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Lecture 16: What I Was Hired to Do is Not Part of My Job

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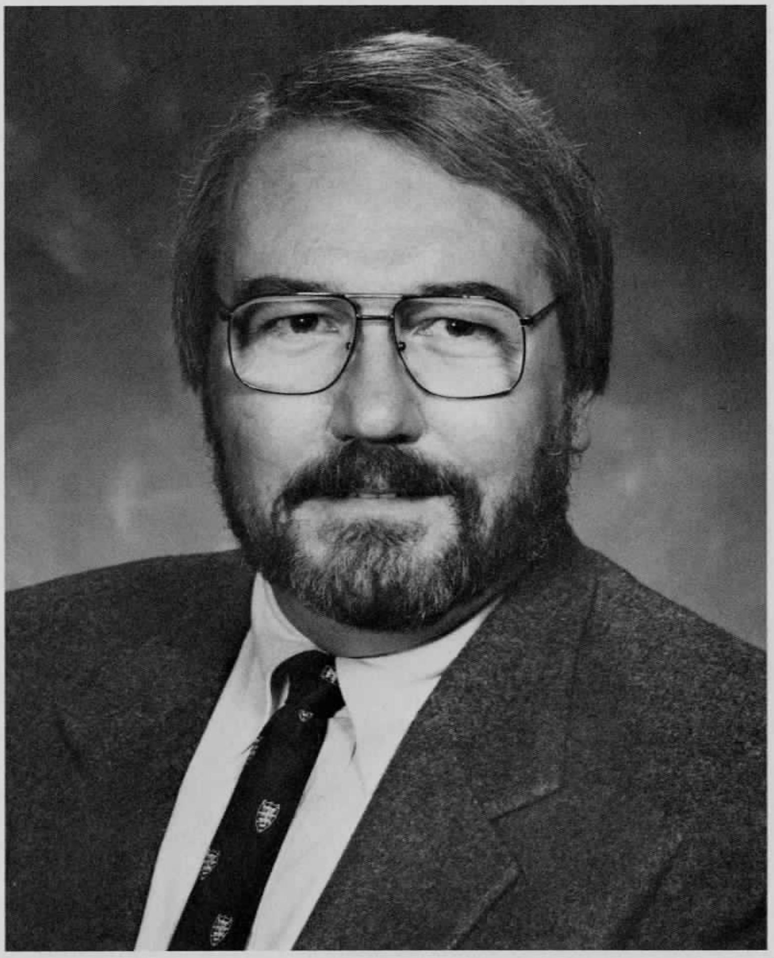

What I Was Hired to Do Is Not Part of My Job: Teaching, Research, and the State of American Education

by

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What I Was Hired to Do is Not Part of My Job

INTRODUCTION

Twenty-eight years have passed since I took my first position as a college professor. I was hired to teach experimental embryology and developmental biology but promised that I would, someday, teach ecology. What I did not realize was that my responsibilities were to develop a research program that would accrue grant dollars, generate overhead funds that my university could use, publish papers to establish my reputation as a contributing scholar, and sit on numerous committees to deal with university matters. In a very real sense, what I was hired to do --teach--was not a significant part of the day-to-day things that would assure my advancement and promotion. In a very real sense, what I was hired to do was not part of my job.

Today we are much more open about our expectations that college professors do research, but we still wrestle with the proper balance between teaching duties and research. It is often asserted that universities, including Utah State, give higher priority to rewarding the research efforts of faculty members than their teaching. This is especially troublesome because I know that Utah State and other universities place a high premium on teaching--we just have a hard time deciding how to evaluate it. We have less trouble evaluating research because we can count publications in peer-reviewed journals and dollars and grants per year and present these data in a very quantitative and comparative fashion. This quantification lulls us into believing we have measured the quantity and quality of research productivity.

We ignore the problem of evaluating teaching because it is generally believed that good teaching and research are integrally related. I often hear that the best teachers are likely to be active researchers. Whether this is true is of more than passing interest to scientists in the 1990s. Our current national emphasis on effective science education and on the proper balance between teaching and research was precipitated by the observations that fewer students are interested in careers in science and that the public is less informed about scientific issues than is desirable in an increasingly technological world.

In this context, what I will discuss here are: 1) the magnitude of the problem of decreasing interest in science, 2) some, but not all, of the causes of this decreased interest, and 3) some considerations in developing solutions to the problem.

At the outset, I need to make clear that I am not presenting only my own thoughts. The problems resulting from the declining interest in science have been highlighted in many national forums and much of what I offer had its genesis in the work of others. Legions of scientists and educators, not necessarily mutually exclusive categories, are addressing the problem of contemporary science education. My contribution to the dialogue will be small, however. Because this is my Last Lecture I want to be quite pointed as I survey facets of the problem.

THE PROBLEM

The United States has long prided itself on being a world leader in science and technology. We revel in being the best in both basic and applied research and in having the best educational system. These things have been important to us as a nation because they mean our scientific and technological industries can prosper and our citizens can lead lives characterized by quality that is possible only through the application of scientific and technological knowledge.

Unfortunately, our position is being challenged by other countries. For example, it is clear that Japan is moving to control industries that have predominantly scientific bases, e.g., the development and production of semiconductors. Additionally, Japan is surpassing the United States in the scientific literacy rate of its citizens. Our deficit is pitifully obvious when we compare the performances of American students with international norms (Fig. 1).

In addition to generally low student performance, fewer and fewer students are becoming scientists (Fig. 2). Since 1985 the numbers of bachelors degrees awarded to natural science and engineering students has declined. The number of U.S. citizens completing B.S. programs in science and engineering has decreased, while the number of non-citizens completing Ph.D.'s in these programs has increased (Fig. 3).

The loss of student interest in science is a progressive phenomenon that begins in grade school and continues unabated through the Ph.D (Fig. 4). The National Science Foundation calls this phenomenon the "pipeline." While the loss of interest in careers in science is alarming in its own right, there is a concurrent, and perhaps related, general decrease in interest in science and in scientific literacy. Together, these trends are cause for national alarm and action. They foretell a nation that cannot produce the numbers of scientists and engineers necessary to educate its students and contribute to the functioning of its society.

Scientists commonly approach the "decline" by suggesting that we get better teaching and teachers in grades K-12. This relieves us, the university scientists, of direct responsibility. Meanwhile, we continue to lament how little scientific knowledge freshmen at the university have achieved. The solution is more complex than merely pressuring colleges of education to improve the quality of teacher education in the sciences. University scientists must bear some responsibility for both the problem and its solution.

In my view, we college-level scientists do not offer challenging, interesting, and useful courses to non-science majors, and we dull and lose science majors by imposing unnecessarily strict, inflexible, jargon-filled, overly discipline-specific coursework requirements. Additionally, we do not train graduate students to enter the professoriate by providing them the tools they require to be teachers as well as researchers. Although we can take little solace in the fact, we come by this dulling effect honestly: we merely require of our students what we endured during our own training. That being the case, it may be informative to examine our own educational experiences further.

THE PROFESSOR'S PROCRUSTEAN BED

I have chosen an unusual heading for this part of my talk: The Professor's Procrustean Bed. Webster's 9th New Collegiate Dictionary defines Procrustean Bed as "a scheme or pattern into which someone or something is arbitrarily forced." Procrustes, a villainous son of Poseidon of Greek mythology, forced travelers to fit into a bed by stretching their bodies or cutting off their legs. I think this is an apt description of the professoriate in American universities and how we were trained.

As graduate students, we were forced into a mold that left little leeway for individuality. There were constraints on the topics for our dissertations, the style in which they were to be written, and even our interactions with our graduate committees. This was done, it was asserted, because there are certain standards in the practice of science.

In fact, the bland writing style that scientists often use has also been referred to as part of the "cult of dullness" that pervades contemporary science. We learned to write in a manner that would not be offensive and in a telegraphic style that showed little creativity or enthusiasm about our findings. The products of our work were seldom understandable except to those who were familiar with the jargon of our respective fields. Our writing was also influenced by the fact that the people who reviewed us, members of our graduate committees, had personal biases of perspective and style. We had to avoid conflict with these biases. After all, graduate school was a form of trade school where we were trained for academic careers. We got what one would expect from a trade school: a homogenization of style, approach, and substance that dulls the spirit, stifles creative thinking, and drives students away from science. We have passed our own experience on to new generations of students.

Once graduate school was finished, norms dictated a few years of post-doctoral work that enabled us to get more publications on our records, which increased our competitive edges for available jobs. During this period, there was little possibility of teaching or learning how to teach. When, finally, we landed jobs, we were expected to teach: a task that was not part of our job preparation. As young professors we had discipline-specific knowledge but not the skills to convey that knowledge in a palatable and interesting manner. But, we knew how to conduct research and publish papers in esoteric journals.

Let me state at this point that I am completely in accord with the general concept that a faculty member should always be intellectually alive. Certainly, conducting original research is one manifestation of such vitality; however, it is not the only one.

As I mentioned previously, it is often asserted, that researchers are our best teachers. As a generality, nothing is further from the truth. I have known, and I am sure you have known, excellent teachers who were also excellent researchers; however, I have known more excellent researchers who were simply dull. I have also met people who had no recent research experience yet were some of the best informed and challenging individuals with whom I have ever interacted.

It is not surprising that teaching and research are not correlated. The vast majority of research done by professors in the United States is esoteric and would be of little interest if included as part of the undergraduate experience. Page Smith, in his recent book, Killing the Spirit, says this about the characteristics of good teaching: "It is my contention that the best research and the only research that should be expected of university professors is wide and informed reading in their fields and in related fields. The best teachers are almost invariably the most widely informed, those with the greatest range of interests and the most cultivated minds. That is real research and that, and that alone, enhances teaching."

I don't agree with Dr. Smith's assertion that "his" is the only research or even the most relevant research; however, I think that teachers who are widely informed in their own fields are likely to be excellent teachers, if they also have the ability to present information in a palatable way. Neither being well informed nor having teaching skills is related to doing research per se, and thus, the ability to perform research may have little to do with teaching.

There is a further problem with the research activity/teaching ability illusion. In most university settings faculty members receive raises and other favors, including the adulation of their colleagues, based on evaluation of their performances as professors. Because there is the perception that teaching is hard to evaluate, there is a tendency to use the supposedly quantifiable measure of research as an indicator of a professor's overall contribution to a university. This is usually not done in any sense of believing that research is more important than teaching. It is more a product of the convenience of being able to "quantify" research productivity and the belief that we do not have an adequate measure for quantifying teaching.

The use of research productivity as a surrogate measure of teaching and the general emphasis on grantsmanship has led, inevitably, to a proliferation of publications in all fields of human endeavor. There are nearly 74,000 scholarly journals produced in the world each year. All professors, because they feel their greatest advancement is based on research productivity, attempt to publish in these journals. Not all of these journals are of equal quality, and not all of the papers published each year make a contribution to our knowledge. In fact, there are some alarming data that suggest that the vast majority of publications are essentially useless--except, perhaps, to the individuals who produced them.

A study by the Philadelphia-based Institute for Scientific Information indicates that 55% of the papers published between 1981-1985 that are indexed by the Institute were not cited in other papers in the five years after they were published. This means that half of all papers analyzed are never important enough to be used in the works of other researchers. This is even more alarming in light of the fact that the IFI data base includes only 4,500 of the 74,000 journals that exist. If the analysis had included all existing journals, the average citation rate would have been exceedingly low, probably less than 5%. I should note that there is no consistency of citation by field. Ninety-eight percent of all arts and humanities papers are never cited. In contrast, in some fields, for example atomic molecular and chemical physics, only 9.2% are uncited.

One disturbing trend that has resulted from these kinds of analyses is the use of citation indices to measure the quality of a paper. I recently surveyed over 600 citations of a major paper. Most workers cited the paper because it contained a popular definition rather than for the substance of the research.

Evaluating our effectiveness as professors is compounded by the problems I have mentioned. We feel uncomfortable evaluating teaching and, at the same time, we delude ourselves that we have a quantitative measure of research. Since we believe teaching and research are intimately related, we use research productivity as a surrogate measure of good teaching. We evaluate a professor's overall performance based on the production of research papers and most research papers are useless. They are written for the investigators' own purposes and have little impact on their fields. That being the case, we should assess the quality of teaching directly and not rely on research as an indirect measure.

An additional, rather disturbing, outcome of the pressure to publish is the increase in either the level of fraud in the research enterprise or in the level that it is being discovered. I find it an extremely unsettling trend to see the pages of major scientific journals, for example, Science, dominated by reports of investigations of fraud in the scientific community. An indication of how pervasive fraud has become within the research community is indicated by a recent National Academy of Science report entitled "On Being a Scientist." This document was written primarily for students embarking on scientific research. It was intended to describe "the basic features of a life in contemporary research." In that document are sections that deal with plagiarism, deception, fraud, error, and determining priority of authorship. More evidence that emphasis on the publication of papers in journals may be woefully misplaced.

As we try to improve teaching, it seems reasonable that we might pay more attention to students. In this vein, two questions seem obvious: 1) What do students perceive as characteristics of good courses/ teachers? and 2) Are student evaluations valid?

Results of a recent study conducted by Richard J. Light, a professor at the Harvard School of Education and the Kennedy School of Government, indicate that students' evaluations of courses are fairly consistent. He says, "Students have remarkably clear and coherent ideas about what kinds of courses they appreciate and respect the most. When asked for specifics, students of all sorts (strong and not so strong, women and men, whites and minorities, freshmen and seniors) list three crucial features: A) immediate and detailed feedback on both written and oral work; B) high demands and standards . . . with plentiful opportunities to revise and improve . . . work before it receives a grade, . . . learning from . . . mistakes in the process; and C) frequent checkpoints such as quizzes, tests, brief papers, or oral exams." Most students feel they learn best when they receive frequent evaluation combined with the opportunity to revise their work and improve it over time. Unfortunately, this strongly suggests that a more intimate association with students is the best milieu for learning. As enrollments increase and we are forced to increase the sizes of our classes, the opportunities for personal association are diminished.

To do a better job at teaching, we must be able to recognize when we are being effective and when we are not. The primary data for this recognition are likely to be student evaluations. Faculty members in general and scientists in particular rail at the idea that students have the capacity to fairly judge their courses. There are a variety of comments concerning the utility of student evaluations. How often have you heard faculty members say they received low evaluations because their courses are more rigorous and that teachers who get higher evaluations are simply popular and undemanding? How often, too, have you heard that students cannot evaluate the effectiveness of teaching until they are out of school or that teaching evaluations do not really measure teaching effectiveness? However, despite assertions to the contrary, student evaluations may be the best measure of teaching currently available.

It is clear from a variety of studies that the most highly rated teachers tend to be those who push their students to achieve higher levels of performance. In a recent editorial in American Biology Teacher, Randy Moore collated the results of a variety of studies of teaching. He came to the following conclusions: 1) highly rated teachers tend to be those whose students achieve the most; 2) the perceived difficulty of a course has no significant relationship to student achievement; 3) student ratings are not significantly affected by the amount of work an instructor assigns; 4) students in the classes of teachers with high ratings develop more sophisticated ideas about subject matter than students in the classes of teachers with lower ratings; 5) the ratings of alumni do not differ significantly from those of current students evaluating the same teachers; 6) students generally give the highest ratings to the teachers from whom they learn the most; 7) there is no significant relationship between an instructor's research productivity and students' ratings (neither does research involvement detract from good teaching); 8) characteristics of a superior college teacher are clarity, understandability, knowledge of subject, preparation for and organization of the course, enthusiasm, and student/teacher rapport.

Given the above, we have no good reason to reject out of hand this valuable source of information on how well we are doing our jobs as teachers; in fact, I think it is incumbent on us to use every datum that we can find to increase the effectiveness of our teaching.

In addition to increasing the quality of education at all levels, we must recruit more students and teachers into science. An increase in the quality of education will help increase the numbers of scientists; however, the main influence may be to increase the retention of those who already have a scientific interest.

We must find new sources of talented students who might not be oriented to scientific careers. Two pools of such individuals have been recognized nationally. The first is a group of students who, on the surface, does not seem to be interested in science. This group, referred to as the "second tier" by Sheila Tobias in her book <u>They're not Dumb, They're Different</u>, "...may have different learning styles, different expectations, different degrees of discipline, different 'kinds of minds' from students who traditionally like and do well at science." To tap into this pool we may have to configure science education in quite a different way; however, the result may be scientists qualified in a technical sense who approach problems with different perspectives and who add greatly to the richness of the scientific endeavor.

The second relatively untapped pool is one that is quite well known. In general, scientists are white males. While some scientific fields have attracted non-white males, the pool of females, hispanics, and blacks remains largely untapped (Fig. 5). We must find ways to entice these individuals into scientific careers. One enticement could simply be to treat them as equals and to provide mentoring experiences as they attempt to "crack" the white male-dominated bastion of contemporary American science. This process is already occurring for women. Blacks, hispanics, and other minority groups have not yet begun to scratch the surface, and it is a national tragedy that we have not recognized this large pool of talent.

It should be obvious that we have to increase the quality of our science teaching in colleges of science, and we must interpret our research findings for the public at large. To promote this, we must reward faculty for good teaching as well as good research. We must offer potential scientists opportunities to creatively jump through our hoops, turn on teachers through the training we give them, enthuse graduate students, and encourage the efforts of faculty to offer challenging courses. Additionally, we must tap unused pools of human talent to fill the ranks of the scientific community.

DEVELOPING SOLUTIONS TO THE PROBLEM

In this brief consideration of the problems of the education system, it is not possible to include all of the background information necessary to understanding the causes and the consequences of the poor science education we provide students and the public at large in America. Despite the fact that I have not fully developed all of the ideas in my text, I would like to finish this discourse by making a series of recommendations for actions. I divide my comments by the groups affected.

All Ages

- We must spend more time recruiting and retaining individuals who are not traditionally interested in science, the so-called "second tier." We must find ways to recruit and retain females, blacks, hispanics, and other minority groups at every level of the educational process. More detailed attention to the quality of education of non-female minorities may help. Treating women as colleagues rather than curiosities will undoubtedly help expand that pool.

Grades K-12

- We must increase the amount of homework students are required to do. Currently American students average only 3.5 hours of work/week; they attend classes an average of only 20 hours/week. This is far below the levels required of students in countries that are surpassing us in science. I am not against extra-curricular activities, but our students are capable of much more than we require of them. We must offer courses that integrate a variety of sciences and emphasize the coherency of science as a discipline rather than the uniqueness of each of its fields. I am not proposing a generic general science course but rather a course that uses the perspectives of each of the sciences to address a particular topic. We must demonstrate the overall significance of science in everyday life.

- We must begin to teach mathematics earlier and to provide more math in the early years of education. The level of achievement in mathematics of students in American is far below that of students in Europe and in Asia, where mathematics education begins earlier and is provided over a longer period. When European and Asian students begin college they are at a higher level than second-year American college students.

Undergraduate College Level

• We must teach problem-solving and computational skills as well as the fundamental concepts that are crucial to our fields in our core courses. We must not allow our scientific courses to continue to rest on teaching students new sets of jargon. We tend to have students spend more time memorizing terminology than learning to understand the phenomena represented by the terminology.

• We must make effective use of computers, but we should not allow computers to replace laboratory experimentation. The best way to teach students about science is to allow them to go through the thought processes and procedures involved in developing research problems. This includes allowing false starts and going down wrong paths in hands-on experimentation.

• We must spend more time teaching our students about the origins, processes and goals of science and less time with discipline-specific matters. Perhaps the most important thing for students to learn is that science is not simply a body of knowledge--it is a way of knowing.

Graduate Students

- We must teach graduate students to teach.

- We must permit greater flexibility in thinking, and we must not force our own ideas on students. Our own approaches to science are not always the best. This is not to say we should allow students to make mistakes we can help them overcome, but rather we should provide an environment wherein they have a greater opportunity for freedom of expression, both in research work and writing.

Faculty

- We must find ways to reward good science teaching. This should be fairly easy. We must develop a system whereby teaching, research, and service to the university are rewarded in proportion to activities in these areas. We should not reward more for publishing research papers than we do for developing innovative classroom methods. We must find ways to judge and reward the public presentation of scientific information. This means that the university will have to accept and all of our colleagues will have to value attempts to write in the popular literature or to make presentations that interpret science to the general citizenry.

The Public

• We must find creative ways to deepen the public's understanding of science. It sometimes escapes scientists that everything we do either directly or indirectly requires both the finances and the acceptance of the public. Most of us are paid and have our research sponsored by public funds. Sometimes funds come to us directly from state allocations. At other times they are funneled to us through monies that are allocated to funding agencies and awarded to successful grant applicants. These are also public funds. We cannot expect the public to continue to blindly support research they cannot understand. It is my contention that if we could communicate the excitement and importance of what we do, we would never have to be concerned about public support for our endeavors.

This is certainly not an exhaustive list of ways to improve science education in America. It is an incomplete mosaic rather than a highly integrated fabric of thought. I hope reflecting on these ideas will inspire my colleagues to address these topics and to determine for themselves the veracity of what I have said. If we are going to restore America's preeminence as a scientifically based culture, we must improve the education of both students and the public. This will require that scientists do new and different things with their time. As members of the university community, we must judge our colleagues and reward them so that what they are hired to do is actually part of their job.

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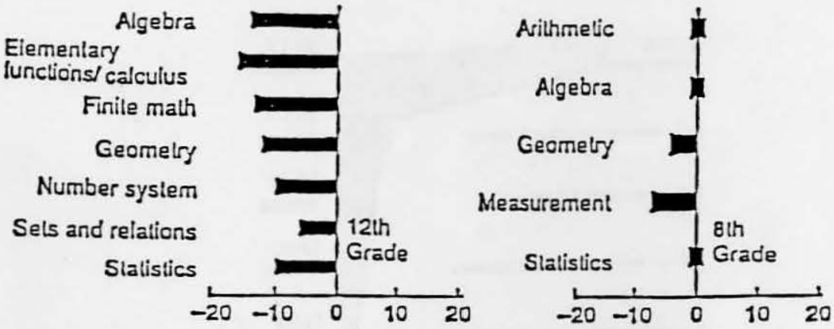


Fig. 1. Performance of 12th and 8th grade U.S. students in a number of fields, showing the difference from the international median. [Reprint with permission of the Rand Corporation]

Fig. 2. Natural Science and Engineering (NS & E) B.S. degrees to U.S. citizens, assuming current participation rates. [Source: National Science Foundation]

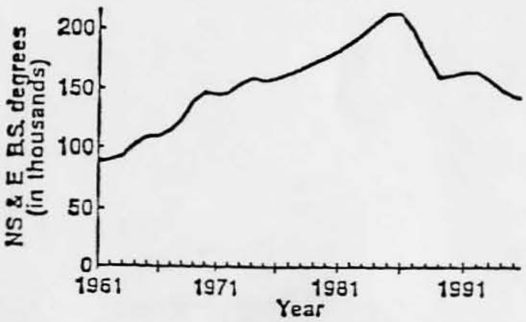
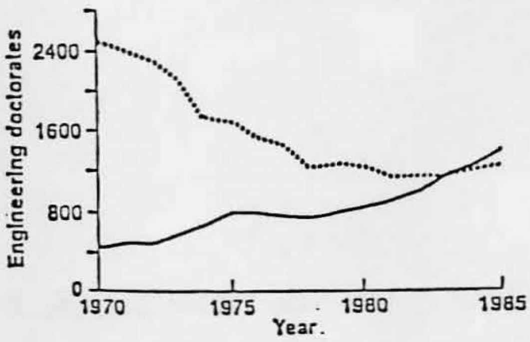


Fig. 3. Engineering doctorates awarded to U.S. citizens (dotted line) and to holders of temporary visas (solid line), 1970-1985. [Source: National Science Foundation]



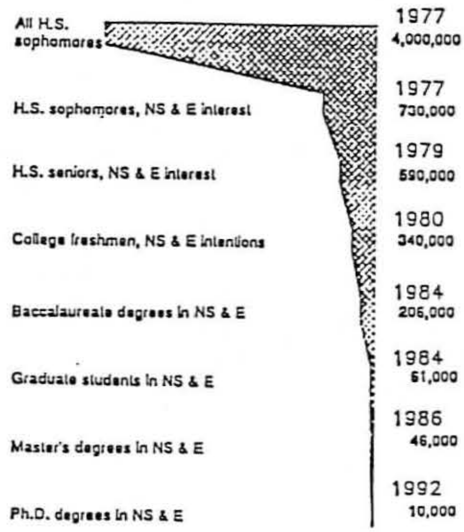


Fig. 4. Illustration of the pipeline, showing the persistence of natural science and engineering interest from high school (H.S.) through Ph.D. degree. [Source: National Science Foundation]

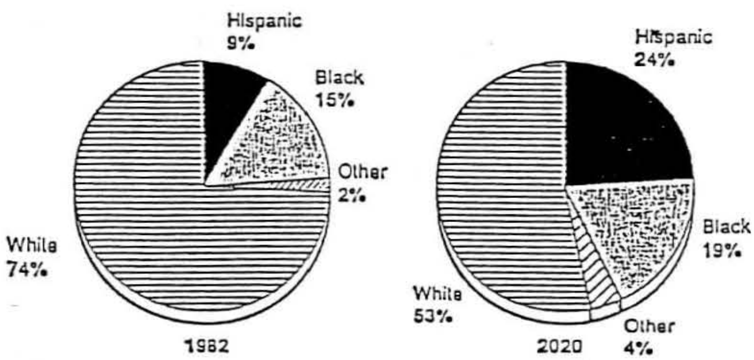


Fig. 5. Distribution of students, age 5 to 17 years old. [Source: National Science Foundation]

Figures are taken from Massey (1989) Science 245:915-921.