Phoenix MATH TALK

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Latest copy with all changes made by Bill Hines on text & graphs.

Ann

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Ann:

Here's your copy back. Thanks.

REMARKS OF BASSAM Z. SHAKHASHIRI
ASSISTANT DIRECTOR OF THE NATIONAL SCIENCE FOUNDATION FOR SCIENCE AND ENGINEERING EDUCATION
AT THE JOINT WINTER MEETING OF THE MATHEMATICAL ASSOCIATION OF AMERICA AND THE AMERICAN MATHEMATICAL SOCIETY, PHOENIX, ARIZONA, JANUARY 13, 1989

Developing a National Will to Enhance the Quality of Science and Mathematics Education in America

Thank you for this opportunity to talk with you today about the state of science--and particularly mathematics--education in the United States and what we can do to improve it. I know the old joke about the fellow who says, "I'm from the government and I'm here to help you," but here, I believe, is a case where we from the government can help you from academia and the private sector to mobilize our resources for the resolution of an educational crisis that threatens to engulf us.

On New Year's Day, the front page of the New York Times Book Review carried an article on innumeracy--the mathematical equivalent of illiteracy--by a man who is at once both literate and numerate; one of your own, as a matter of fact, Professor John Allen Paulos of Temple University. Professor Paulos, who has several books to his credit including one defining and examining innumeracy, discusses the implications for our society of a widespread inability on the part of its members to grasp and deal with the simplest, most essential numerical relationships.

It is probably true that the typical American's reaction to mathematics is "MEGO," M-E-G-O, short for "my eyes glaze over," and indeed this attitude even borders on the stylish. As Paulos says in his thought-provoking article (which I heartily commend to your attention), the underlying cause for this general turnoff on mathematics is a set of attitudes and misconceptions that--and I quote Paulos--"welcomes and even encourages inadequate mathematical education and pride in ignorance"--close quote--a pride that permits an otherwise educated person to proclaim, "Math was always my worst subject."

Someone was carrying on in this vein on a talk show program the other day back in Washington, D.C., where I live, and after telling how he never could learn arithmetic in school went on to say that he taught himself long division by calculating batting averages for the sandlot baseball team he played on. Maybe that's the answer: make it interesting, make it fun, make it relevant, and kids will learn it, and once they learn it they won't forget. Professor Paulos, whom I will quote just this final time, comments at the end of his Times piece, "It is distressing that a society and culture that depend so critically on mathematics and its uses should nevertheless seem so indifferent to the innumeracy and general mathematical ignorance of even its brightest citizens." Of course, with millions of Americans just barely able to read signs and simple directions, the same thing could be said about illiteracy, but that's another story. On the subject of innumeracy, we've got to do something about it, and who can do the job better than those among us who by training are the most numerate of all our citizens--YOU? I have some suggestions about what mathematicians can do in this regard, especially to those of you who are engaged in educating tomorrow's citizens and leaders.

In my judgement, the situation that we face now is by far more critical and more consequential than what we faced in the immediate post-Sputnik era and it is so for many reasons. Let me quickly share with you three major reasons. The first one is that the population of the United States in the past 30 years or so has increased by about 50 million people. To put that number in perspective, that turns out to be approximately the population of Great Britain. So the increase, the delta, has been about 50 million people. What does that mean? It means that we have more students to teach and we need more qualified teachers to teach them. We need more qualified teachers at all educational levels. The first reason is the change in scale and we have to make adjustments because of that change in scale. The second reason is that for our country to maintain its international preeminence in the global economy, in science, in technology, in the arts, in the humanities, in all walks of life, we need to have a good supply of scientists and engineers coming through our educational systems. By the way, that's what NSF set out to do in the immediate post-Sputnik era. All the teacher institutes, all the curriculum reform developments were aimed at increasing the supply of mathematicians, scientists and engineers. And to a very large extent, NSF succeeded in that regard. What I am saying is that we now have to maintain that and some demographic data that I will share with you very shortly are cause of alarm to all of us. The third reason as to why the situation is now more critical and more consequential than what it was in the immediate post-Sputnik era, and in my judgement, the most important of all three reasons, is that we now live in a much more advanced scientific and technological society than we did back then. It is the education in science and technology of the non-specialist that we have to pay very special attention to. We need to have an educated citizenry that can distinguish between astrology and astronomy. We need an educated citizenry that understands the complex issues of animal rights. We need to have an educated citizenry that understands issues related to pollution control. We need to have an educated citizenry that understands the advances in the nutritional sciences and their effect on our health. Otherwise the citizenry that we belong to may be bamboozled into making foolish decisions.

So the mission of the National Science Foundation, now-a-days, is a dual one. The first one is to see to it that the scientific personnel, the so called pipeline, is adequately staffed and adequately maintained. Seeing to it that we have a good supply of scientists, mathematicians, and engineers coming through the educational system. And the second one is to see to it that we have an educated citizenry that is supportive of what the scientists, mathematicians, and engineers do. The way I put this sometimes to have the citizenry, at least, be tolerant of what the scientists and mathematicians do. The issue of literacy in science and mathematics is a very important one that has to be addressed head-on. In this connection, I'd like to have an analogy. This analogy comes from sports. Just like we have professional basketball players, professional baseball players, professional football players, professional hockey players, etc., we also have sports fans. Without those fans, the entire professional sports enterprise would be nothing, and you know that's not an exaggeration. So that's what we need. We need scientists and we need science fans. We need to cultivate the development of active participation on the part of science fans. We want the science and math fans themselves to be physically fit. We want them to be scientifically literate and numerate. If you don't like that analogy as some people don't, let me offer another one. We need good orchestra players and we need audiences that appreciate what the performers are doing.

We who were born in the first half of the 20th century--and I suspect that this includes the majority of us here today--grew up thinking of the 21st century, and even its immediate precursor, the year 2000, as almost infinitely remote. But here, today, we are closer to the millennial year 2000 than to the bicentennial year 1976 that we all remember so well--and we still talk about "the year 2000" as if it were centuries away. Before some linguistic and mathematical purist buttonholes me to protest that the 21st century will begin in 2001, not 2000, let me point out that I referred to 2000 as the next century's immediate precursor. The 21st century is still 12 years off, but that's hardly a cause for complacency when we consider the task ahead of us in bringing an informed body politic into that new century just 144 months from now--and how can any body politic in this day and age be truly informed if it is largely innumerate?.

The college class of 2001, right now, is midway through the third grade. It behooves us to wonder what sort of fundamental knowledge of mathematics and other sciences they are receiving--to say nothing about other school subjects that we are not here today to discuss. On the basis of an international study I'm sure many if not most of you are aware of, I wouldn't be too sanguine about what our youngsters are absorbing in the classroom.

Last March the International Association for the Evaluation of Educational Achievement published the results of this study, which compared American kids' scientific information with that of contemporaries in a dozen or so other countries in varying stages of development. The results were not calculated to reinforce America's cherished image of itself as Number One.

The best performance by American students as a group **[Fig. 1]** was at the fifth grade level--boys and girls eleven years of age, and let me say that the best was none too good. Among 15 countries large and small, advanced and developing, the United States ranked right in the middle: No. 8. Among ninth graders, 15-year-olds **[Fig. 2]**, the U.S. ranked 14th in a field of 17.

But that's not all. Among 12th grade students who apparently were serious about science--all of them had two years of some science in high school--the United States performance ranged from poor to shameful. In physics **[Fig. 3]** the U.S.

ranked 9th in a field of 13, in chemistry **[Fig. 4]** 11th and in biology **[Fig. 5]** 13th--right at the bottom, and biology, mind you, is the most widely taught of the natural sciences in American secondary schools.

The quick-eyed among you, by the way, may have noticed that there were 14 bars in each of these last three charts, but I spoke in each case of only 13 nations. The explanation is that in these comparisons of specialists, Hong Kong had two entries: sixth form and seventh form. It might be worth noting that in physics and chemistry, Hong Kong seventh formers placed No. 1. Eighteen-year-olds in Singapore were the top of the heap in biology.

In your own field, the results of another survey shows that American achievement in math is no more praiseworthy. The Second International Mathematics Study of twelfth-grade students in 15 countries found the U.S. in 14th place **[Fig. 6]** in algebra, and in 12th place in **[Fig. 7]** elementary calculus and in **[Fig. 8]** analytic geometry. Again, kids from Hong Kong were right up at the top, in all three categories this time. I wonder what they are trying to tell us; maybe they are trying to improve their position in the international job-market place in anticipation of Big China's takeover of the crown colony in 1995.

I'd like to note in passing one thing that really surprised me, and that was the low ranking of Hungarian mathematics students: almost as low as American students in algebra and even lower in calculus and geometry. This from Hungary, if you please, the country that before World War II gave this century some of its brightest mathematical minds, from John Von Neumann to Paul Erdos.

If you did not think that the low achievement of American students in mathematics and indeed all the sciences is a cause of concern to all of us, you wouldn't be here listening to me, and if I didn't think it was important, I wouldn't be here talking; we'd all be outside enjoying what passes for wintertime in Arizona, which has a lot more to offer than what the comedian Mark Russell has said of it: "One hundred thousand square miles of Kitty Litter."

Here we are, demonstrating our mutual interest in a serious national problem that's too big for any one, or any small group of us, to solve. We've got to work together to improve the scientific literacy--the numeracy, if you will--of our young, and that's what I meant at the start when I said, "I'm from the government and I'm here to help you."

The National Science Foundation can't do it all; indeed, it cannot--for a variety of reasons--be any more than a catalyst, which as a chemistry teacher I can't resist defining for you: "Catalyst: A substance, usually present in small amounts relative to the reactants, that modifies and especially increases the rate of a chemical reaction without being consumed in the process." That's us; a catalyst for change (to borrow the slogan of the John D. and Catherine T. MacArthur Foundation, which shares with NSF the privilege of being one of the underwriters of National

Public Radio programming).

In our role as catalyst for change in science, mathematics and engineering education we'll put a little money and a little effort in--a little relative to the amount of both that will be needed--and if we do it right, we will speed the rate of change (one hopes!) and will avoid being consumed in the process.

It is not our job but that of grassroots America to provide most of the funding and most of the effort, because education is a state and local responsibility, not a national one, under our system of government. And that is why, really, NSF is a catalyst in this mix.

Why do I persist in using the analogy of a catalyst? Why not talk of NSF's contribution as a leaven--a yeast added to the other ingredients to make things bubble and rise? I'll tell you why: In the context of the total national outlay for education, NSF's share is much smaller than the amount of yeast in a batch of dough. Let me be specific:

This year, in the United States, education at all levels will account for around 300 billion dollars--one of the major accounts, you will agree, in the national economy. The budget this year of the office I head at NSF--the Directorate for Science and Engineering Education--is $171 million dollars, of which about 147 million is available to use in influencing the future course of science and engineering education at the precollege and undergraduate levels. Unless my pocket calculator is out of whack, that means that our share--NSF's share--of the overall educational mix is a little less than one-twentieth of one per cent, and that's why I say it's more like a catalyst than a leaven.

You are probably wondering how mathematics has fared in the NSF funding for educational activities. In fiscal year 1988, which ended last September 30, you'll be happy to know that the queen of sciences was treated royally: Out of about 110 million dollars approved in that year for projects aimed at improving of education, mathematics got by far the largest single bite--roughly 20 per cent. The nearest disciplines--chemistry, physics, and biology--each got a little over 9 per cent of the total, and engineering almost 5 per cent of the total.

The National Science Foundation first got into the science and engineering education business in response to the shock of Sputnik--the Soviet Union's October surprise of 1957. You may remember the preparedness hearings on Capitol Hill, chaired by Lyndon Johnson--then the Senate majority leader--at which our educational system was weighed and found wanting (even as is happening today, a generation later). **[Fig. 9]** **[Fig. 10]** **[Fig. 11]** The S-E-E function (science and engineering education) burgeoned, peaked in the late '60s--just about the time Project Apollo was going to the moon and we were Top Nation again (or thought we were). Support of education fell off quickly, while research support (the main activity of NSF) and the Antarctic program remained fairly constant over the years or even grew.

Taking a closer look at the SEE part of the NSF budget in this same time frame **[Fig. 11]**, we see that while the whole enterprise suffered in the post-Apollo letdown, support of pre-college education suffered most, and with the reordering of priorities that came early in this decade, support of pre-college and undergraduate education was zeroed out in the budget for fiscal 1982. We've jumped back in the last six budget cycles, and if you weren't a sophisticated, numerate audience, I'd flash this transparency before your eyes **[Fig. 12]** to show you what a great operation we have going today. But you are sophisticated, and you are numerate, and you're not fooled by charts that display current-year dollars. For comparison purposes, constant dollars are what count, and here is **[Fig. 13]** the Science and Engineering Education picture on that basis: constant 1988 dollars. We are devoting less than half the resources today to pre-college educational support than we did at the post-Sputnik peak, despite the fact that the educational crisis today is fully as great, if not greater, and the number of students for whom a decent education is needed is about 30 per cent larger.

These numbers pretty well define the nature of our role at NSF, over time, as a catalyst for change. A bright and perceptive young mathematician in my office back in Washington commented the other day that the default setting on education in the United States is the status quo, that change comes only with prodding. Right now the default setting on mathematics education in the United States (as we have seen from the Second International Mathematics Study) is woefully low. We've got to set it higher, because a command of mathematics is absolutely essential to an understanding of science and engineering--disciplines that in turn are essential to our status as a leader in a technological world.

Mathematicians must continue to respond--as you have been doing--to our national need for imaginative approaches to the enhancement of education in their discipline. The money for these projects may come from the government but the ideas behind them must come from you. We all are aware that if we ignore or shortchange mathematics education nationally, we do so at our peril.

Change comes only with prodding, as my associate back in Washington observed, and I'm here to prod you a little. This is the time in the sermon when the preacher nods to the ushers and they start up the aisles with the collection plates. I'm about to do a little prodding, to suggest to you as professional mathematicians what you can do as catalysts for change, quite independently of what NSF is doing. I'm not asking for money but for something more precious--brainpower, effort. None of you, individually, will be able to do all the things I am about to suggest, but collectively you can--and I hope you will.

Every one of you lives in a school district, and I will hazard a guess that not many of those districts are without problems related to the quality of instruction. Because of the essentially local nature of education in the United States, these are <u>your</u> schools, and <u>you</u> are paying for them; as a matter of fact, you are paying plenty--nationally the number is pretty close to 200 billion dollars for K-through-12 education, paid for largely by local taxes.

So my first suggestion is, get involved; work informally with your local schools. Chances are those in charge will welcome your expertise; the worst that can happen is you'll be told to get lost--and that's something for you to remember when the next school board election rolls around.

Still at the local level, work with schools on a more formal basis to develop test beds for innovative curricular materials, teacher enhancement programs, new models for teacher preparation, and materials to be used outside the classroom. Some of this may involve more time and effort than you are willing to devote pro bono; keep in mind that there may be money out there for support of such activities. Professional organizations, such as your own, are frequently used channels for funds from the NSF for state and local programs.

Carrying this line of activity a step further, work with state or regional groups in your professional associations in developing networks of mathematics professionals.

Next: the National Research Council's Mathematical Sciences Education Board, in two weeks' time, (Jan 26) will issue a report entitled "Everybody Counts" that will lay out in plain language the need for mathematics education reform and propose directions that this reform should take. This will mesh with a new set of standards for pre-college level mathematics that the National

Council of Teachers of Mathematics will issue in March. Get these materials when they become available and familiarize yourself with them. Consider what these new directions might mean for the nation's schools, colleges, and universities.

For those of you in academia, pay attention to your undergraduate curriculum. Are you happy with the status quo? Are students appropriately prepared? What do you do to cope when they are not? Ask yourself what you are really teaching: Are you teaching fundamental concepts and ideas, or are you teaching techniques? Do you have the resources to do your job right, to teach these fundamental concepts and ideas? NSF is focusing at present on calculus. Go beyond calculus.

Again, as academics, do a little missionary work among the undergraduates in your orbit. Talk to them about career plans; point them, when you can, toward advanced work in mathematics. Let them know about NSF graduate fellowships--we are financing fellowships for the next academic year to the tune of 38 million dollars--2,000 fellows. Suggest that your best and brightest apply for a piece of this action, and when they do, follow up with encouragement and letters of support.

Work to have your campus designated as a site for the REU program--Research Experiences for Undergraduates, which is one of several efforts supported by NSF to stimulate the interest of students at that crucial period when they make career choices with which they'll stick--or be stuck--for the rest of their lives. If you'd like to learn a little about this program, contact the Division of Mathematical Sciences where Judy Sunley is the Division Director.

Look into our "Young Scholars" Program for pre-college students at the middle-school grades and above. There's a wealth of brains and talent in our young people; all it needs is a little encouragement.

Journeyman, working academics need encouragement, too, and there's something you can do to help your junior colleagues along. You have a promising young man or woman in your department with a flair for research? Give him--or her--a lift in the form of a nomination to the Presidential Young Investigator program, which carries White House prestige as well as funding.

Find out more about NSF's faculty enhancement program and other undergraduate activities by contacting the Division of Undergraduate Science, Engineering and Mathematics Education where Bob Watson is the Division Director.

Find out more about the precollege programs in mathematics and science.

-Curriculum

-Teacher Enhancement

-Presidential Awards

Finally, there's something else you can do to help catalyze change: Join the NSF staff and be a catalyst yourself; we can practically guarantee that like any true catalyst you will not be destroyed in the course of the action. Like the U.S. Marines, the National Science Foundation is looking for a few good men--and women--and you could be among them. Though perforce a part of the bureaucracy, we at NSF try not to be bureaucrats, but rather to retain the outlook we brought with us to Washington. I myself am a tenured professor at the University of Wisconsin-Madison; my principal associate in the Directorate of Science and Engineering Education is from the University of Illinois. Let me rattle off some names that won't be strange to you: John Thorpe, Bill Lucas, Gail Young, Louise Raphael, Florence Fasanelli, Chris Stevens, Tom Berger, John Bradley, John Kenelly--mathematicians all, and all of them present or recent members of the staff of SEE. Public service? Try it; you'll like it. If you do come aboard you'll be among friends. Want some more? Henry Pollak, Anneli Lax, Diane Bishop, Joe Crosswhite, Jaime Escalante, Melvin George, Ken Hoffman, Irwin Hoffman--again, mathematicians all, and all members of our Advisory Committee.

I'd like to raise your consciousness now about a large and important mass of brainpower that has historically been excluded, or at least ignored, in science, mathematics, and engineering--women and ethnic minorities. They need all the help they can get, and <u>we</u> need <u>them</u>. As you probably know, females are in the majority in the adult segment of our population; as you may <u>not</u> know, studies of population trends in the United States show that by the end of this century, 85 per cent of those entering the labor force will be either women or minority males.

There's another underutilized group in our society: those with physical disabilities. Consider Stephen Hawking, the English cosmologist. It's hard to imagine a person more severely impaired physically than Hawking--he cannot even vocalize intelligibly to strangers--yet he has developed a view of the universe that has taken the intellectual world by storm, and has even produced a book--"A Brief History of Time"--that quickly became a dark-horse best seller after its publication last year.

This underrepresented pool of talent--women, minority males, and the disabled--must not be lost to us in the years ahead. "A mind is a terrible thing to waste" is the slogan of the National Negro College Fund, and those words hold equally true for other ethnic minorities, for women, and for the physically handicapped. As things stand, so much is stacked against them that these individuals often drop out when, with just a little bit of effort, they could be persuaded to hang in there.

Let me give you a datum-point to consider. Do you know how many blacks received Ph.D. degrees in 1986--not just degrees in mathematics or even the sciences as a whole, but all the Ph.D. degrees awarded in this country in every discipline from nuclear physics to dog grooming? Just 820, and that was down from 1,116 black Ph.D. recipients in 1977. Among these 820 there were only 25 blacks who got Ph.D. degrees in all the physical sciences--and there's nothing to suggest that things are improving.

I've talked so far about the foreseeable problem of 21st century personnel shortages in science and engineering without really defining it, so let me show you a few pictures that will serve to fill in these blanks. We are close enough now to the 21st century that we do not need to fall back on estimates and projections for such matters as the size of the pool of talent available to us in 2000 and beyond.

Here's a curve **[Fig. 14]** showing, by year, the number of 22-year-olds in the United States, from a low of a little over 2 million in 1959 (when the baby boom's impact on the educational system was just beginning to be felt) until 1981, when there were roughly twice that many 22-year-olds. Twenty-two, of course, is the age when people typically graduate from college. The national population of 22-year-olds peaked in 1981, and as far ahead as we can look, we don't see that number--roughly 4 1/4 million--being achieved again.

There's something nice about this curve--"nice" in the sense of dictionary definition No. 6: "marked by great precision." There's no guesswork in this curve, because all the individuals represented are right here on earth; as I mentioned earlier, the college graduating class of 2001 is in the third grade of elementary school today. The curve goes off the right-hand side in the year 2011, which is when children born this year--1989--will be graduating from college.

While all this is going on, other cohorts will be passing through the pipeline of life at exactly the same rate, and we can make some pretty accurate assumptions about them, too, because like the 22-year-olds, they're already here. Let's consider the case of yourself or one of your professional colleagues, age 55, who is, perhaps, an insurance company chief actuary or a university professor of mathematics. He--or she--was born in 1934, was 22 years old in 1956--just before the starting point of this transparency--and will retire around 1999. We're going to need a replacement for that individual.

Is there going to be a replacement available? It's by no means clear that there will be. **[Fig. 15]** This chart, admittedly a projection (at least, the right-hand half is) strongly suggests that from about 1994 on, as far as eye can see, people at the educational level we are talking about--Ph.D. holders--are going to be in increasingly short supply, with replacement requirements growing faster than new requirements in academia, and the other way around in business and industry.

We don't have to get as far up the educational ladder as [Fig. 16] Ph.D. to see the crisis coming. We know, on the basis of long experience, that about 4 per cent of 22-year-olds win baccalaureate degrees in the natural sciences and engineering--we [Fig. 17] can see a shortfall in BS holders that is already developing and is going to get rapidly worse. **[Fig 18]** Between now and 2000 we will have a cumulative shortfall of 450,000 BS degrees--with half the shortfall occurring in the last six years, from 1994 on.

[Fig. 19] [Fig. 20]

It's manifestly too late to do anything much about 1994; that year's college graduating class is in the 11th grade today and its members probably have pretty fixed opinions about science--many of them are ag'in it--but the world isn't coming to an end in 1994 (at least I hope it isn't) so we've got to plan for the longer haul.

In the "out years," as we say in Washington, there's a long list of big-ticket items that will impose heavy demands on our nation's future brainpower--the superconducting supercollider, the space station, the project to map the human genome, the battle against AIDS, the strategic defense initiative. Think about any one of them without mathematical inputs.

"The past is prologue," as it says on the National Archives building in Washington, so let's look at what's been happening in the educational pipeline over the last couple of decades. **[Fig 21]** We'll start with the entire cohort of young people who were high school sophomores in 1977--four million of them. They were surveyed as to their interest in the natural sciences and engineering, and out of the 4 million only 750,000 expressed any interest. So already science had lost the attention of more than 80 per cent of its potential audience.

They were surveyed again as seniors in 1979, and of the three quarters of a million originally interested fewer than 600 thousand were still turned on. That's a 25-per cent loss, almost, out of this extremely leaky pipeline in just two years.

A year later, in 1980 as college freshmen who had to think seriously about major fields of study, the group was polled again and only 340,000 still were in the running--a further loss of 40 per cent. By now, obviously, what we have is not a leak but a hemorrhage. And by the time these college freshmen of 1980 graduated in '84 forty per cent of the remainder had changed their minds about science as a career.

To make a long story short--it's there in front of you on the screen--fewer than 10 thousand of those science-oriented graduates in the class of '84 went all the way, and are in line to get their Ph.D in 1992.

Take one last, quick look at this curve and then look at another **[Fig 22]** based on the same body of data but differently focused. Note that as bad as the dropout rate was for males all long the line, it was far worse for females, and if you look at this one **[Fig 23]** you can see the same comparison between whites and minority groups.

That set of charts showed the situation in frozen form, from the standpoint of a single cohort of people: high school sophomores of 1977 followed for 15 years to Ph.D. fulfillment in 1992. Now let's look at the situation in fluid form--the attainment of bachelors', masters', and doctors' degrees in one field, year by year, through much of the same period.

[Fig. 24]

[Fig. 25]

[Fig. 26]

Early in this talk I mentioned two studies--one in science, the other in math--that compared U.S. youngsters' achievement against that of kids in other countries. Another germane study, done periodically by the Educational Testing Service and called The Nation's Report Card, gets to the heart of what is wrong with American pre-collegiate education by comparing pre-collegiate achievement against a set of objective standards.

It scored youngsters in three age groups, 9, 13 and 17, on five levels of proficiency, as shown here **[Fig 27]**. What it shows is that, **[Fig 28]** while we stuff our kids' heads full of facts at an early age (96 per cent of 9-year-olds have a grab-bag full of factual knowledge) we don't teach them how to use the facts they have (less than 8 per cent of 17-year-olds are competent to integrate specialized scientific information).

And the situation isn't getting better **[Fig 29]**. About the only comfort we can take is in the fact that we're not getting much worse, and that is cold comfort indeed.

[Fig. 30]

Obviously, this isn't the fault of American kids, although a little more time on the books and a little less time in front of the tube might help improve not only Junior's report card, but the nation's too. The fault is with our educational system, and it's a fault that somehow must be corrected.

Someone has calculated that from eighth grade on, the average American student is exposed to mathematics for approximately one year. One reason for this is that by the time students reached the eighth grade they have been convinced--by both precept and example--that math is "b-o-o-o-r-ing," {heavy accent on the first syllable with a long, drawn-out "o" sound} to use the teen-age catchphrase for everything unattractive. And the way mathematics is taught in lower grades, it is b-o-o-o-r-ing. But it need not be; mathematics, like every subject in the elementary and middle school curriculum, can be made interesting without bring trivialized. But it's got to be taught--and to everybody. Do you realize, as Jon Miller, director of the Public Opinion Laboratory at Northern Illinois University has pointed out, that only 55 per cent of U.S. high school students study algebra--or more specifically, are exposed to algebra; God alone knows how many of them actually study it.

It is up to all of us, in academia, in business and industry, and in government to help achieve a goal of universal numeracy, which is the only basis on which our citizens can live productively in a technologically oriented world. There's no doubt in my mind of our national capacity for dealing with problems, however big--for mobilizing resources to accomplish any task. No; our national capacity is not in question, but I worry that our national will may be. If we as a nation have the will to bring order out of the abyss that yawns in front of us as one century gives way to another, we can look forward to continuing years of greatness; if not--well, the "ash heap of history" is cluttered with the remains of societies that gave up the fight and disappeared. I am often asked why does NSF support mathematics and science education? etc.... **[Fig. 31]**

What goes around comes around, and here I am--at the end of my talk--right where I started. "I'm from the government and I'm here to help you." The National Science Foundation can't do it all; shouldn't do it all. NSF is, and wants to be, a catalyst for change, and that's the basic message today. You in the mathematics community must recognize--as I'm sure you do--the continuous, ongoing nature of the mathematics enterprise, from first exposure to elementary ideas of shape and quantity through the frontiers of mathematical theory and on to the most sophisticated concepts. It is you who must take the initiative, and this is how I and my colleagues from NSF are here to help you: To let you know that NSF is "your person in Washington," to whom you can come with ideas, and from whom not only moral but also financial support can come to those with the most provocative of those ideas.

What is at stake is the quality of life in this country, indeed on the planet. Advances in mathematics and science have no national boundaries. We must promote such advances and must communicate them effectively to the rest of society. Thank you.

GRADE 5 SCIENCE ACHIEVEMENT IN 15 COUNTRIES

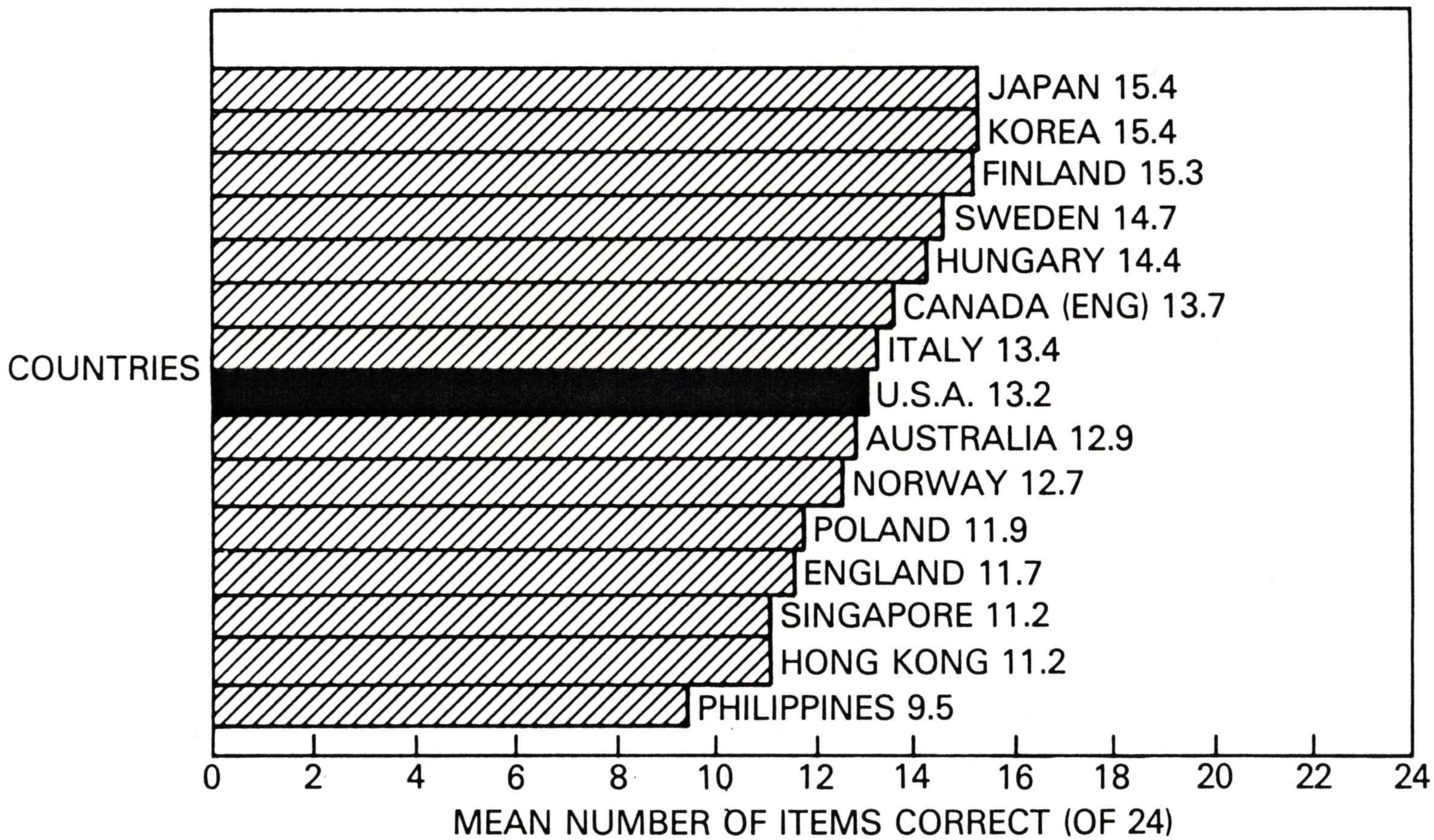


Fig 1

GRADE 9 SCIENCE ACHIEVEMENT IN 16 COUNTRIES

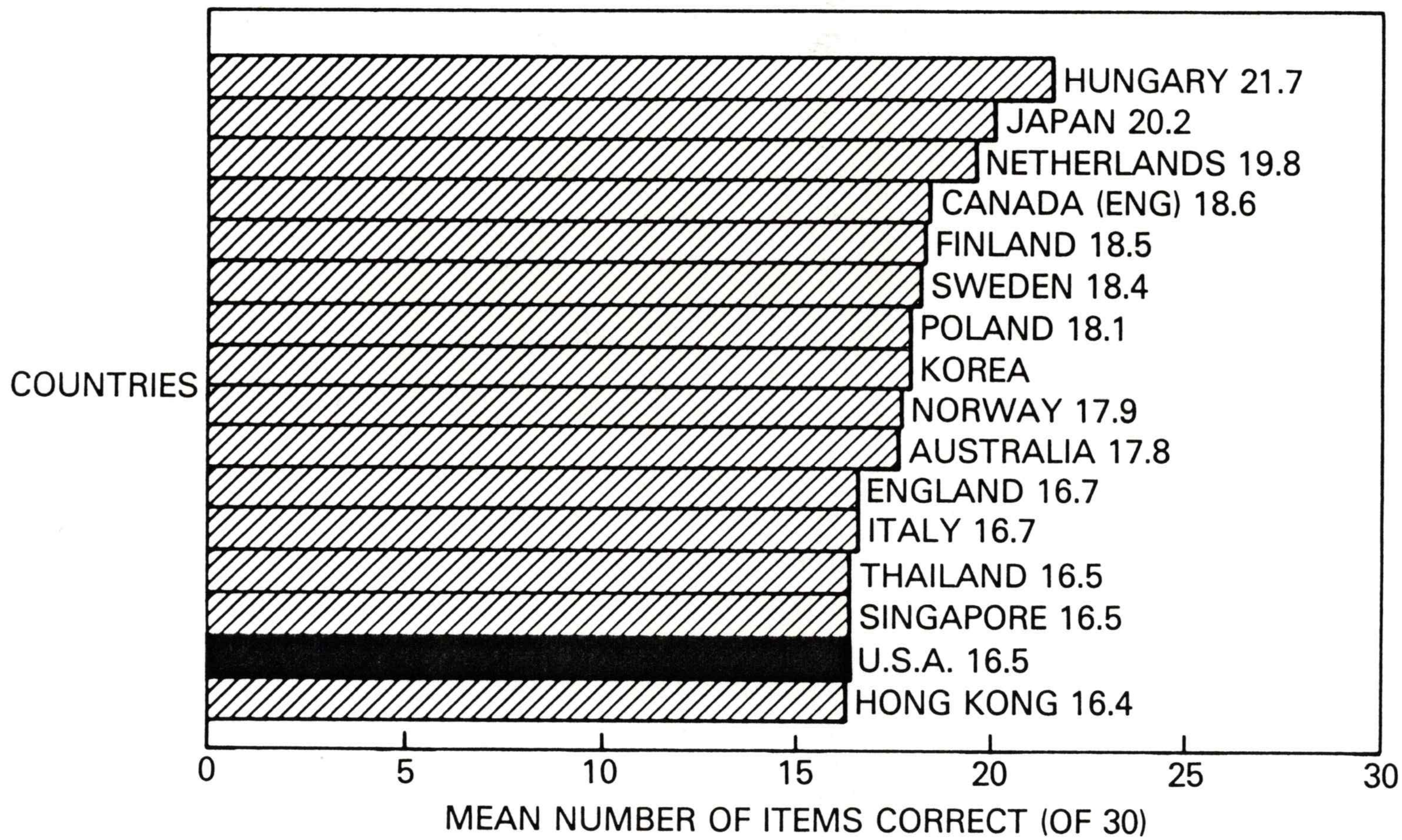


Fig 2

PHYSICS SPECIALISTS (MEAN PERCENT CORRECT)

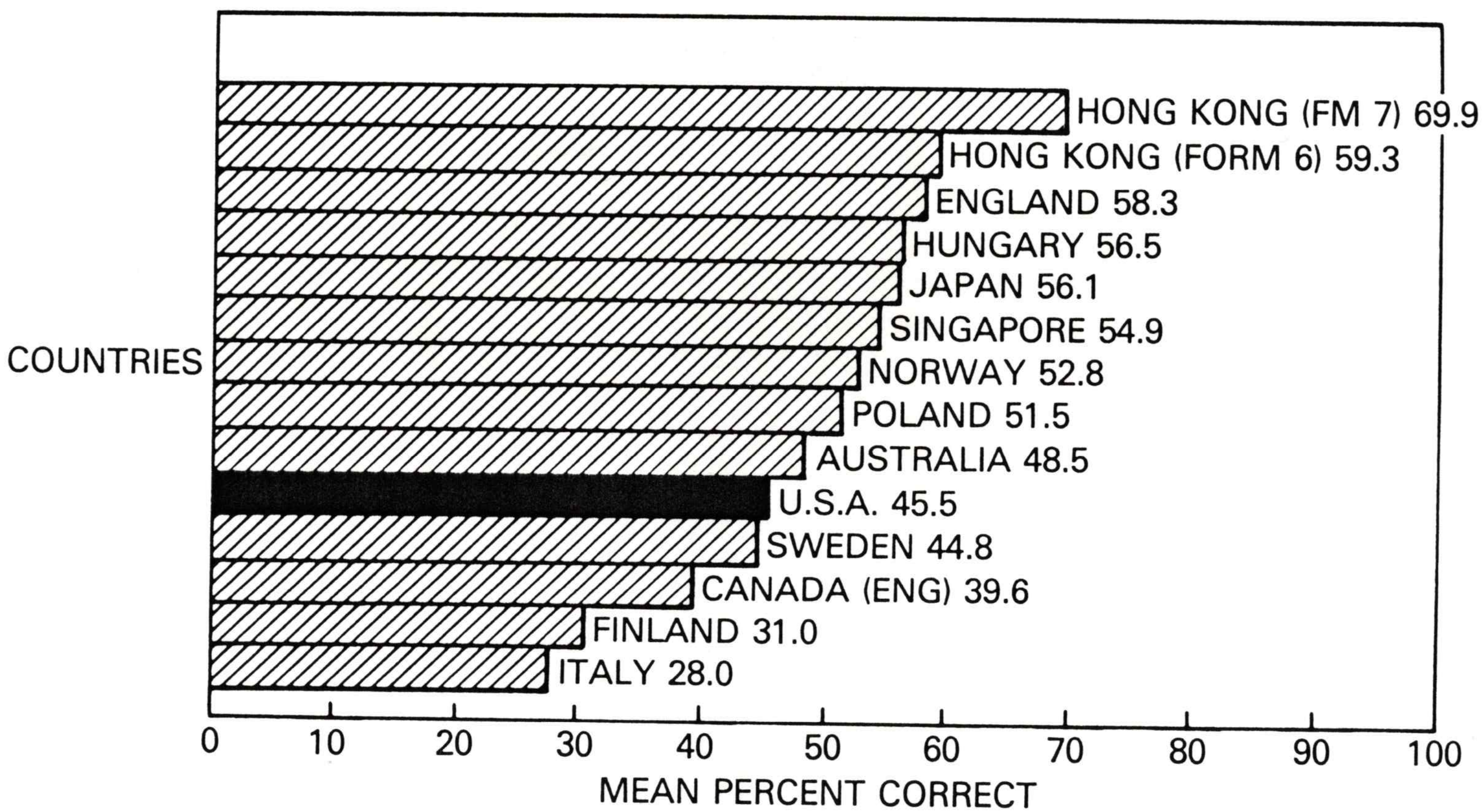


Fig 3

#5

CHEMISTRY SPECIALISTS (MEAN PERCENT CORRECT)

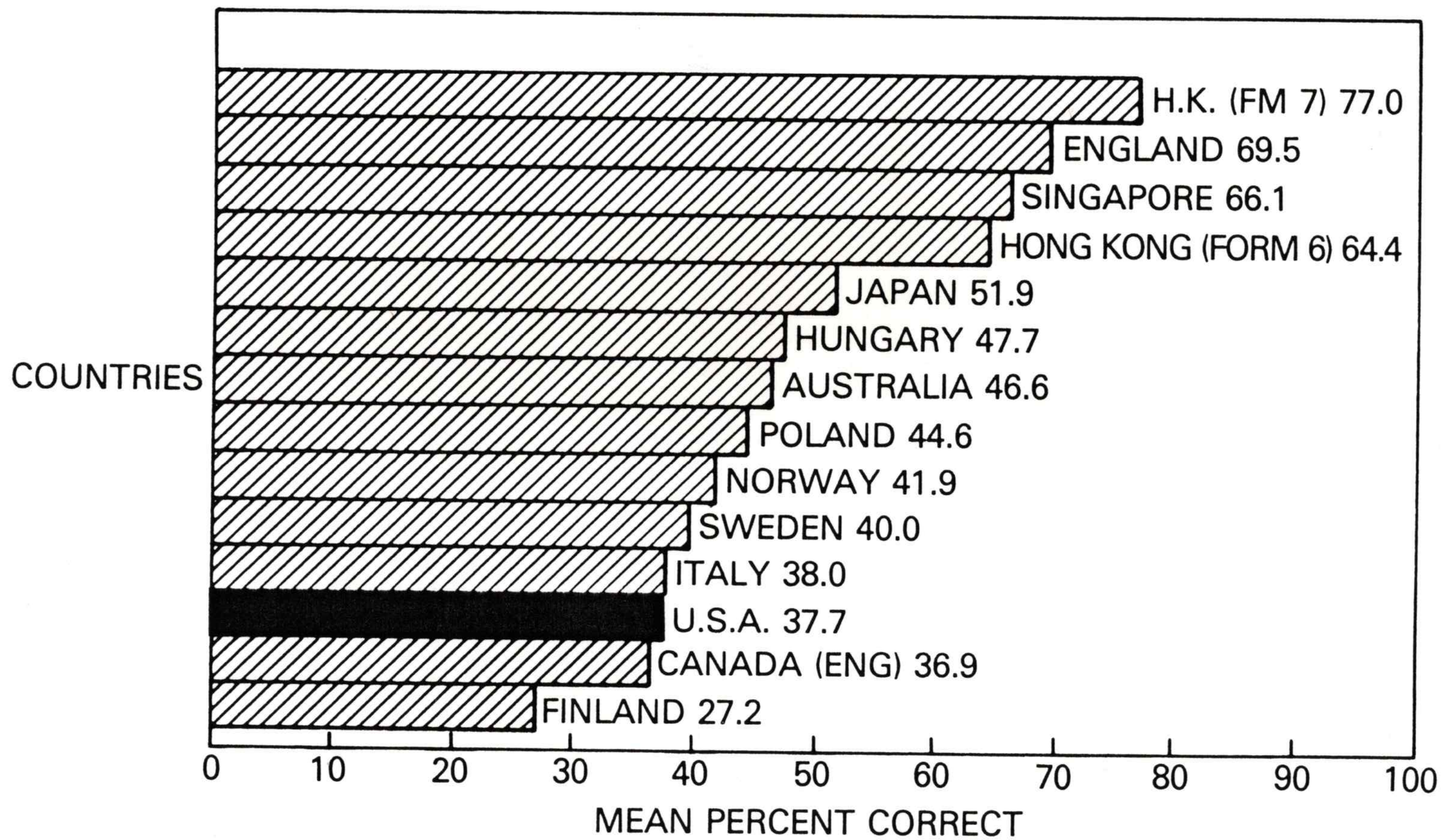


Fig 4

BIOLOGY SPECIALISTS
(MEAN PERCENT CORRECT)

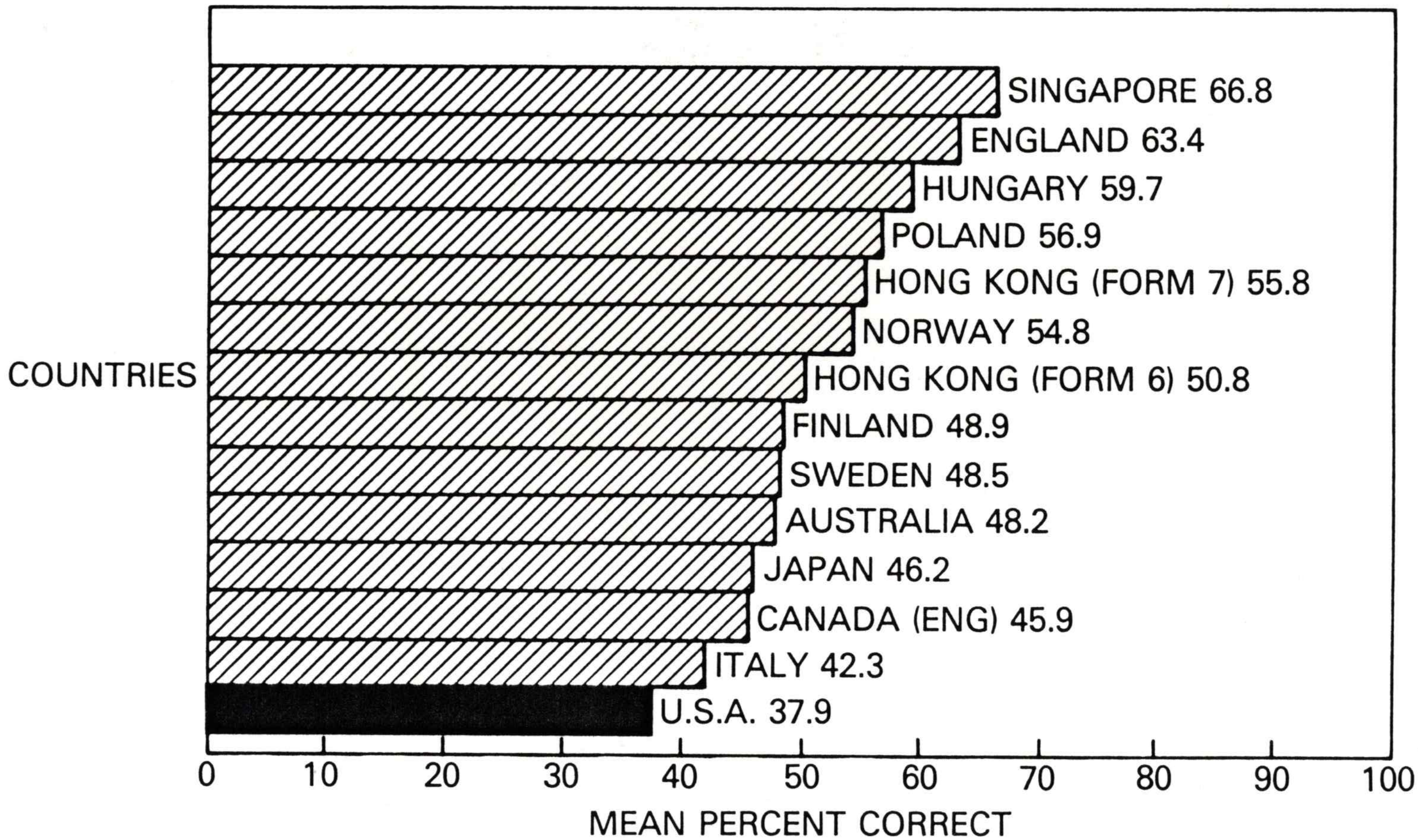
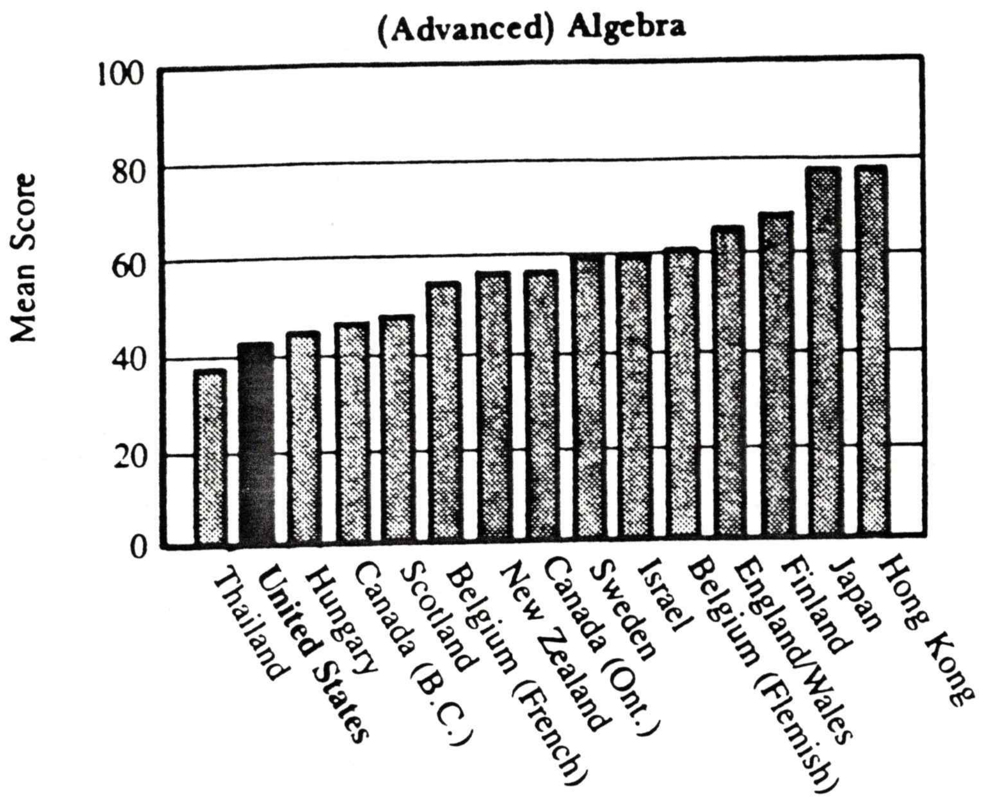
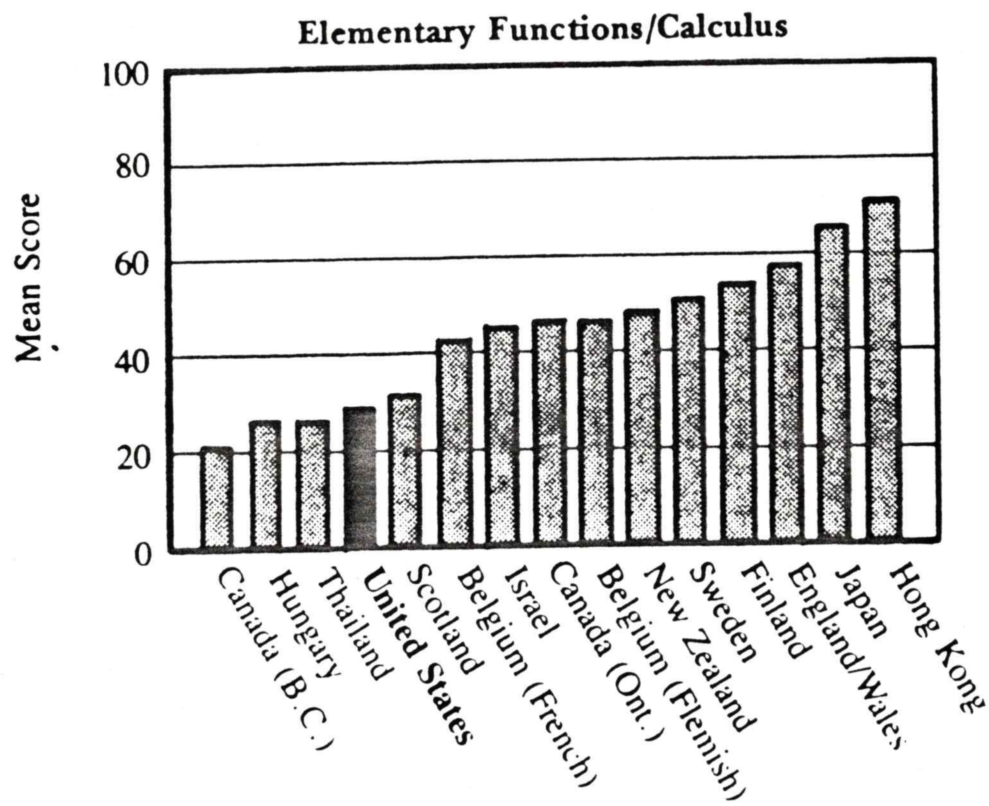


Fig 5

FIG. 6



(Advanced) Algebra
Mean Score
100
80
60
40
20
0
Thailand
United States
Hungary
Canada (B.C.)
Scotland
Belgium (French)
New Zealand
Canada (Ont.)
Sweden
Israel
Belgium (Flemish)
England/Wales
Finland
Japan
Hong Kong



Elementary Functions/Calculus
Mean Score
100
80
60
40
20
0
Canada (B.C.)
Hungary
Thailand
United States
Scotland
Belgium (French)
Israel
Canada (Ont.)
Belgium (Flemish)
New Zealand
Sweden
Finland
England/Wales
Japan
Hong Kong

FIG 7

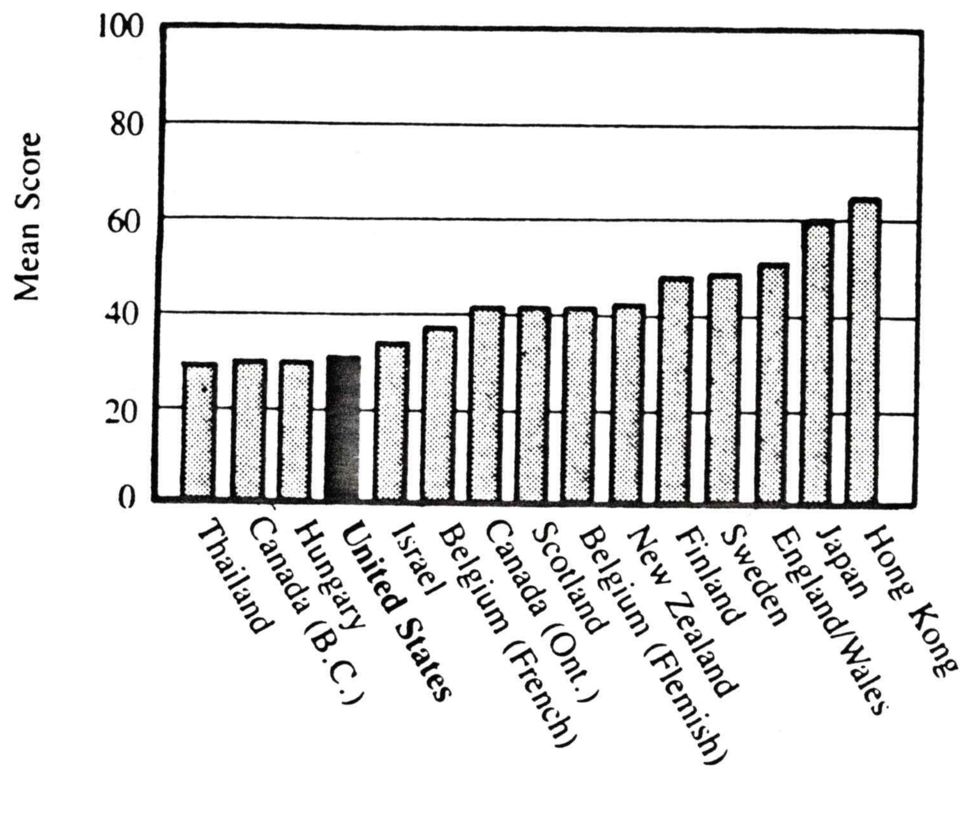


FIG. 8

Population B (Twelfth Grade) achievement scores in geometry for fifteen countries reveal the U.S. to be among the lowest one-fourth of participating countries. Items on this subtest involved primarily knowledge of analytic geometry.

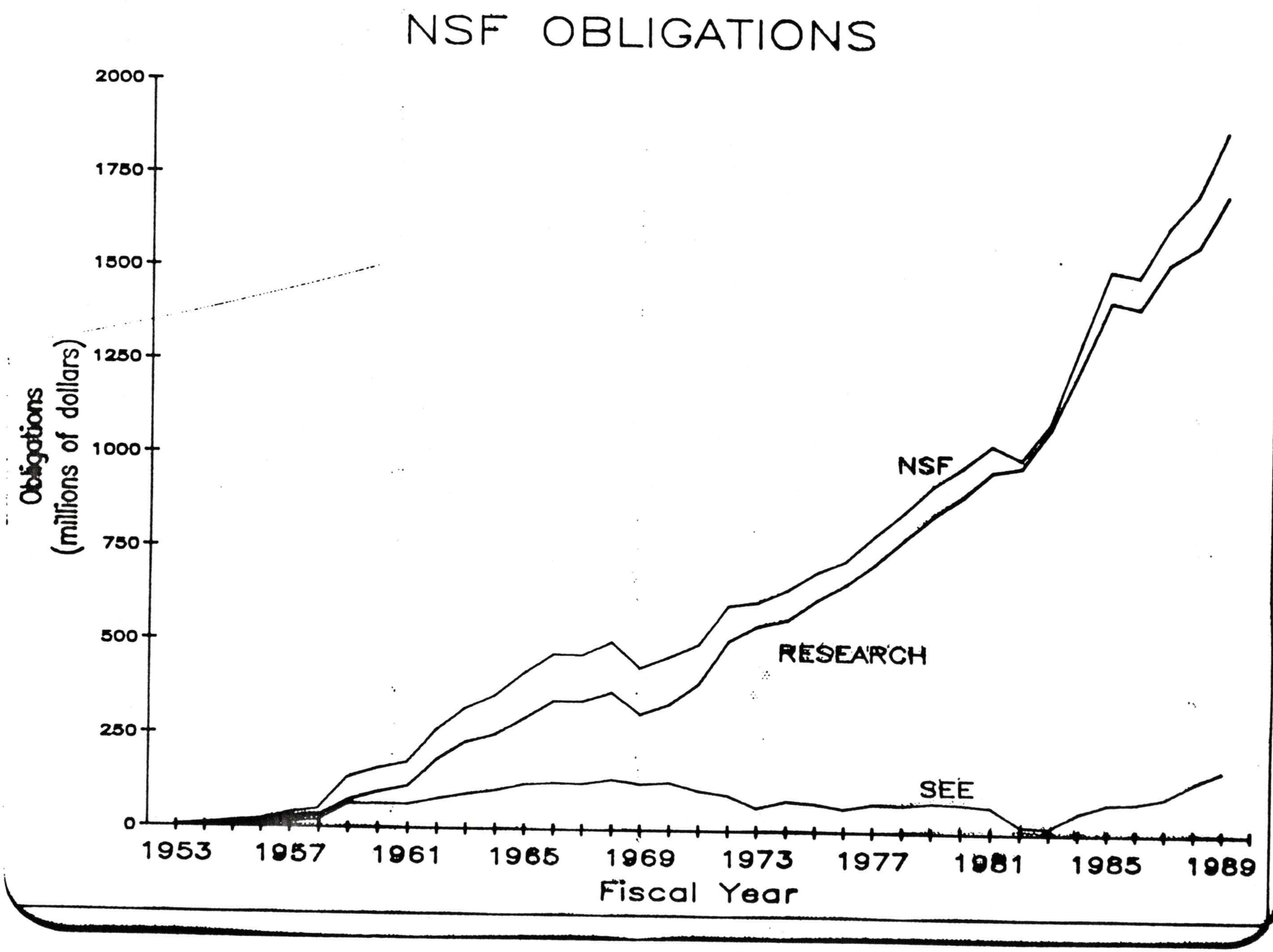

NSF OBLIGATIONS
2000
1750
1500
1250
1000
750
500
250
0
Obligations (millions of dollars)
NSF
RESEARCH
SEE
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
Fiscal Year

FIG 9

Obligations for Science & Engineering Education

as percent of NSF Budget

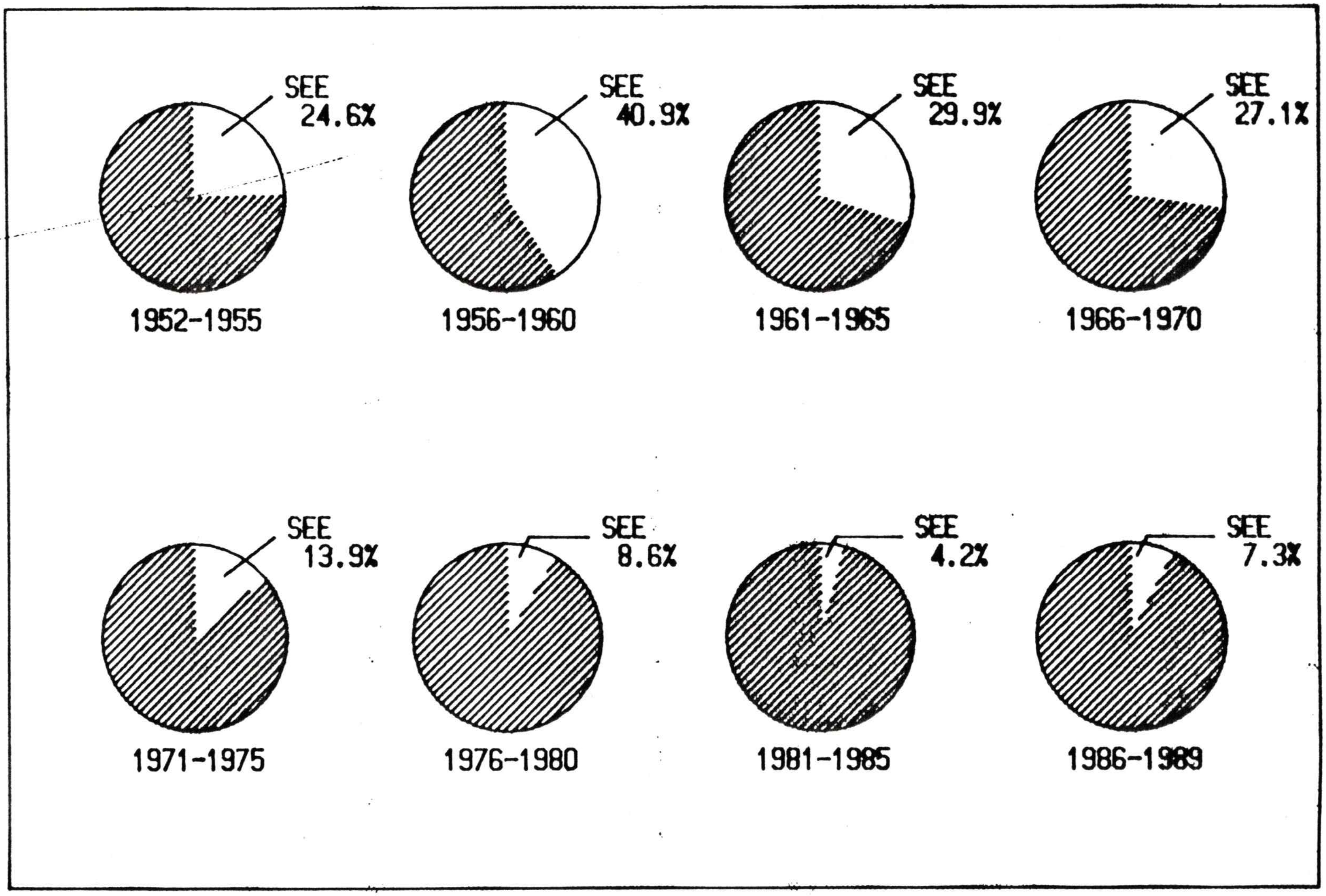


FIG. 10

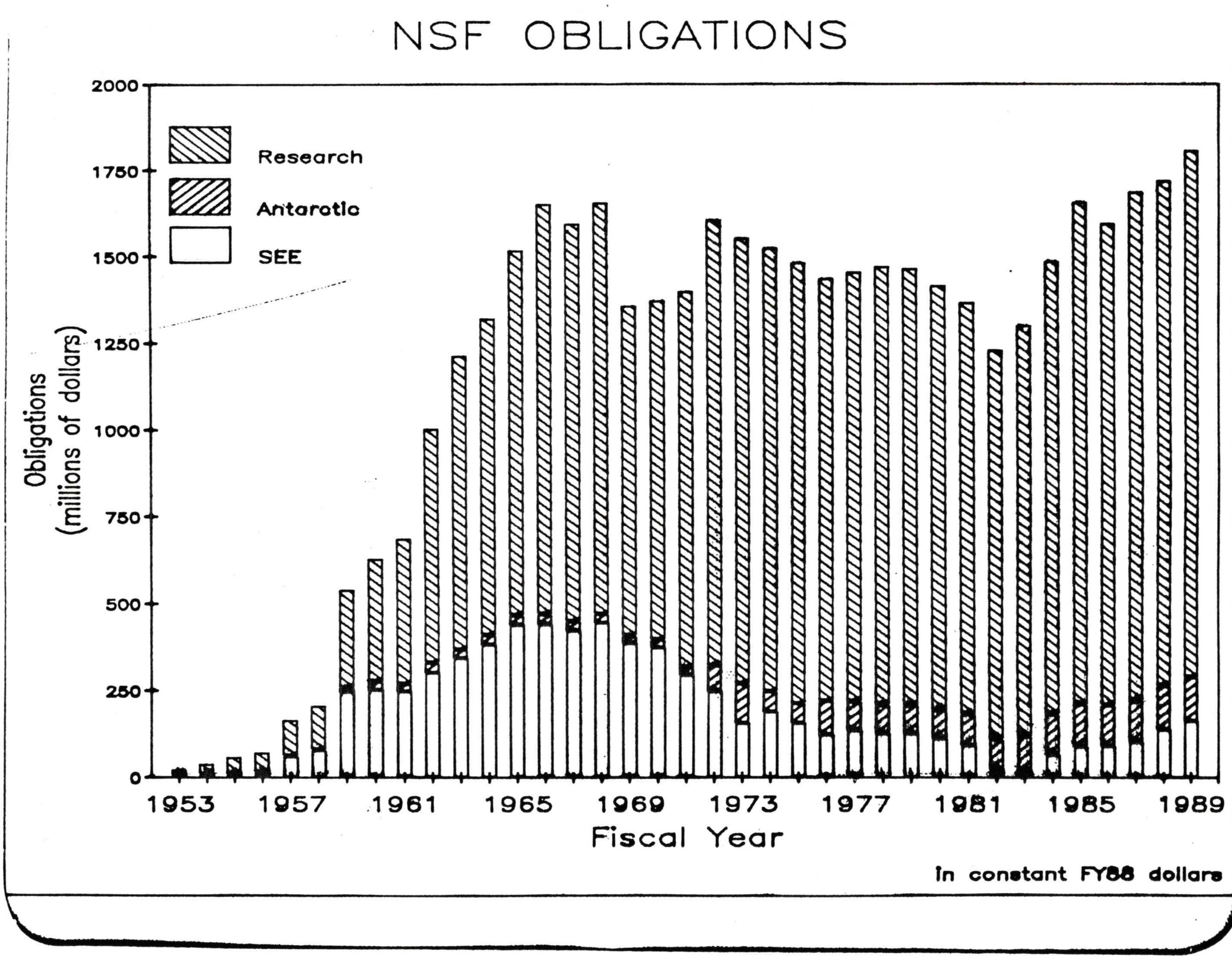

NSF OBLIGATIONS
Research
Antarctic
SEE
Obligations (millions of dollars)
2000
1750
1500
1250
1000
750
500
250
0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
Fiscal Year
In constant FY88 dollars

FIG. 11

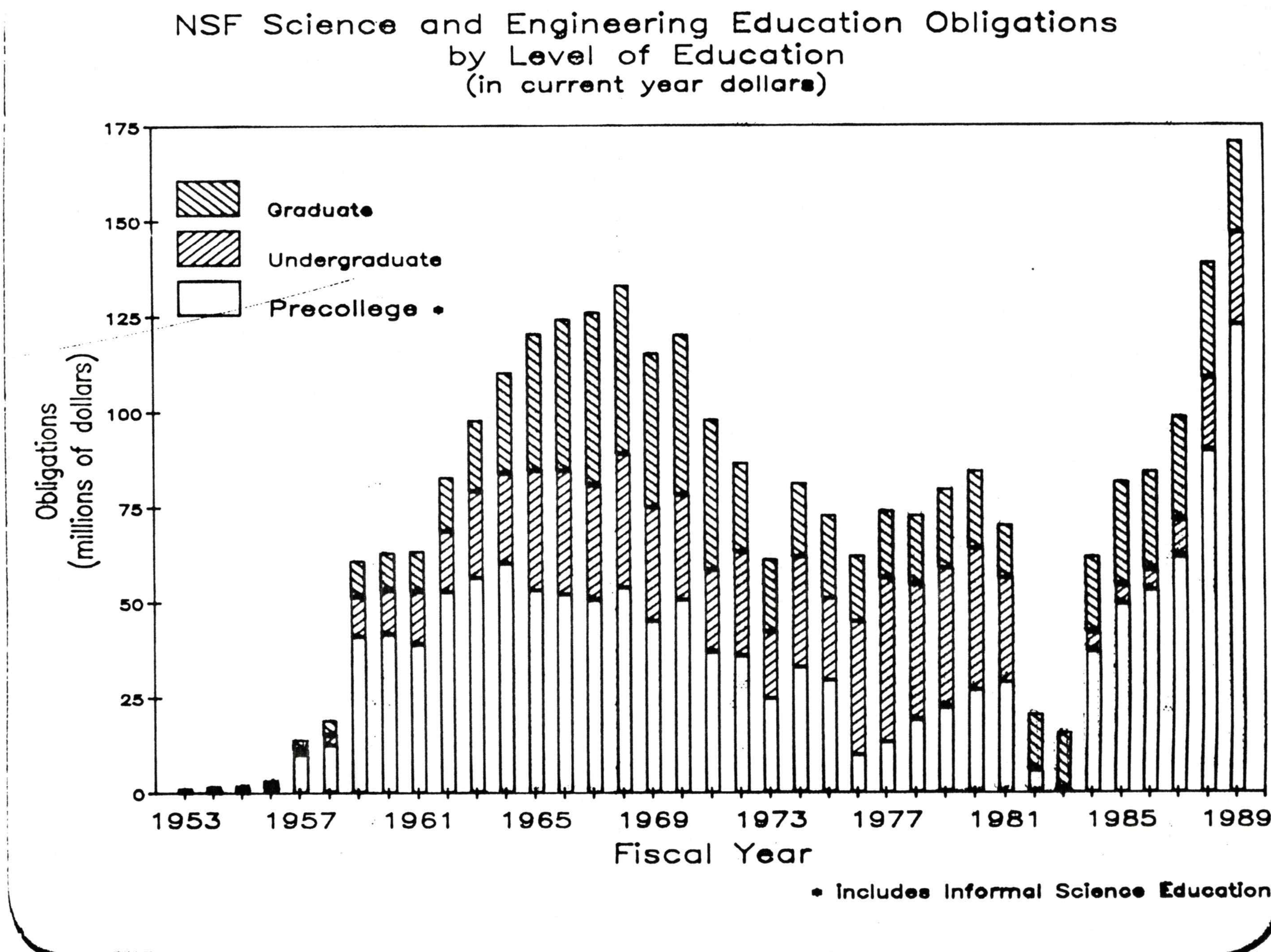

NSF Science and Engineering Education Obligations
by Level of Education
(in current year dollars)
Graduate
Undergraduate
Precollege *
Obligations
(millions of dollars)
175
150
125
100
75
50
25
0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
Fiscal Year
* Includes Informal Science Education

FIG. 12

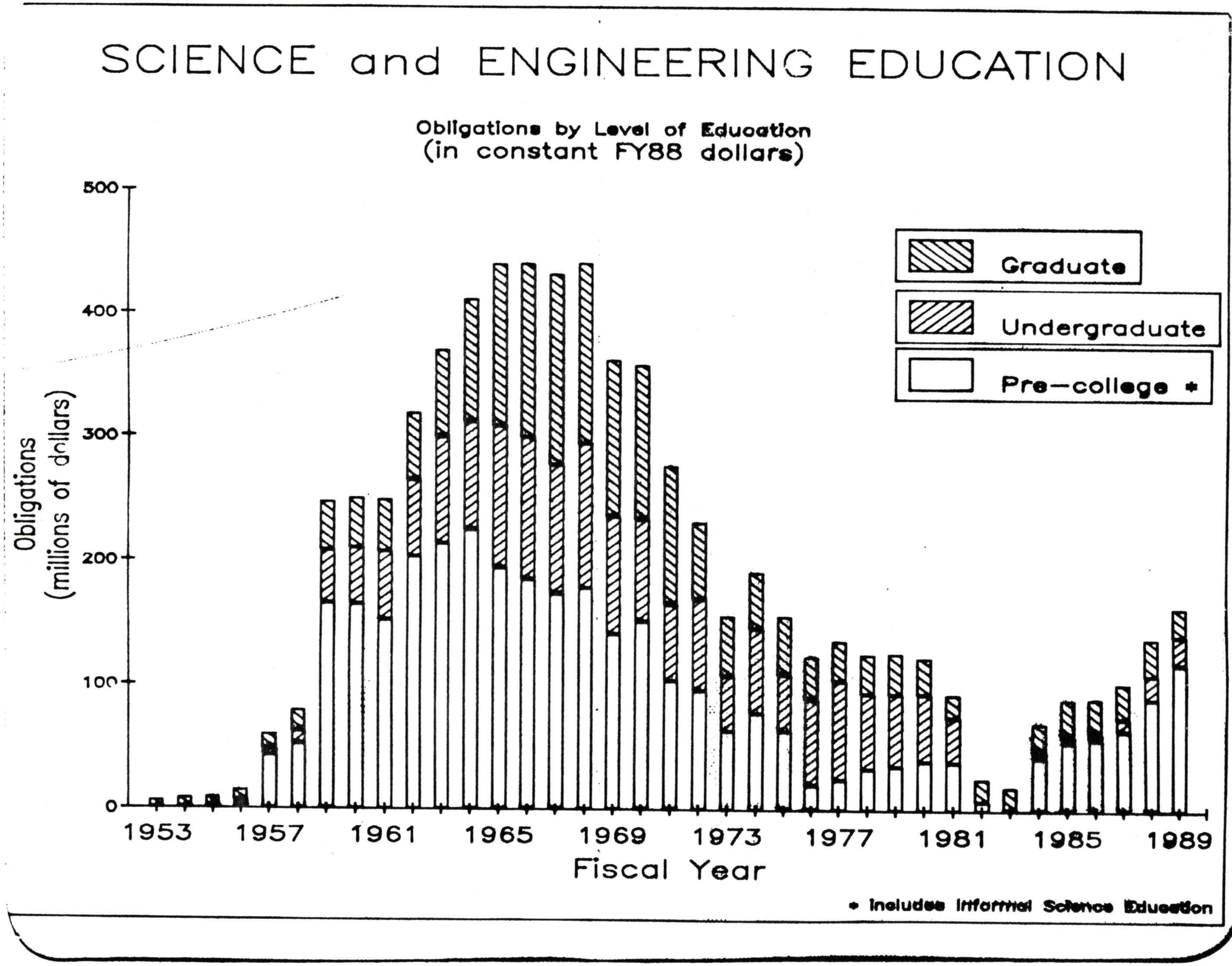

SCIENCE and ENGINEERING EDUCATION
Obligations by Level of Education
(in constant FY88 dollars)
Obligations
(millions of dollars)
500
400
300
200
100
0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
Fiscal Year
Graduate
Undergraduate
Pre-college *
* Includes Informal Science Education

FIG. 13

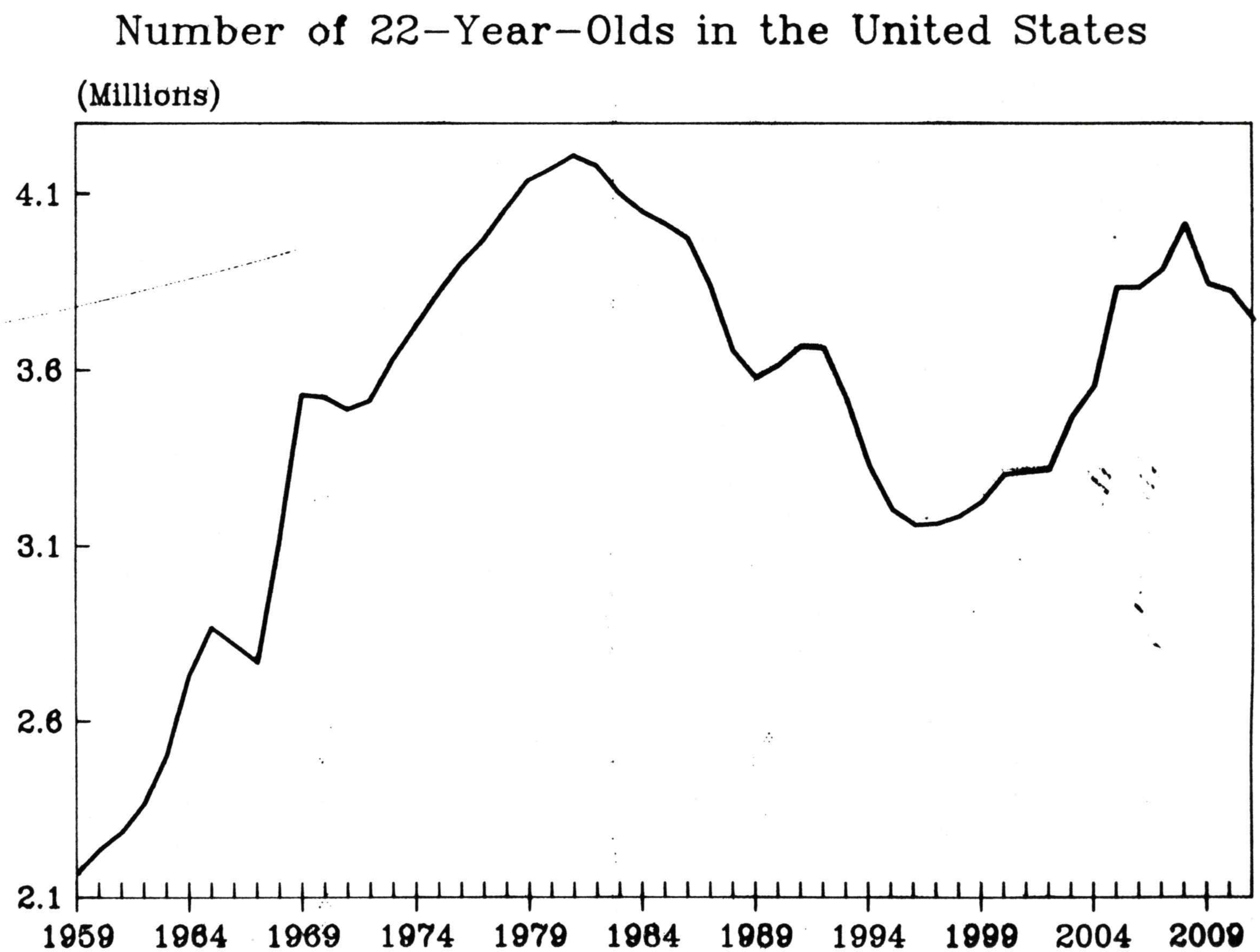

Number of 22-Year-Olds in the United States
(Millions)
4.1
3.6
3.1
2.6
2.1
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004
2009

FIG. 14

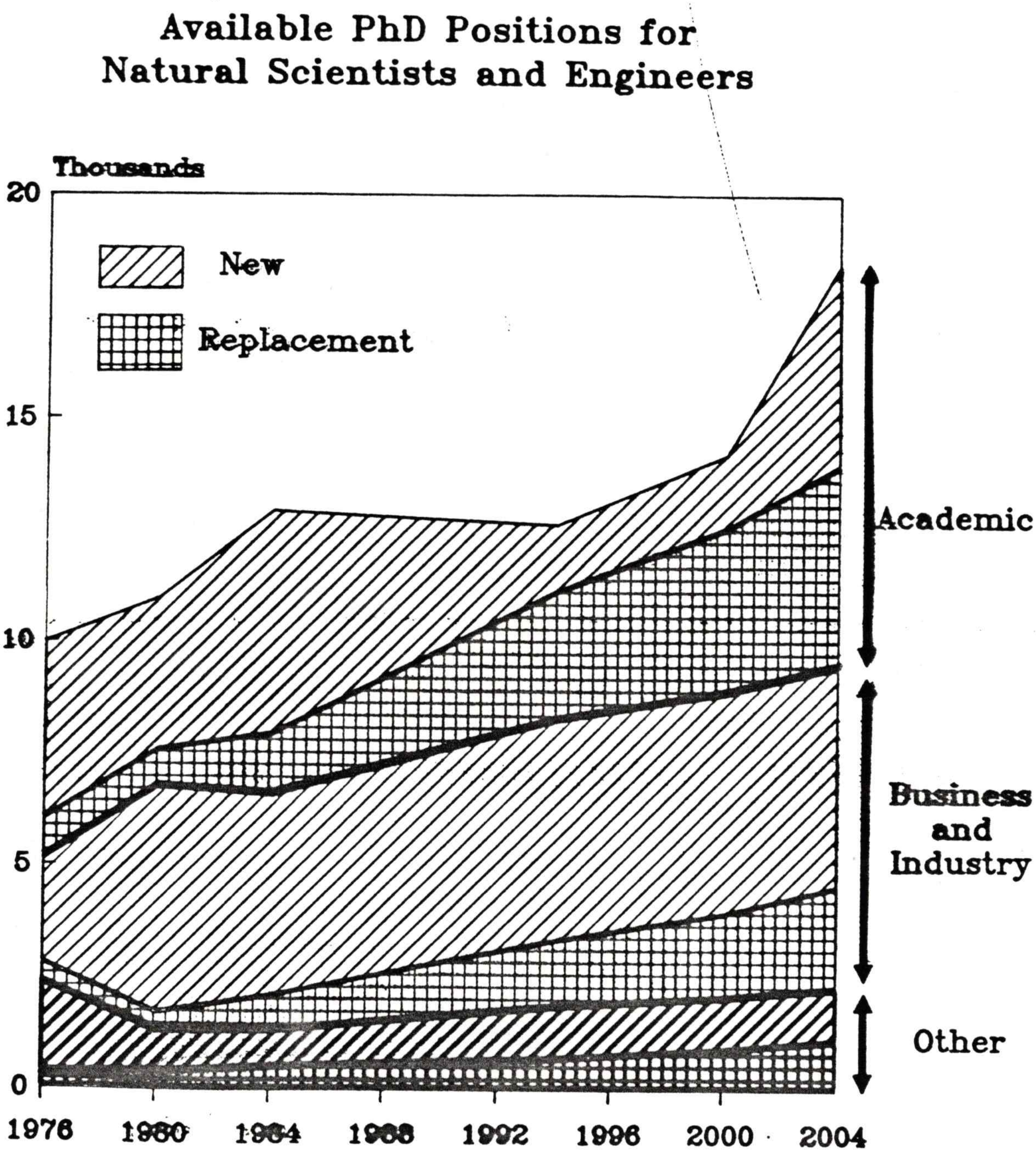
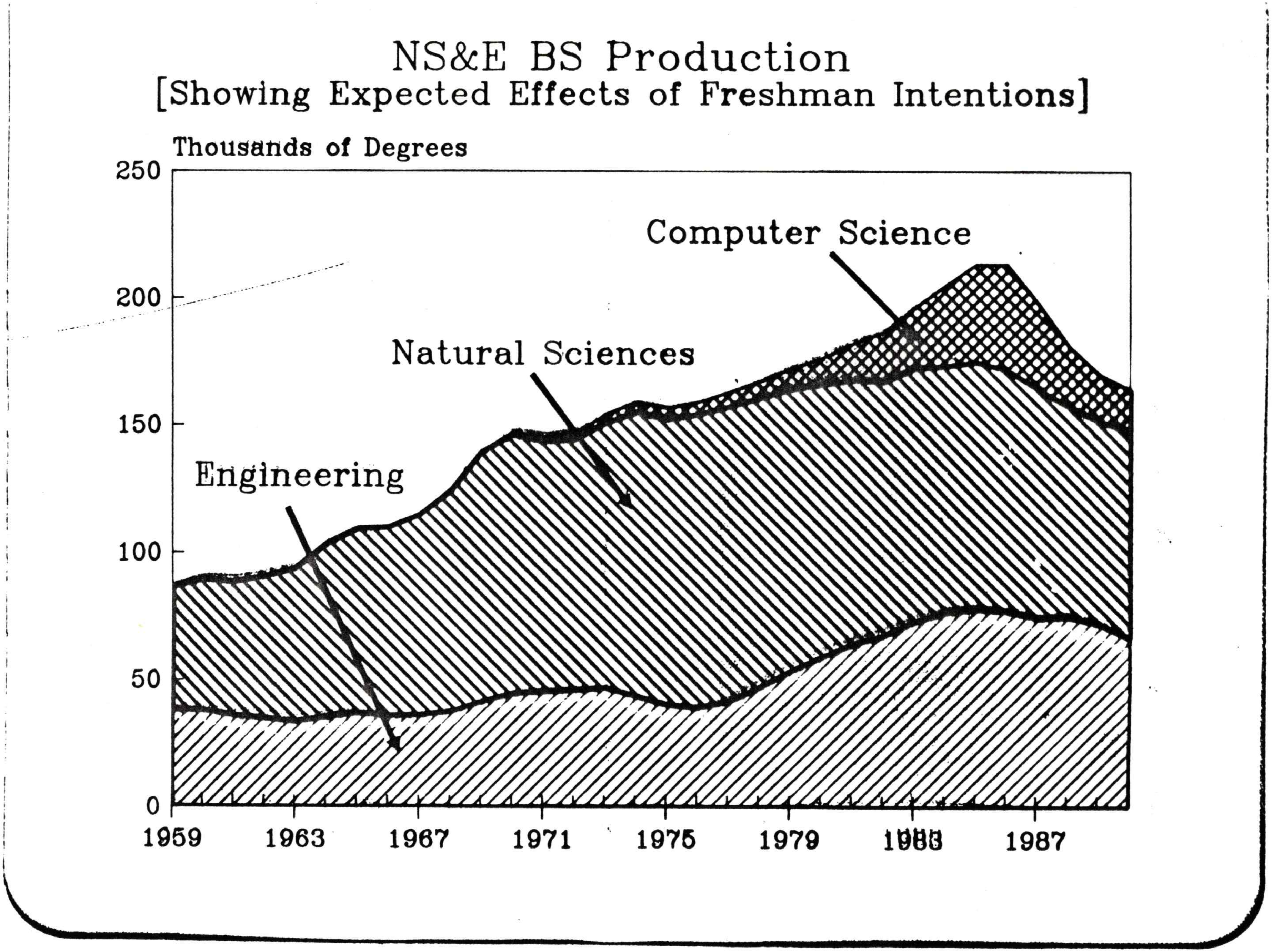

Available PhD Positions for
Natural Scientists and Engineers
Thousands
20
15
10
5
0
New
Replacement
1976
1980
1984
1988
1992
1996
2000
2004
Academic
Business and Industry
Other

Fig. 15



NS&E BS Production
[Showing Expected Effects of Freshman Intentions]
Thousands of Degrees
250
200
150
100
50
0
Computer Science
Natural Sciences
Engineering
1959
1963
1967
1971
1975
1979
1987

FIG. 16

NS&E BS Production Rates
[Showing a Growing Rate in Computer Science]

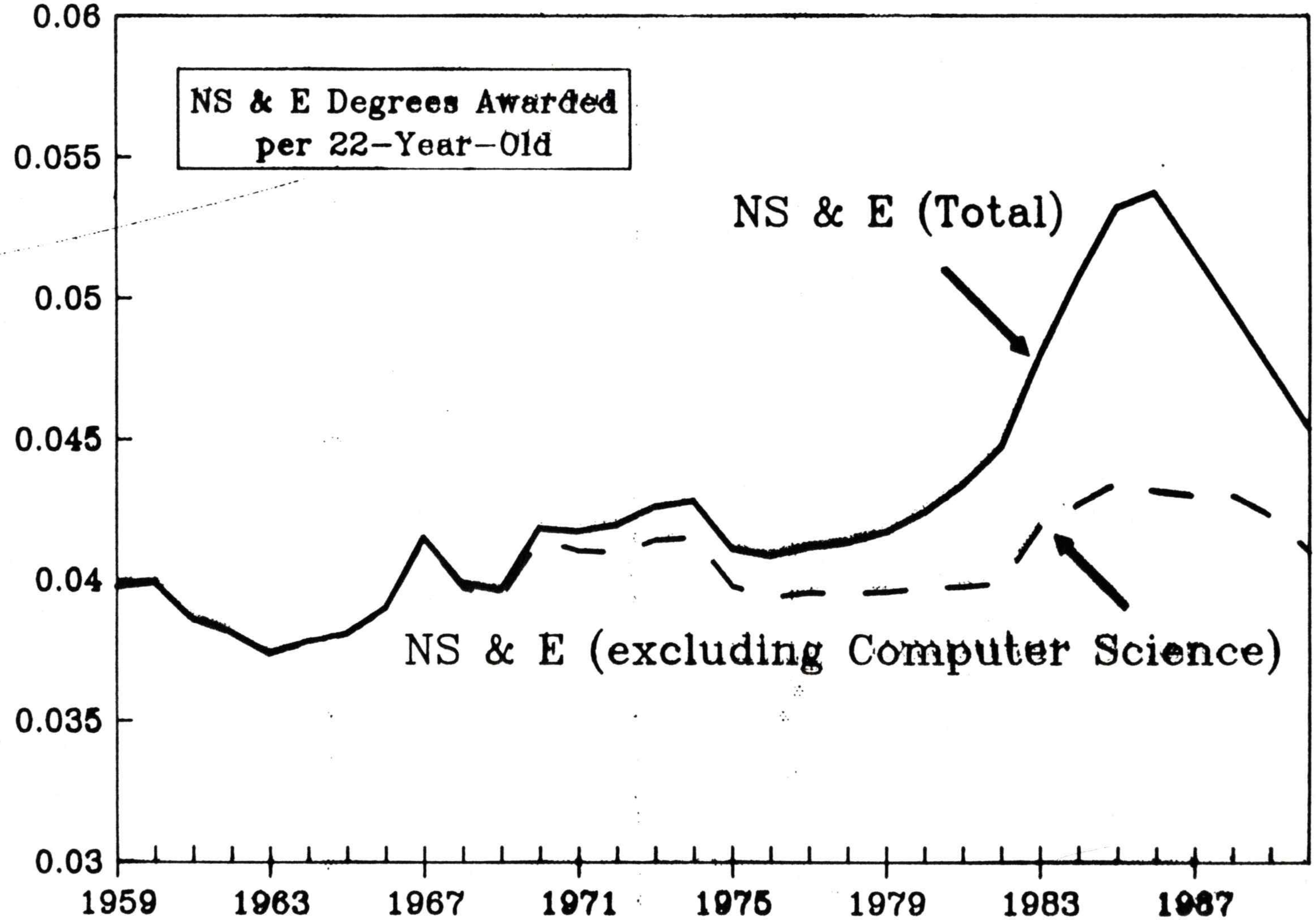


FIG. 17

NS&E Cumulative Shortfalls: BS Degrees

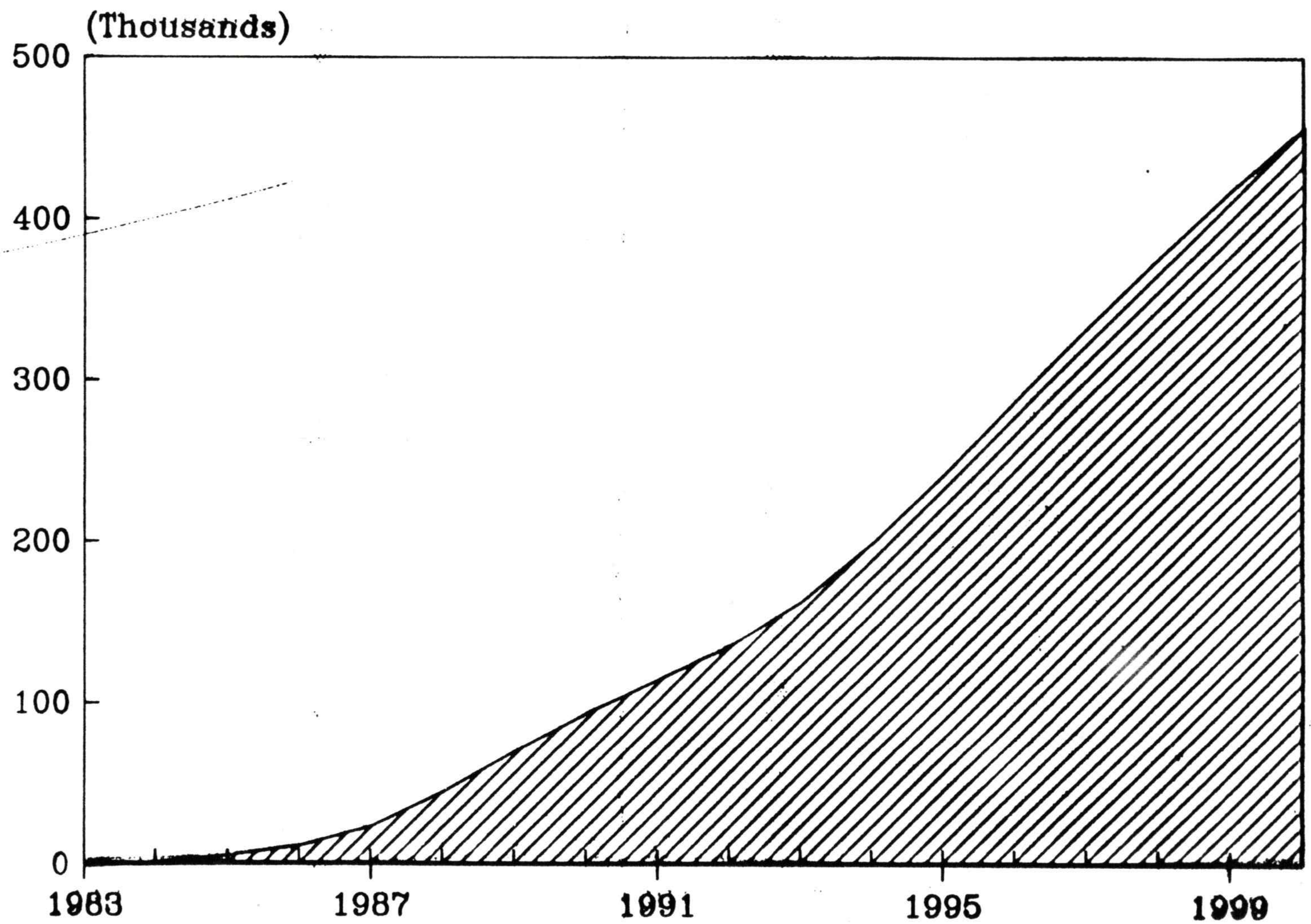


FIG. 18

PhD Degrees in
Natural Science and Engineering

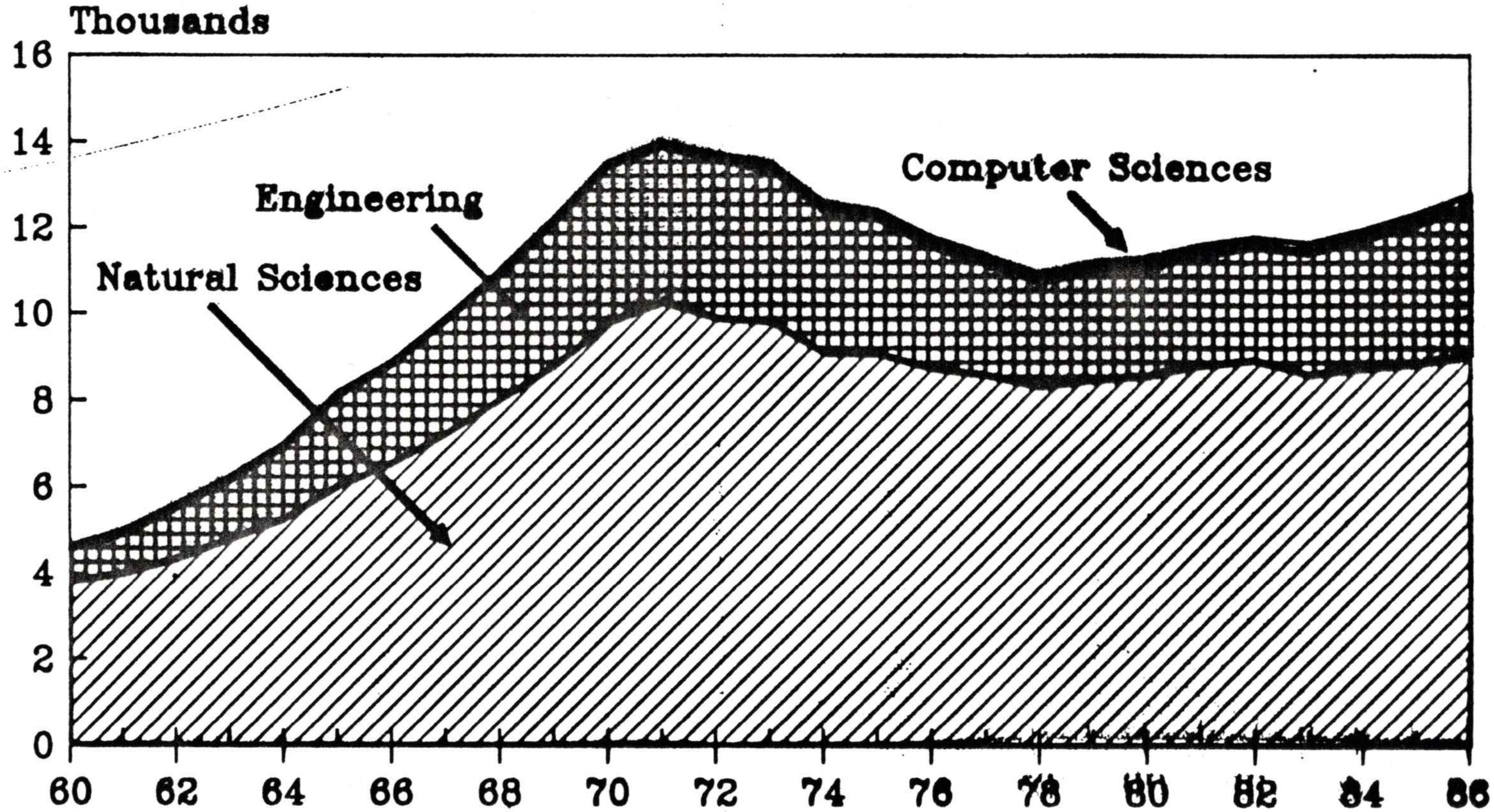


FIG 19

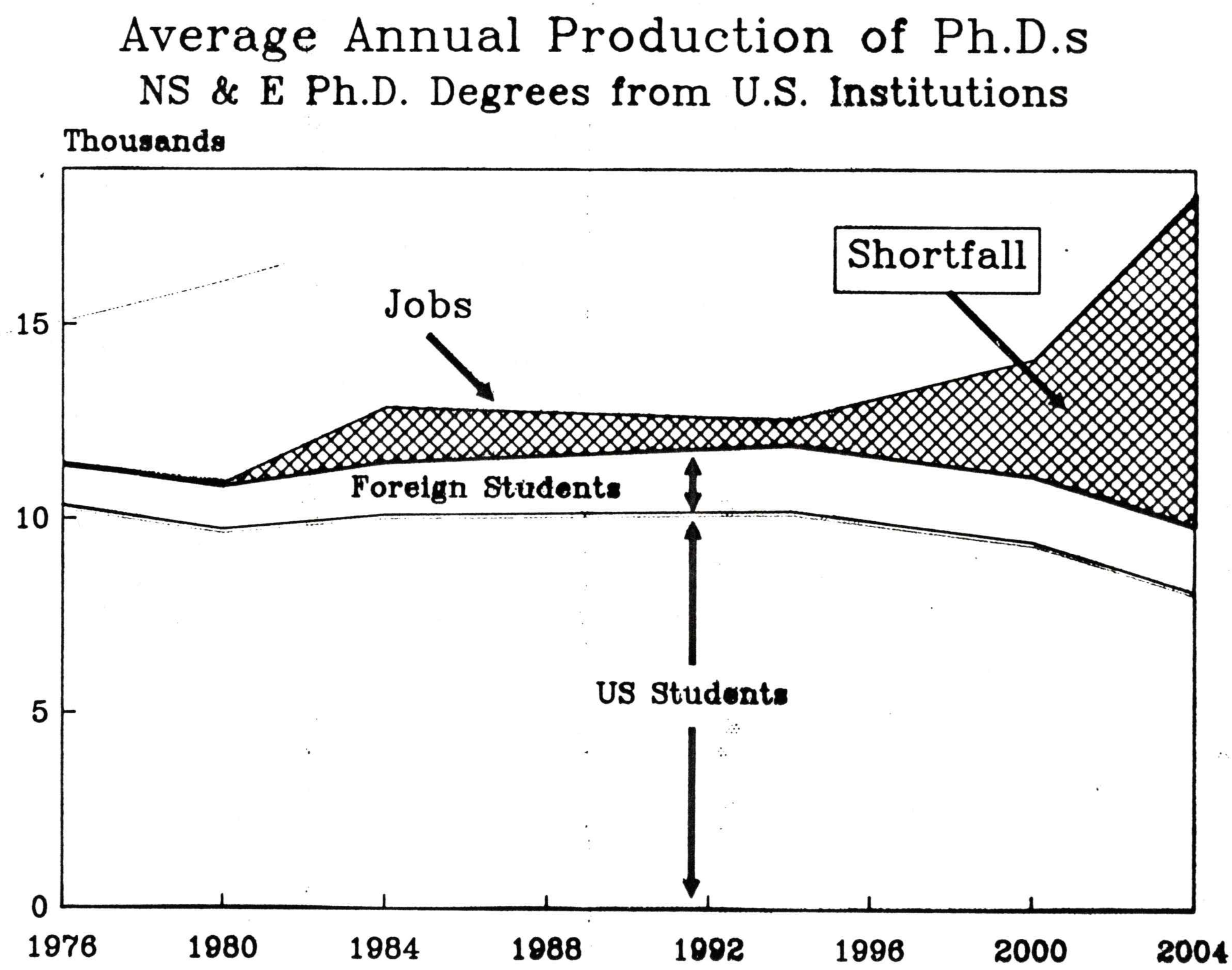
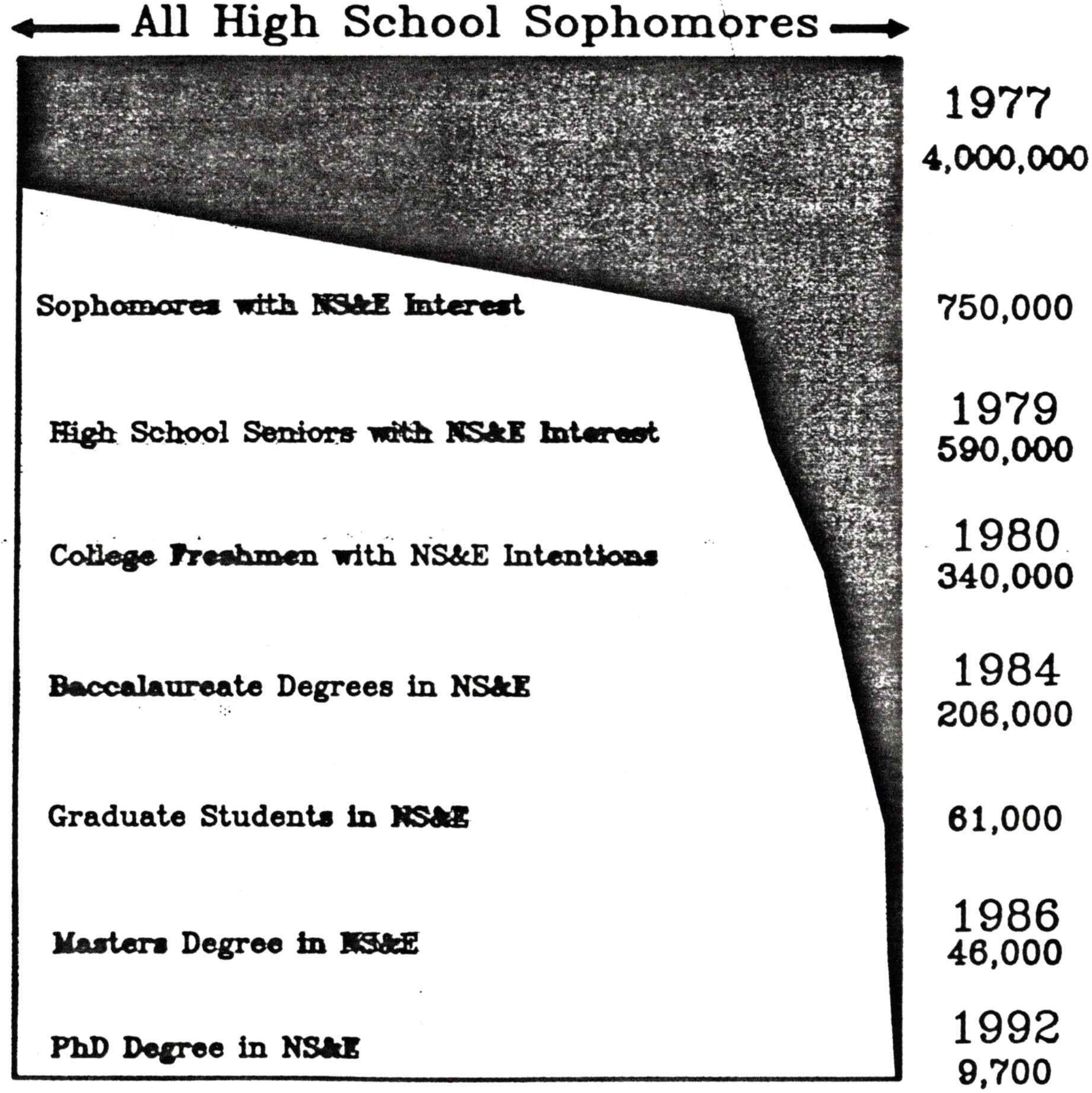

Average Annual Production of Ph.D.s
NS & E Ph.D. Degrees from U.S. Institutions
Thousands
15
10
5
0
Jobs
Shortfall
Foreign Students
US Students
1976
1980
1984
1988
1992
1996
2000
2004

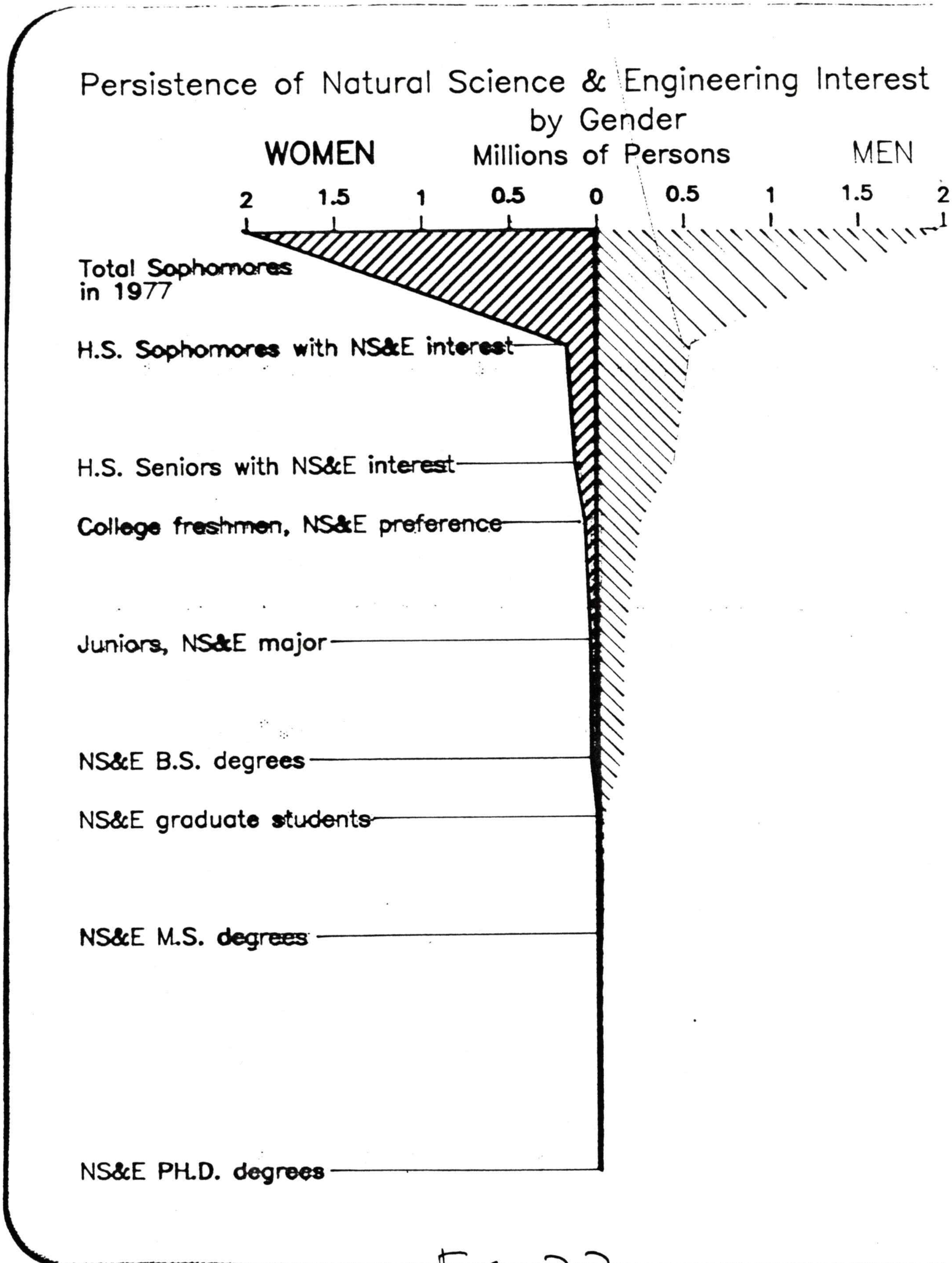
FIG. 20

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

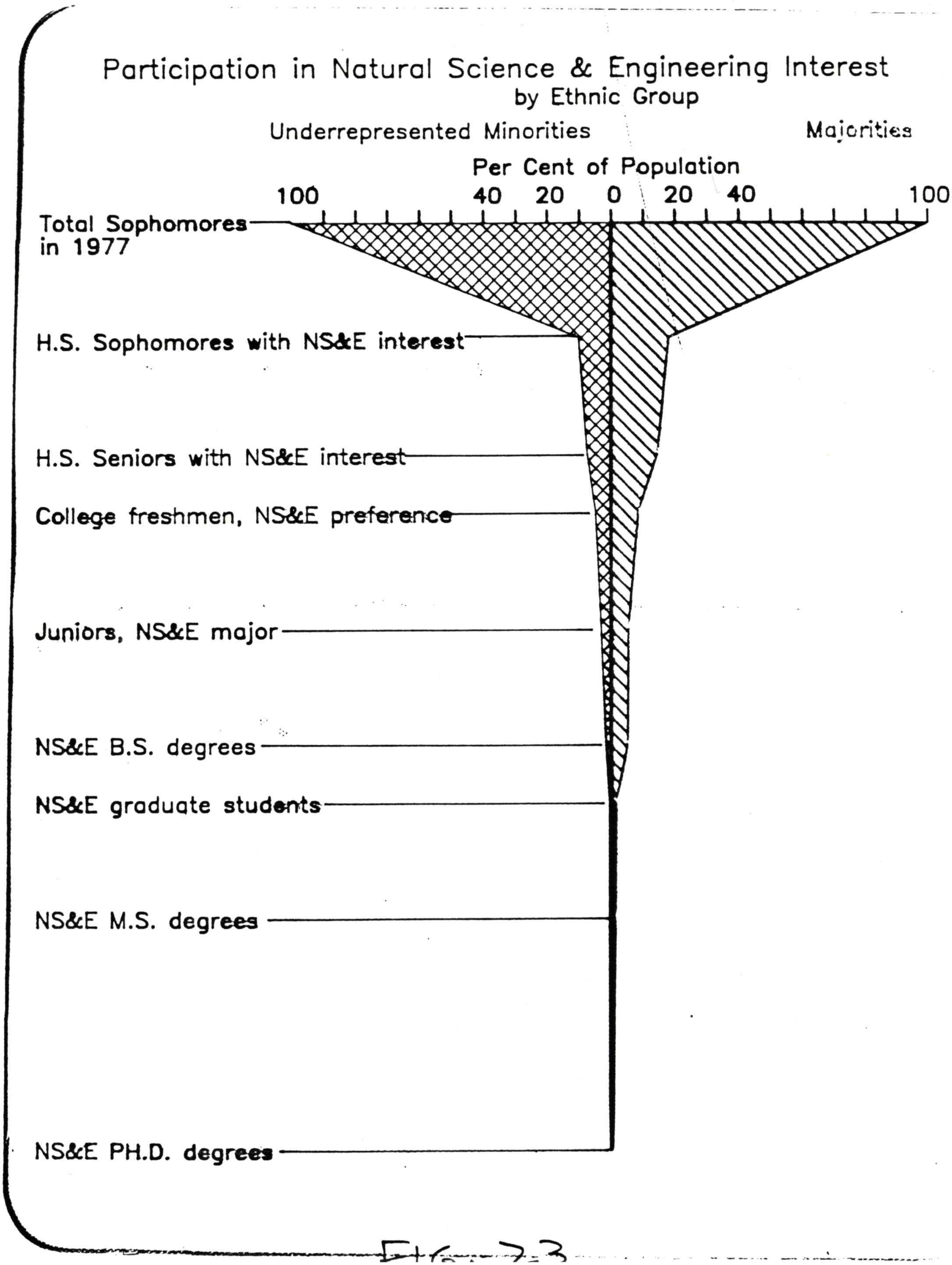


(The Pipeline)

FIG 21



Persistence of Natural Science & Engineering Interest by Gender
WOMEN
Millions of Persons
MEN
2
1.5
1
0.5
0
0.5
1
1.5
2
Total Sophomores in 1977
H.S. Sophomores with NS&E interest
H.S. Seniors with NS&E interest
College freshmen, NS&E preference
Juniors, NS&E major
NS&E B.S. degrees
NS&E graduate students
NS&E M.S. degrees
NS&E PH.D. degrees



Participation in Natural Science & Engineering Interest
by Ethnic Group
Underrepresented Minorities
Majorities
Per Cent of Population
100
40
20
0
20
40
100
Total Sophomores in 1977
H.S. Sophomores with NS&E interest
H.S. Seniors with NS&E interest
College freshmen, NS&E preference
Juniors, NS&E major
NS&E B.S. degrees
NS&E graduate students
NS&E M.S. degrees
NS&E PH.D. degrees

Fig. 23

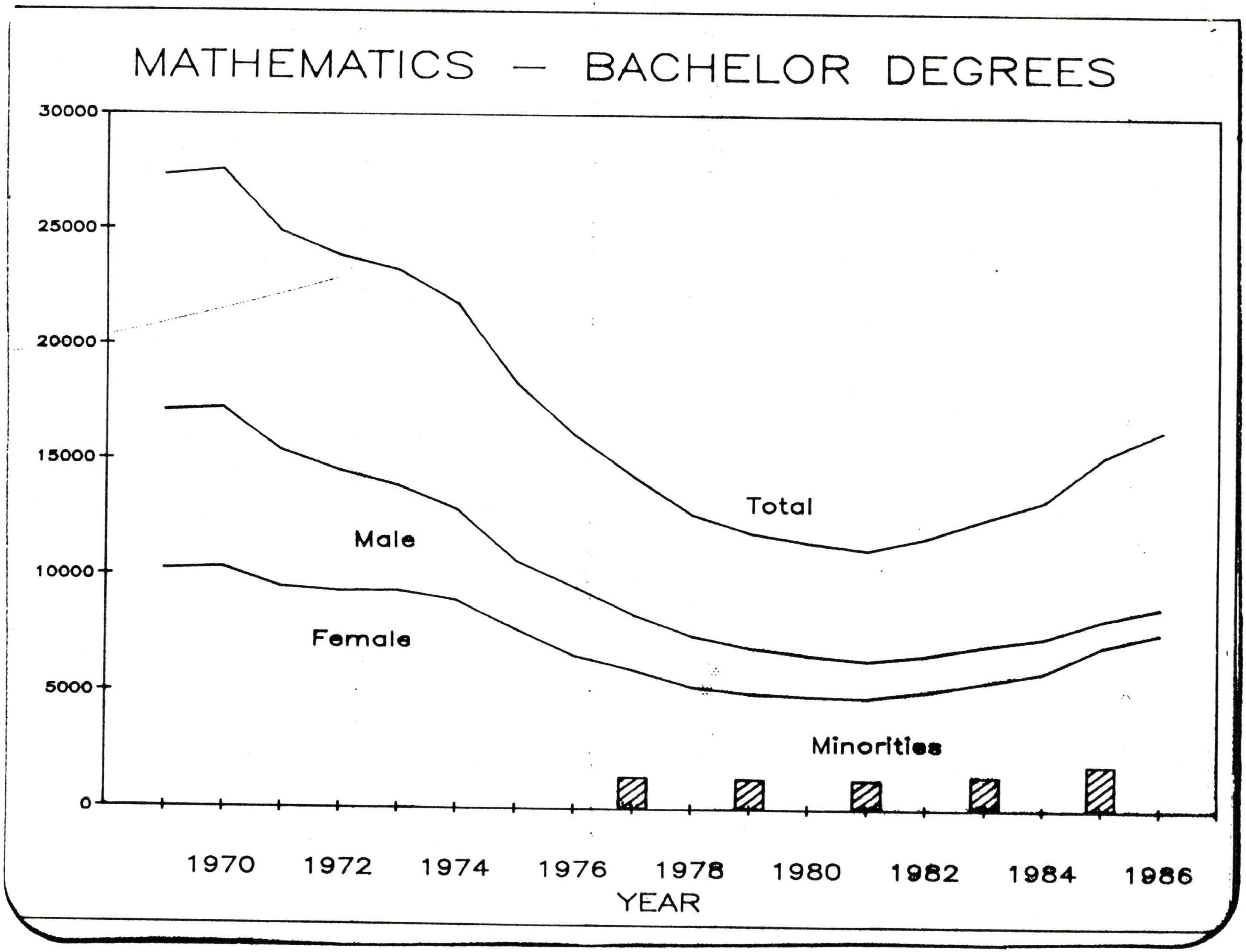

MATHEMATICS — BACHELOR DEGREES
30000
25000
20000
15000
10000
5000
0
Total
Male
Female
Minorities
1970
1972
1974
1976
1978
1980
1982
1984
1986
YEAR

FIG. 24

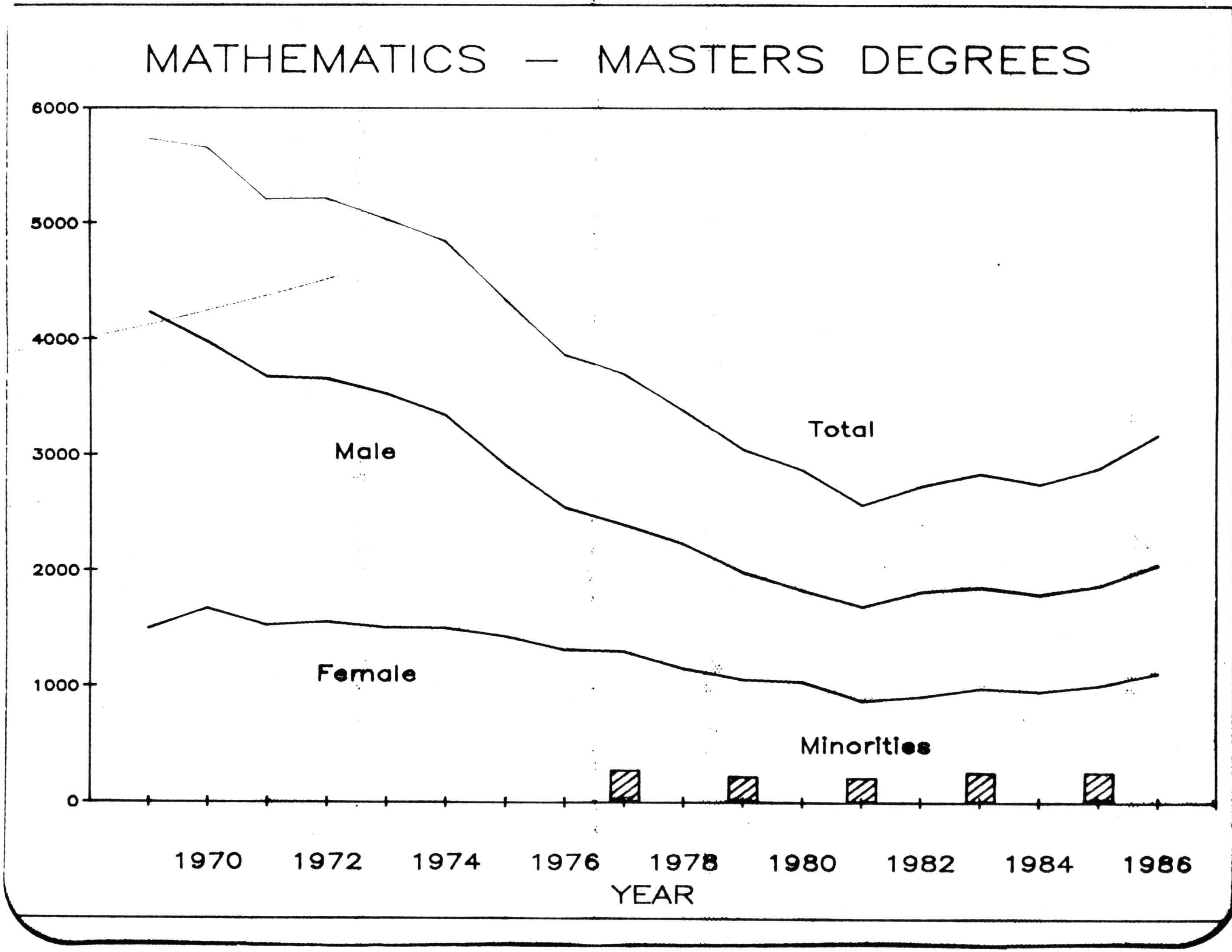

MATHEMATICS — MASTERS DEGREES
6000
5000
4000
3000
2000
1000
0
Total
Male
Female
Minorities
1970
1972
1974
1976
1978
1980
1982
1984
1986
YEAR

FIG 25

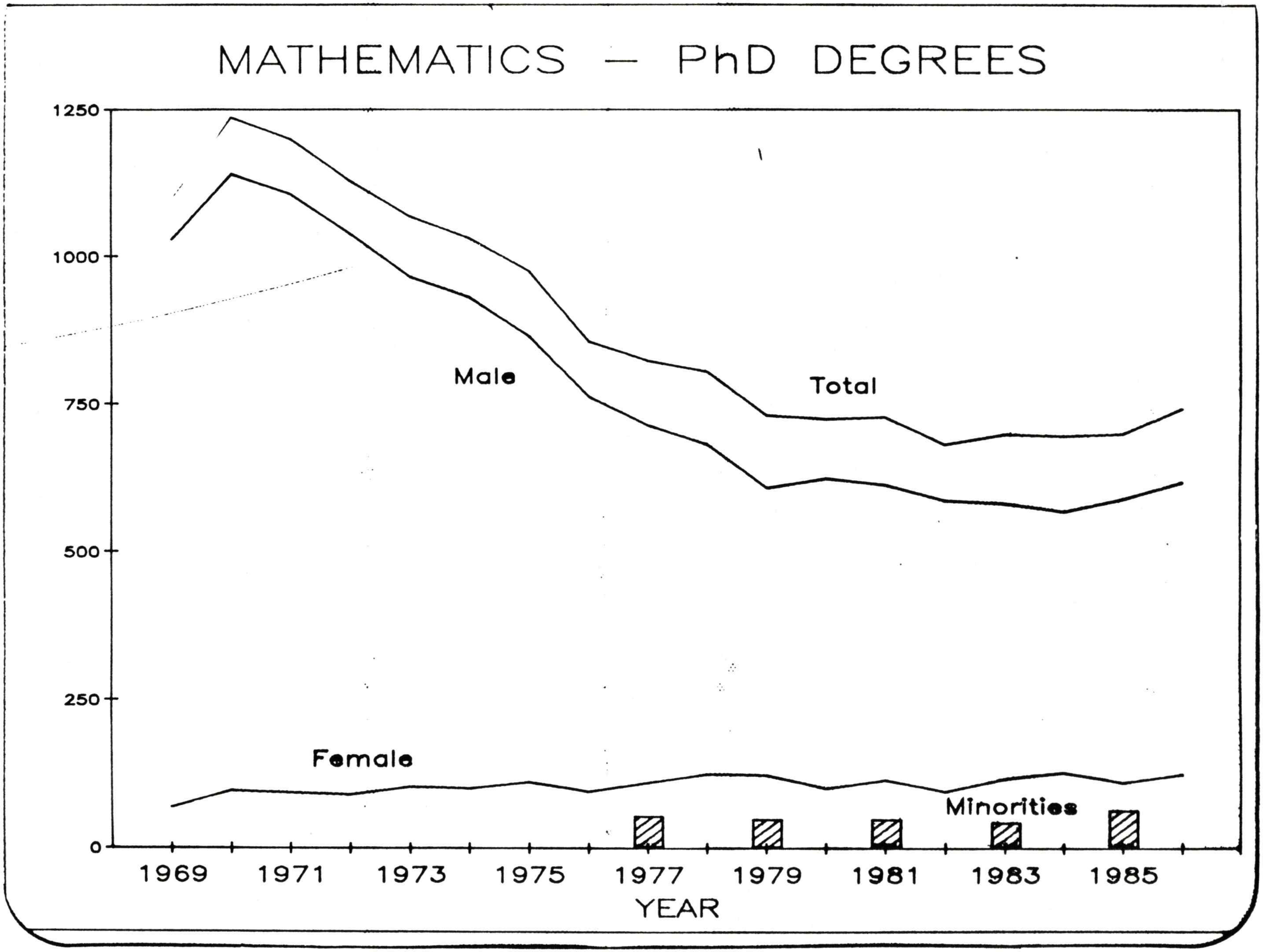

MATHEMATICS — PhD DEGREES
1250
1000
750
500
250
0
Male
Total
Female
Minorities
1969
1971
1973
1975
1977
1979
1981
1983
1985
YEAR

FIG 26

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

FIG. 27

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

FIG. 28

AGES 9, 13, AND 17: NATIONAL TRENDS IN AVERAGE SCIENCE PROFICIENCY

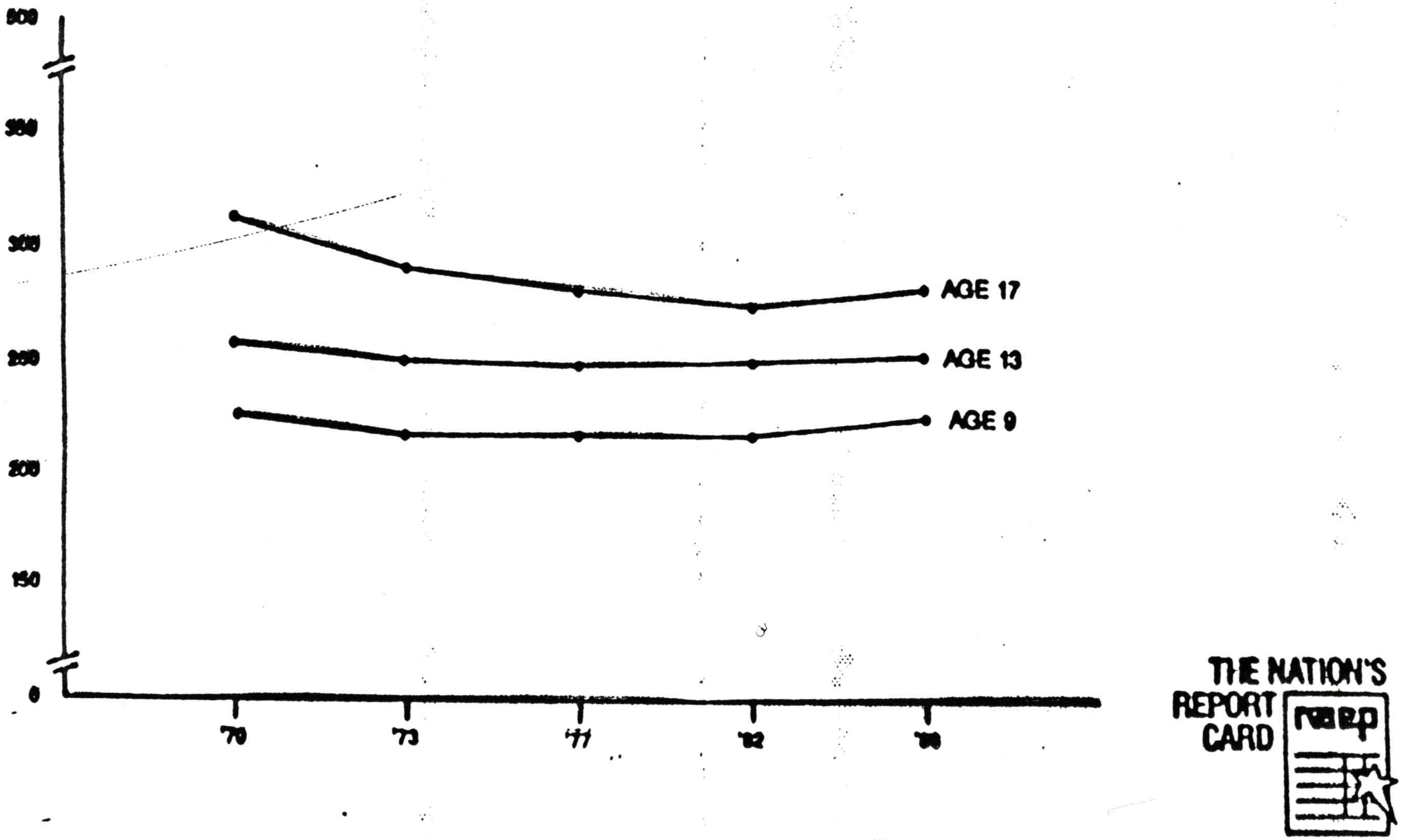


FIG. 29

AGES 9, 13, AND 17: TRENDS IN AVERAGE SCIENCE PROFICIENCY BY RACE/ETHNICITY

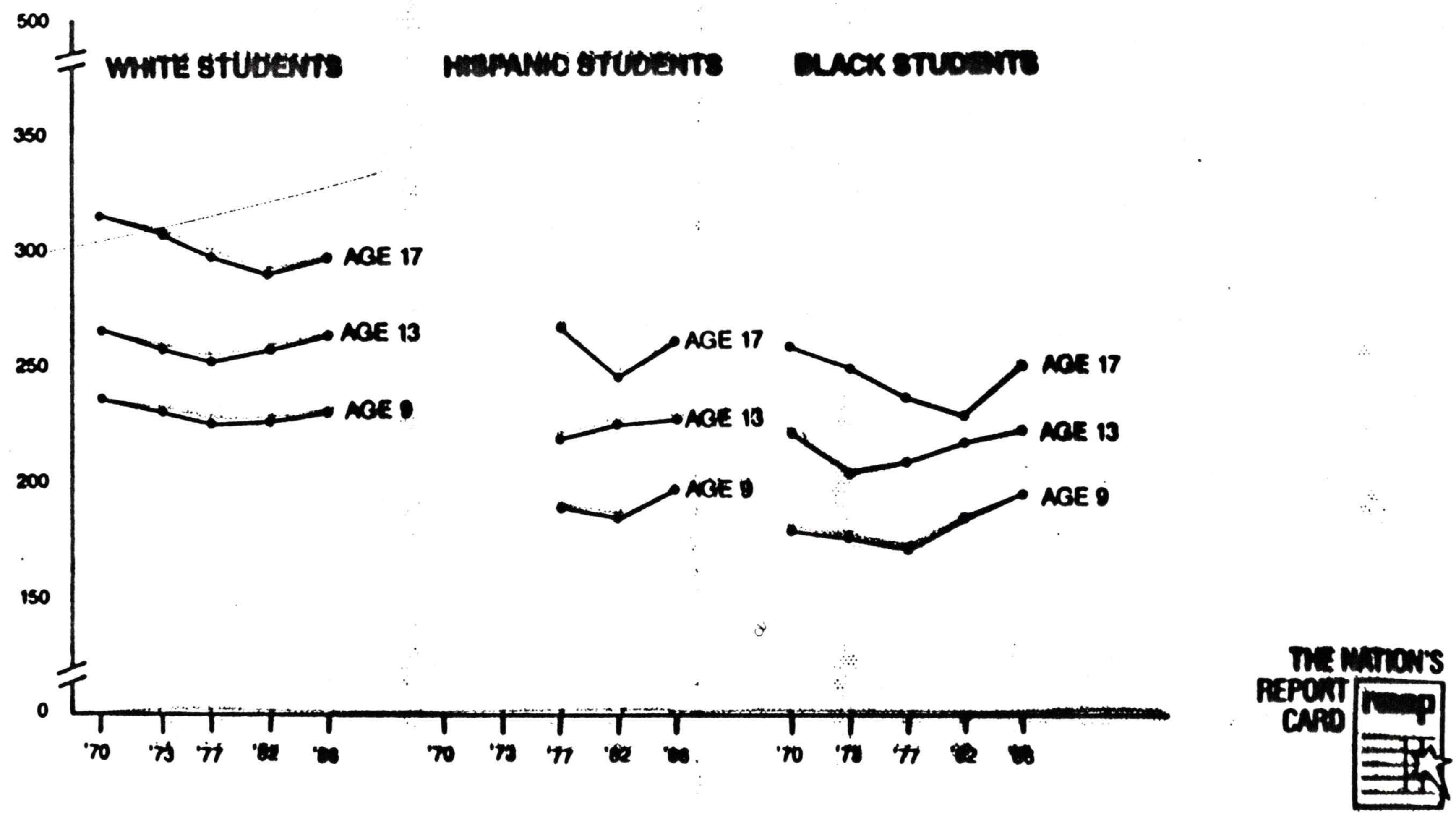


FIG. 30

SCIENCE, MATHEMATICS, AND ENGINEERING FOR:

- NATIONAL SECURITY
- ECONOMIC SECURITY
- EFFECTIVE DEMOCRACY
- PERSONAL REASONS

  ENLIGHTENMENT

  JOY

  JOB

  ETC.

FIG 31