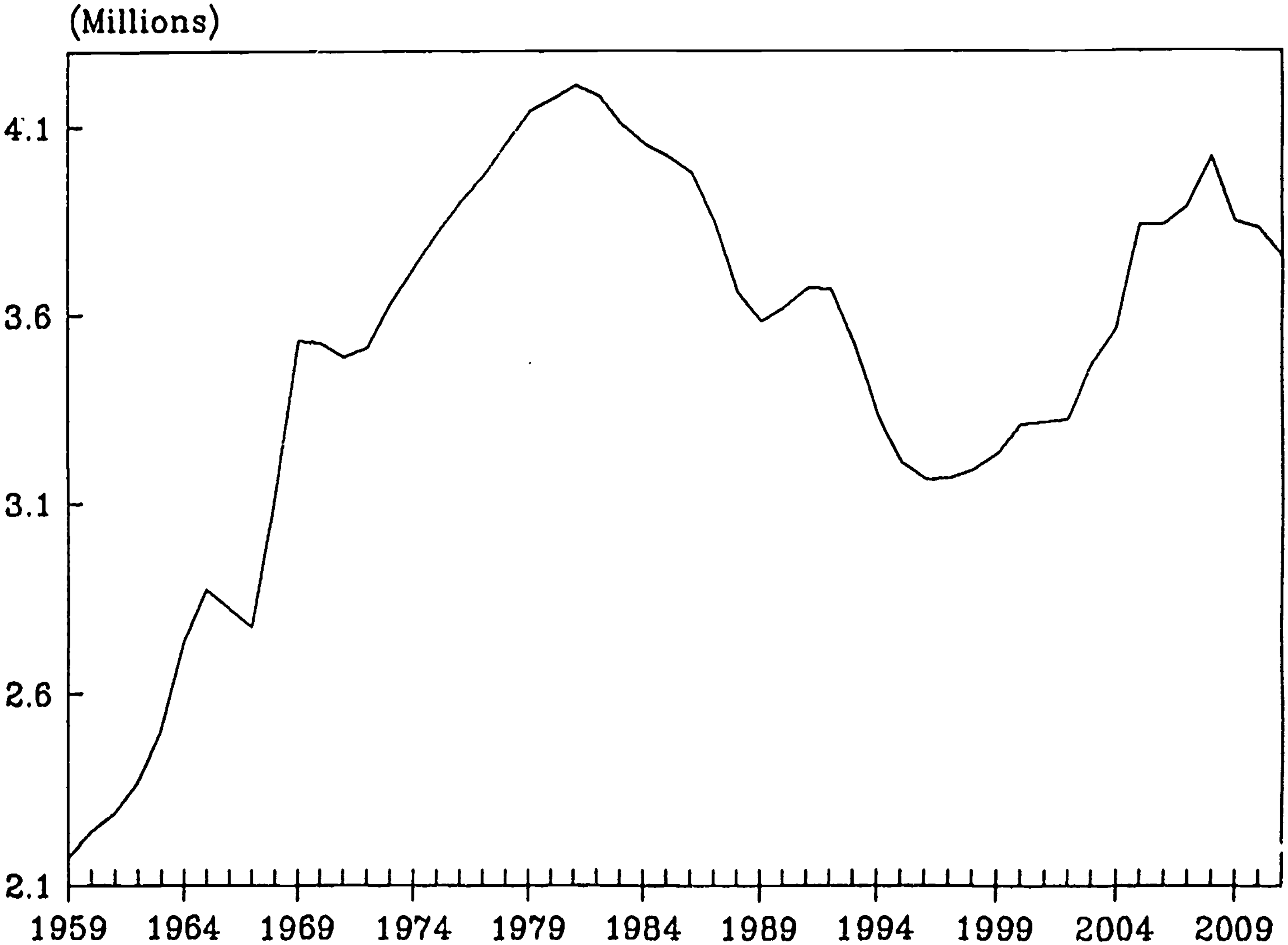
AGES 9, 13, AND 17: TRENDS IN THE PERCENTAGE OF STUDENTS AT OR ABOVE THE PROFICIENCY LEVELS

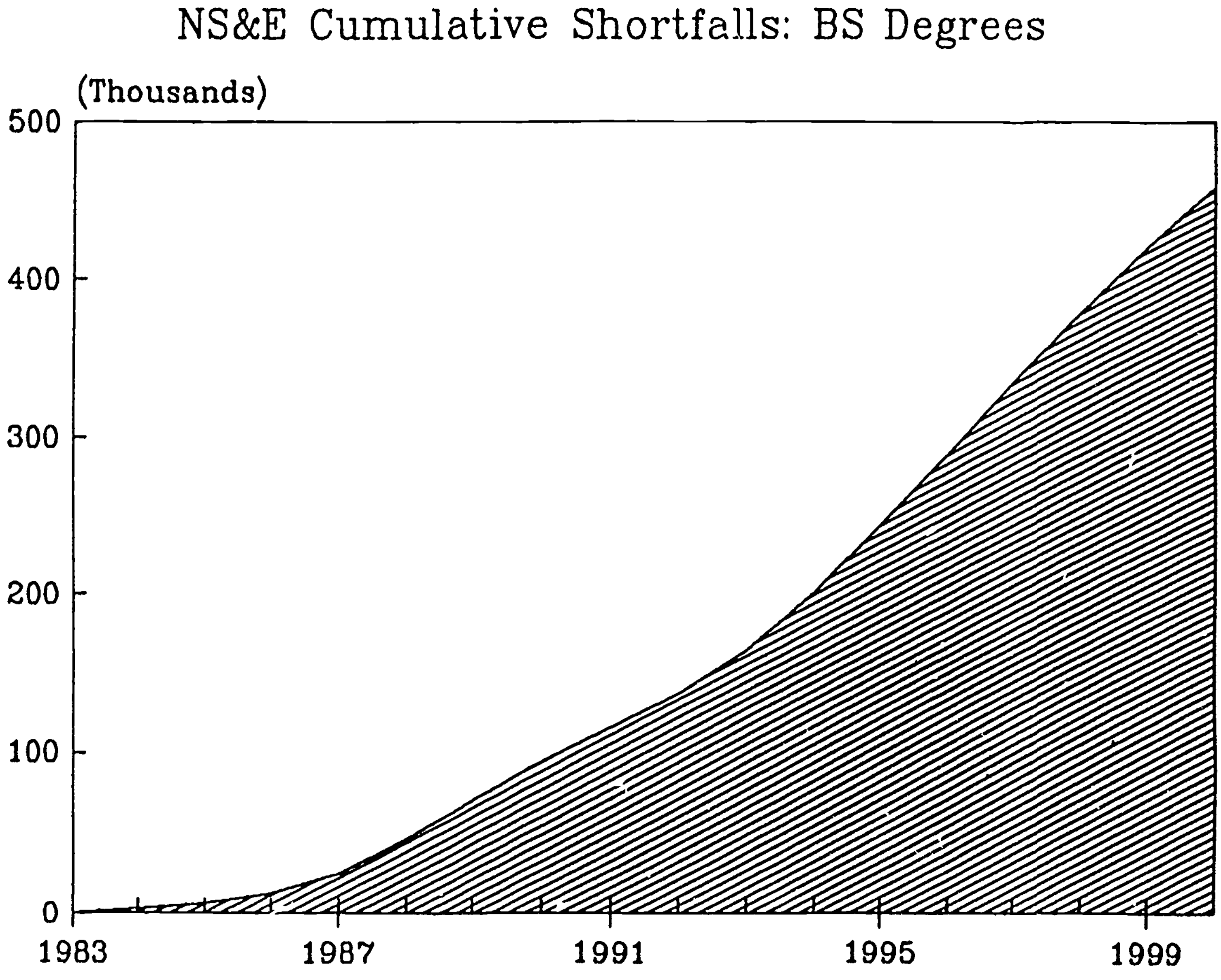
PROFICIENCY LEVELS	AGE	ASSESSMENT YEAR 1977	ASSESSMENT YEAR 1986
LEVEL 150 KNOWS EVERYDAY SCIENCE FACTS	9	93.6	96.3
LEVEL 250 APPLIES BASIC SCIENTIFIC INFORMATION	13	49.2	53.4
LEVEL 350 INTEGRATES SPECIALIZED SCIENTIFIC INFORMATION	17	8.5	7.5

THE NATION'S REPORT CARD naep

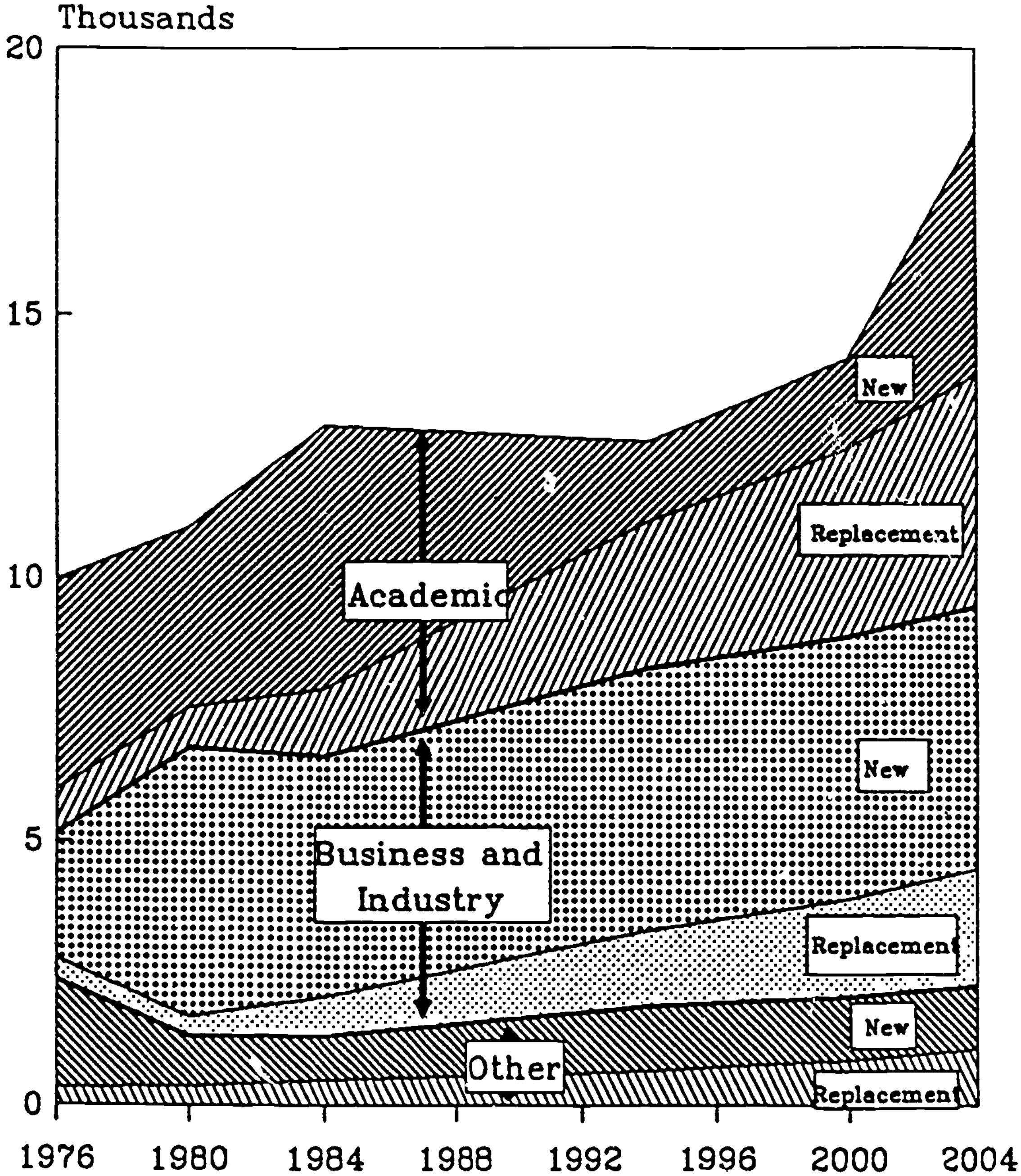
5

Number of 22-Year-Olds in the United States




NS&E Cumulative Shortfalls: BS Degrees
(Thousands)
500
400
300
200
100
0
1983
1987
1991
1995
1999

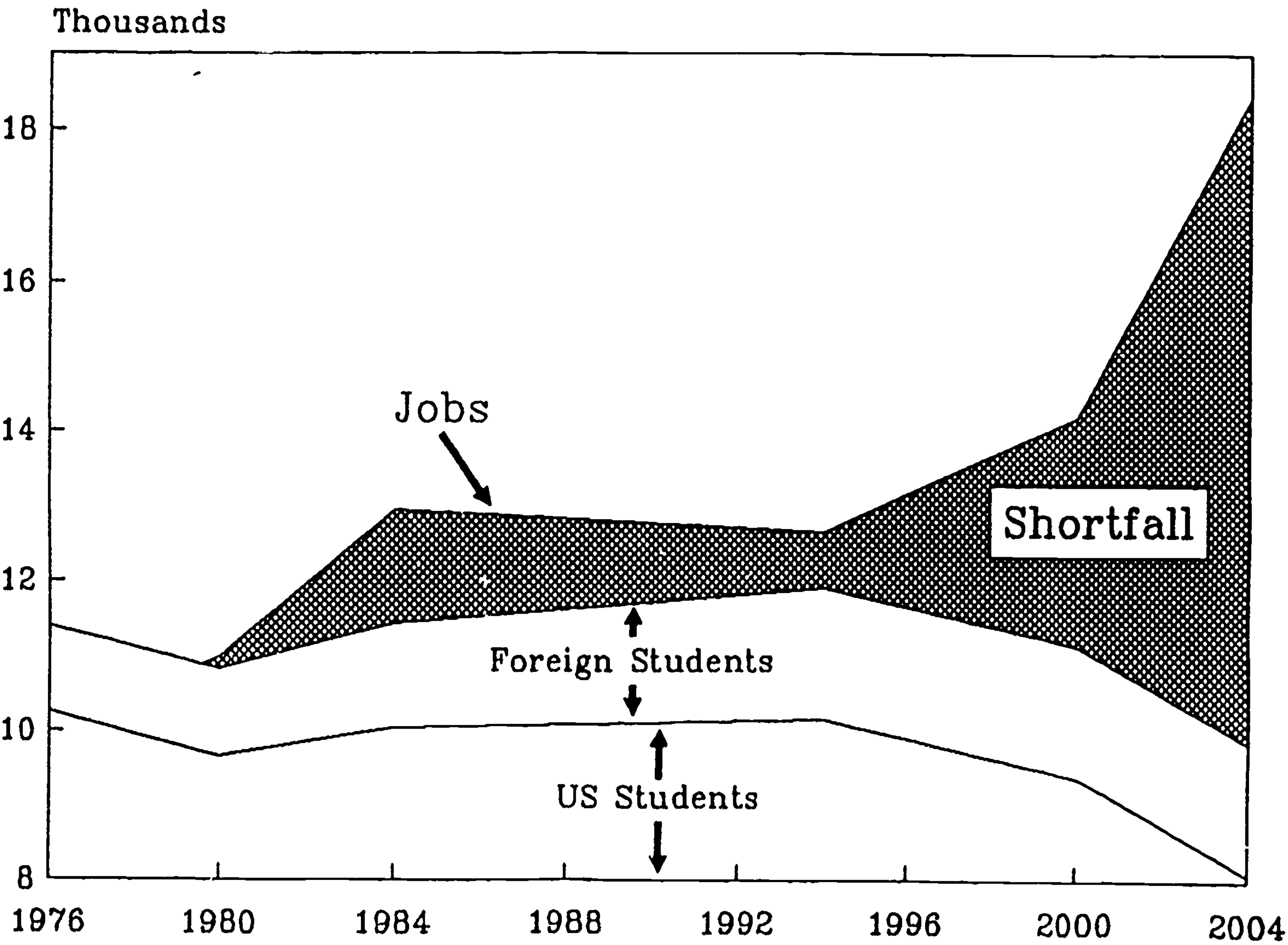
Available PhD Positions for Natural Scientists and Engineers



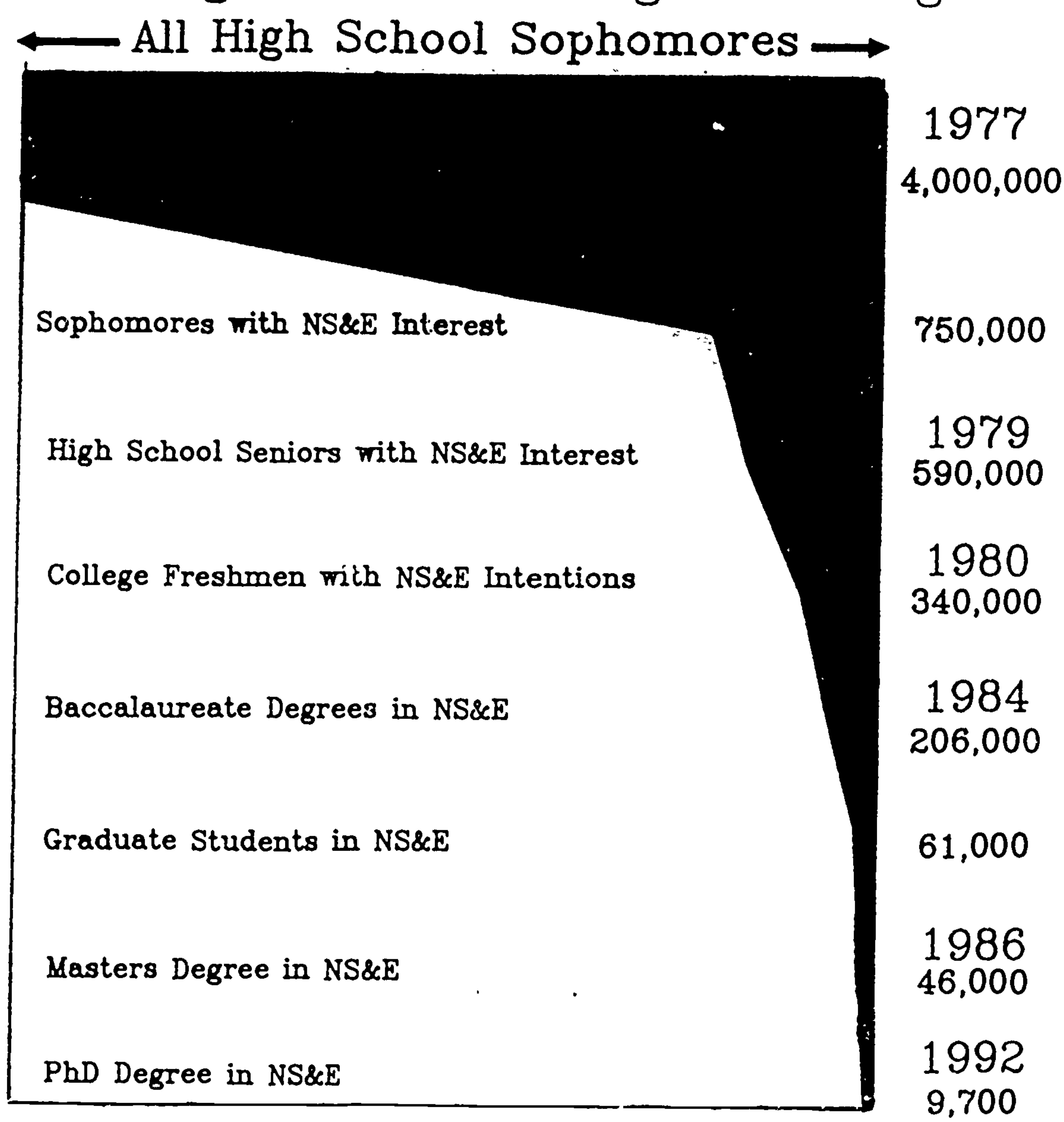
8

Average Annual Production of Ph.D.s

NS & E Ph.D. Degrees from U.S. Institutions



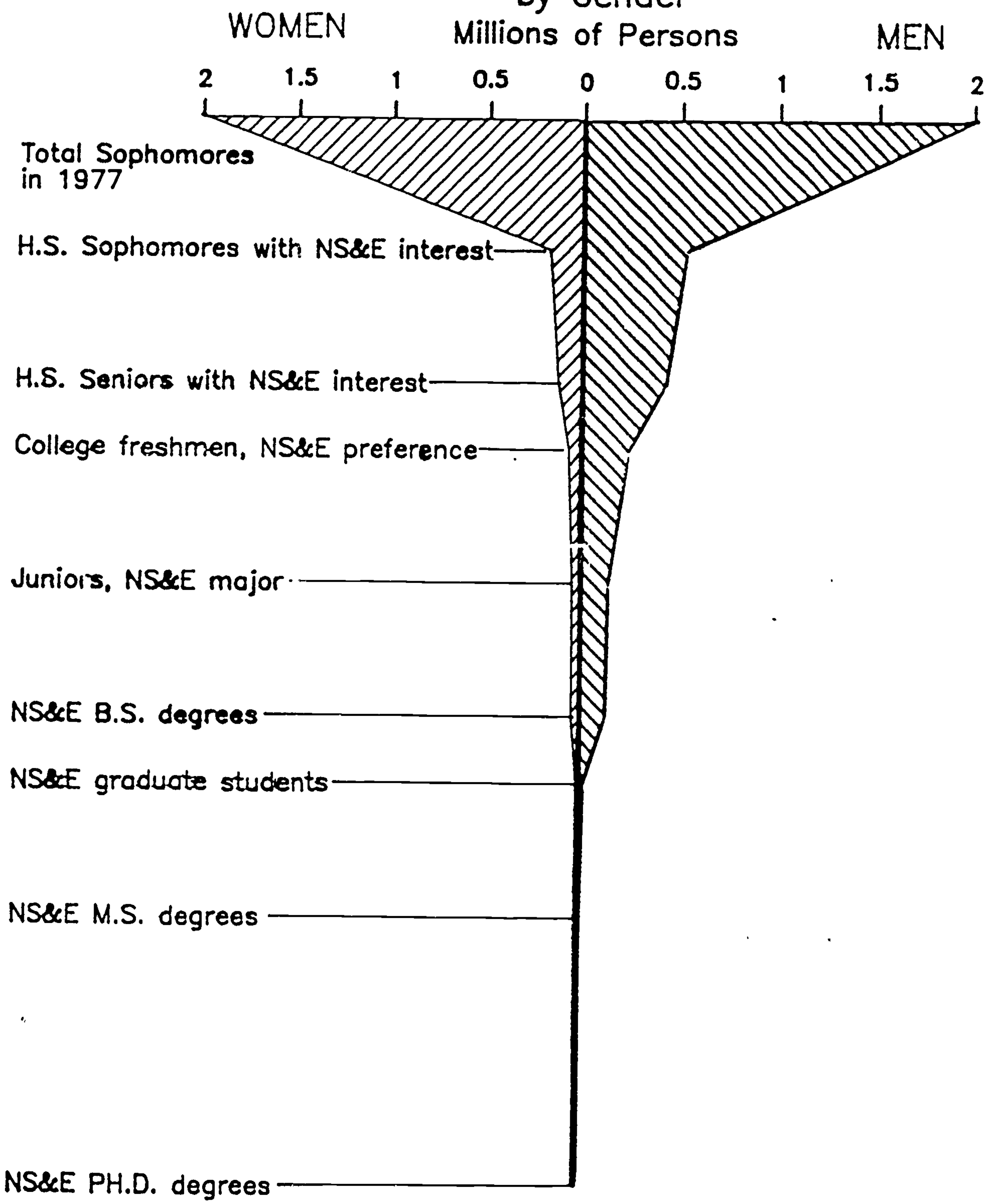
Persistence of NS&E Interest from High School through PhD Degree



(The Pipeline)

10

Persistence of Natural Science & Engineering Interest by Gender



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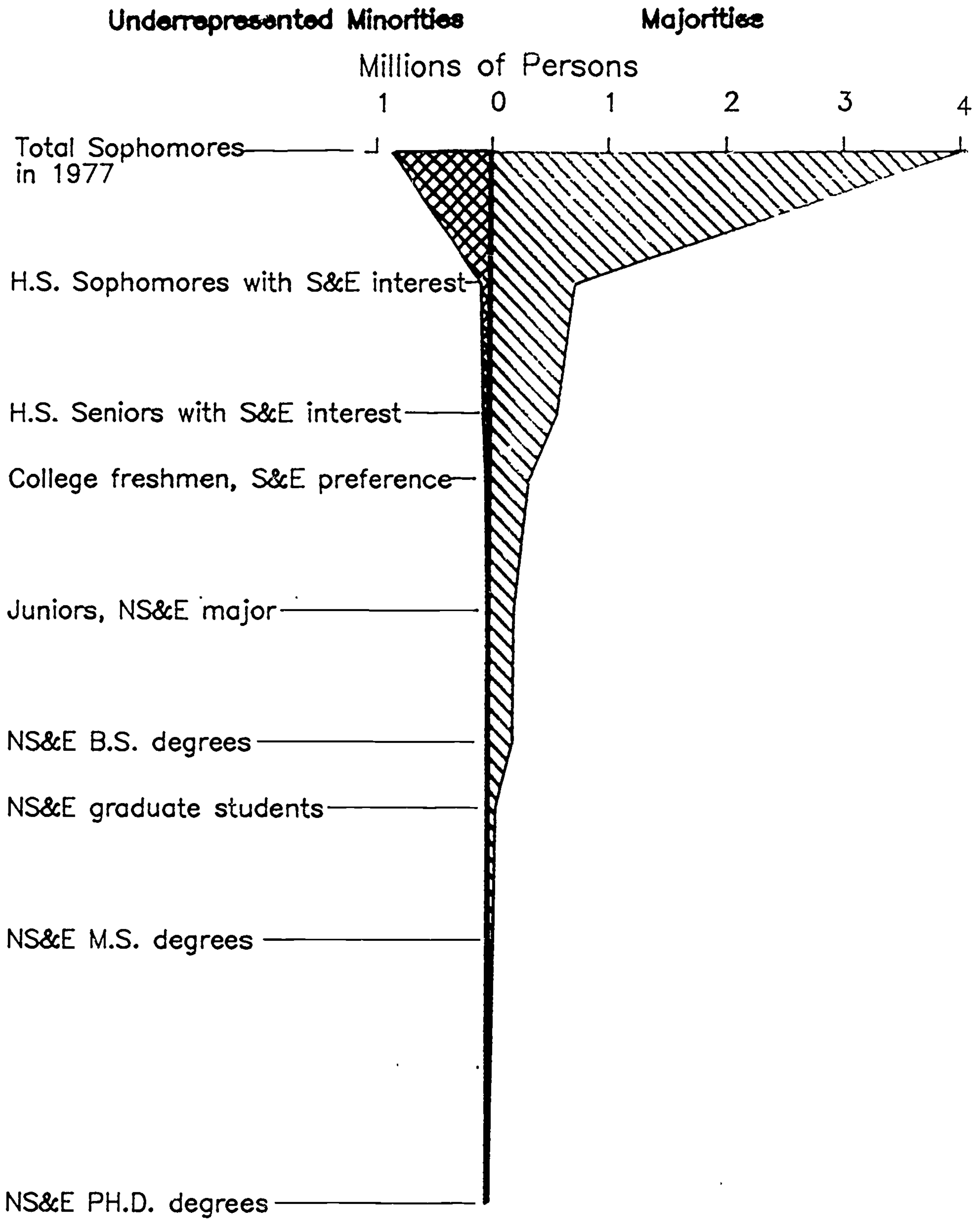
Persistence of Science & Engineering Interest by Ethnic Group



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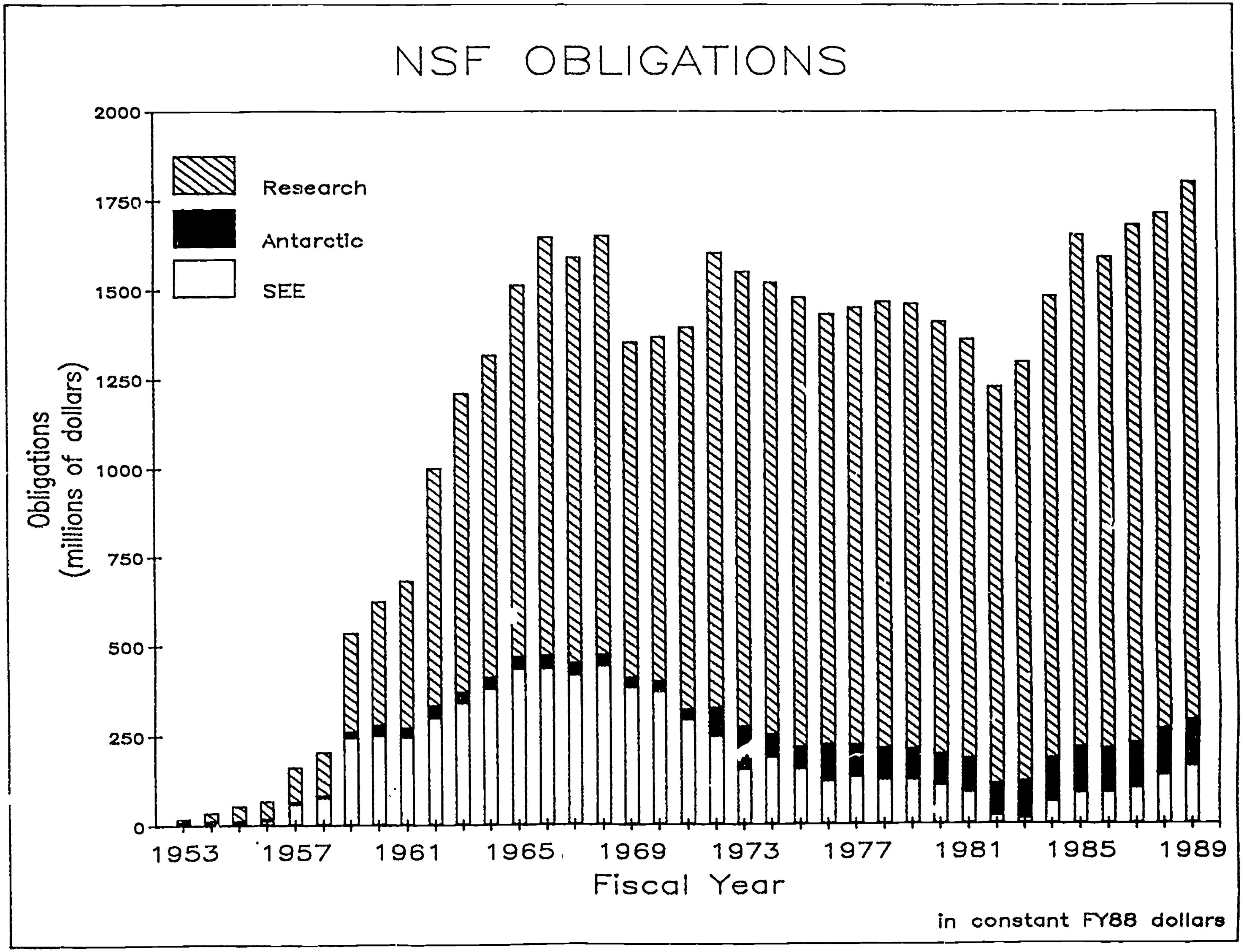
NSF OBLIGATIONS
Research
Antarctic
SEE
Obligations (millions of dollars)
0
250
500
750
1000
1250
1500
1750
2000
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
Fiscal Year
in constant FY88 dollars

Obligations for Science & Engineering Education
as percent of NSF Budget