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I Never Promised You First Place

Goal 4. By the year 2000, U.S. students will be first in the world in mathematics and science achievement.

With regard to science and mathematics education, the bottom line is not so grim as the current rhetoric would have us believe, Ms. Rotberg maintains. Nor are the problems identified by that rhetoric necessarily the ones that are most troublesome.

BY IRIS C. ROTBERG

THE PURPOSE of this article is to reduce the probability that I will be asked at a dinner party, yet again, why the United States ranks near the bottom in international comparisons of science and mathematics achievement. The question is likely to receive even more attention in the context of the fourth national education goal, which holds that U.S. students will be first in mathematics and science by the year 2000.

The conventional wisdom, based on international comparisons of test scores, is that the U.S. is outclassed by other nations. An emphasis on such comparisons, however, is misleading for two reasons:

- the relative rankings of nations are biased by a number of important methodological problems; and
- the preoccupation with the single criterion of test scores as the primary indicator of achievement in science and mathematics – even if methodologically sound – deflects public policy away from far more important issues.

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WITH A PROPER SAMPLE, WE DON'T HAVE TO BE LAST

The U.S. ranks somewhere between middle and last place in international comparisons of science and mathematics achievement for a variety of reasons. In part, the results reflect differences in curricula and teaching strategies across countries.[1] They are also influenced by important methodological problems, some of which relate to the construction of the test itself: the relative weight given to subjects emphasized by one country but hardly touched by another, the representativeness of the items chosen to measure mastery of the subject matter, and the extent to which the test results correlate with other measures of achievement.[2]

However, the major problem with international comparisons relates to sampling methodology. Specifically, it is important to know how the research design controls for differences in the proportion of the age group actually attending school in each of the countries and grades tested and whether the geographic and socioeconomic composition of the sample is a fair reflection of an entire country. Because of practical difficulties in implementing even a well-designed plan, the sampling problems in previous international comparisons are likely to be even more evident in future assessments, which will include a more varied set of countries.

PREVIOUS COMPARISONS

The first set of international comparisons, conducted by the International Association for the Evaluation of Educational Achievement (IEA) in the 1960s and early 1970s, did not take into consideration the percentage of the age group actually enrolled in upper-secondary school. These attendance rates are much higher in the U.S. than in most other countries (with the exception of Japan, which has an even higher attendance rate than the U.S.). At the time these tests were administered, only about 20% of the age group in Europe attended upper-secondary school – the *highest*-achieving 20% – compared to 80% of the age group in the U.S. Thus the IEA assessments compared the average score of more than three-fourths of the age group in the U.S. with the average score of the top 9% of the students in West Germany, the top 13% in the Netherlands, and the top 45% in Sweden.[3] It is not surprising that U.S. students did not do well in these comparisons.

Of course, this type of sampling problem is not limited to international comparisons. To a considerable extent, the well-publicized decline in scores on the Scholastic Aptitude Test (SAT) resulted from the fact that more students took the SAT and attended college, and not from a decline in the quality of the educational experience. The relative rankings of states on average SAT scores are also a reflection of the proportion of students who take the test. The states with the *highest* proportions of students taking the SAT tend to have the *lowest* average SAT scores. Indeed, one way to increase a state's average SAT score would be to discourage students from applying to colleges that require the test![4]

More recent IEA assessments have tried to deal with the sampling problem by comparing, at the 12th-grade level, only those students who are in an academic track and are taking mathematics or advanced science. While these revisions have helped, it is extremely difficult to eliminate the problem.

Consider, for example, the results for Hong Kong and Japan in the most recent mathematics assessment.[5] Only 3% of the age group in Hong Kong takes 12th-grade mathematics, compared to 12% in Japan. In the eighth grade, however, the proportions of the age group taking mathematics in both countries are more comparable. The eighth-grade mathematics assessment ranks Japan number one, with Hong Kong in the middle of the distribution. By 12th grade, after the great majority of Hong Kong's young people are no longer taking mathematics, Hong Kong scores first and Japan second. The reality is that Hong Kong's *schools* are not dramatically better in the 12th grade than in the eighth. The outcome is simply a matter of student selectivity.

It is also useful to compare the *pattern* of results for countries with a high percentage of students taking 12th-grade mathematics with the *pattern* for countries with a low percentage of students in these classes. I hypothesized that countries with a high proportion of young people taking 12th-grade mathematics would rank relatively *lower* in the 12th-grade comparisons than they did in the eighth-grade comparisons, while countries that retain only a small, highly selected group in mathematics would rank relatively *higher* in the 12th-grade comparisons. To examine this hypothesis, I selected the two locations with the highest percentage of the age group taking mathematics in the 12th grade: Hungary at 50% and British Columbia at 30%. I compared the data for these two locations with data for the two locations with the lowest percentage of students taking 12th-grade mathematics: England/Wales and Israel, both at 6%.

Hungary ranked among the top countries in the eighth-grade comparisons. By the 12th grade, when Hungary retains proportionately *more* students than any other country, its students scored near the bottom. Are Hungarian secondary schools that much worse than Hungarian elementary schools? Or does the normal pattern – more students, lower scores – explain the dichotomy?

Illustration by Jimmy Margulies

British Columbia also has a high proportion of students taking 12th-grade mathematics. The students scored quite high in three-fourths of the eighth-grade tests. They scored at or near the bottom by the time they got to the 12th grade.

By contrast, England/Wales, which has one of the *lowest* percentages of students taking mathematics in the 12th grade, ranks among the top countries in the 12th-grade comparisons – a significant increase from its rank in the bottom half in three-fourths of the eighth-grade comparisons. Did the schools

Each country's sample ought to reflect its entire population.

improve or is it more likely that selectivity simply resulted in higher average test scores for the relatively few students taking mathematics in the 12th grade?

Israel, which also has a low proportion of young people in 12th-grade mathematics classes, is an exception to the pattern. Israeli students rank approximately the same in both the eighth- and 12th-grade comparisons.

The comparative rankings of the nations also reflect differences in the 12th-grade curriculum. In the IEA assessment, U.S. students who took calculus, which is included on the test, met or exceeded the international average. Those who did not study calculus scored well below the average – not a surprising finding. In most other countries in the assessment, *virtually all* advanced mathematics students take calculus. In the U.S., however, only about one-fifth of students taking 12th-grade mathematics study calculus.

Clearly there is room for debate about whether a higher proportion of U.S. 12th-graders *should* take calculus, but this issue cannot be resolved by examining the results of international comparisons. If we think it wise to teach calculus to a larger proportion of 12th-graders, let us do so after an analysis of the issue on its merits – Who would teach it? What course would it displace? Are students who take calculus for the first time in college at a disadvantage? – and not on the basis of the lower test scores of students who have never taken the subject.

In addition to the assessments conducted by the IEA, the Educational Testing Service initiated the International Assessment of Educational Progress (IAEP) in 1988.[6] This assessment, which tested 13-year-olds in mathematics and science, showed that the U.S. ranked last among the participating countries. Because of the small sample size and the acknowledged methodological problems, this assessment was labeled a "pilot" – although this label has not been reflected in public rhetoric about the results.

Only a few countries participated in the assessment: Ireland, Korea, the United Kingdom, the U.S., and Spain, along with some Canadian provinces that were further subdivided according to language group. (For instance, Ontario was broken down into English-speaking and French-speaking populations.) I will not try to unravel all the sampling problems inherent in such a list, but we clearly need a lot better information than we have to interpret the findings accurately.

For example, we do not know how representative the samples in each country were with respect to socioeconomic status or geographic location. Thus, when the entire U.S. is compared with individual Canadian provinces, we do not know whether any differences in scores should be attributed to differences in the quality of education or to differences in the socioeconomic status of the students tested. When only the largest of several language groups in Spain is represented by the student population taking the test, we do not know enough about the correlation between language, geographic location, and socioeconomic status in Spain to interpret the results. Similarly, when the Inner London Educational Authority chooses not to participate in the assessment, we do not know how its exclusion affects the representativeness of the sample of British students actually chosen.

The reports on the assessment do not provide these data. The general public understandably concludes that differences in rankings reflect differences in the quality of education across entire nations. Yet it is just as likely that a large portion of the difference is accounted for by artifacts of sampling.

THE 1990-91 IAEP

The pilot International Assessment of Educational Progress has been greatly expanded and includes approximately 20 countries that are conducting assessments during 1990-91. The Soviet Union has been added to the list, as have several developing countries, including Brazil, China, and Mozambique. All the countries will administer mathematics and science tests to a sample of 13-year-old students, while a number of the countries will also test a sample of 9-year-olds.

With the introduction of many additional countries, the sampling problems become even more troublesome. My concern is not that methodological difficulties may cause a country to rank ninth when it really deserves to be, say, eighth, but rather that the comparisons will be seriously biased because only the most prosperous regions or the most elite schools and students will be sampled in some of the participating countries. Such findings would be no more useful to a developing country struggling to maintain an appropriate balance in the allocation of its scarce educational resources than they would be to the countries that rank poorly because their samples are more representative of the entire population.

My point is that each country's sample should represent the entire national distribution of the age group. In other words, if 62% of the Chinese population resides in rural areas, generally the poorest areas in China, then the sample should reflect that distribution. If the students actually tested do not represent the age group in the population, they should be compared only to similarly selected students in other countries. However, the issue is not the technical expertise needed to design a strong sampling plan, but practical considerations that would make implementation extremely difficult.

- There are major logistical problems in carrying out a carefully monitored administration of a standardized test across vast areas and remote regions of such countries as China and the Soviet Union.
- In many developing countries, reliable data are not available on which to base a national sample that reflects the entire population.
- Political considerations make it difficult for countries to include very poor regions or those that have a tenuous relationship with the central government.

- A number of decisions made for practical reasons – e.g., to include only Russian-speaking students in the Soviet Union or Mandarin-speaking students in China – strongly bias the samples toward the most elite regions and schools.
- Countries are likely to differ in the criteria they set for excluding regions, schools, students within schools, or even various ethnic and language groups.
- In countries with strongly elitist education systems – where only a small proportion of students is concentrated in relatively few regions, schools, or even classrooms – these choices will make a major difference in the country's ultimate ranking.

These problems of sampling school populations are compounded by differences in the percentage of low-income students actually enrolled in school in the various countries. We know from many studies that there is a high intercorrelation between family income, family educational level, and student achievement. Therefore, countries with substantial proportions of low-income students taking the test tend to score lower than countries with less poverty or those whose low-income students are not tested simply because they are not in school. Significant differences in the incidence of poverty – even among industrialized countries – can be expected to affect the relative performance of countries in international comparisons. However, the developing countries, which have the highest incidence of poverty, also tend to have the most elitist school systems and the highest proportions of their students out of school and therefore not tested. Thus the scores of developing countries on international comparisons are inflated because only small fractions of their student populations are tested compared to the broader testing that is carried out in more affluent countries.

Sampling problems are compounded by vast differences between urban and rural areas.

Indeed, many students in some developing countries have left school by the eighth grade – the main grade included in the assessment. While data specifically for the eighth grade are not available, we do know, for example, that in Brazil only 39% of the secondary school age group (defined as approximately ages 12 through 17) is in school; in China, the percentage is 43%; in Mozambique, it is only 5%.[7] Thus, even if the students still in school in eighth grade were accurately reflected in the sample, the results would be seriously biased by the exclusion of a substantial proportion of the age group no longer in school and therefore not tested. Finally, it is virtually impossible to ensure an adequate response rate – an essential factor in sampling accuracy – across the range of countries planned for the study.

China illustrates the sampling problems. Like most other developing countries with scarce resources, China has a highly elitist education system that provides advanced mathematics and science instruction to only a very small proportion of its students. The majority of Chinese young people have never studied the material covered by the assessment and are unlikely to be represented in the sample taking the test.

With a low level of resources to spend overall, China has chosen to concentrate on "key schools" that provide a high-quality education to a very few selected students. These key schools receive the highest concentration of resources, including the best teachers, many of whom are university graduates. For the large majority of students, however, the average per-pupil expenditure is well under $100 per year, and it is common for teachers to have only an elementary school education. The problem is compounded by vast differences between urban and rural areas.[8] A comparative assessment, therefore, is meaningless if the test is given only in selected schools. The sample should include all regions of China, all population groups, all language groups, and both high-quality and low-quality schools. Then we would have an accurate picture of science and mathematics achievement, but the results still would not represent the proportion of students who are no longer in school by the eighth grade.

In short, the results are likely to provide little information about educational attainment. Instead, they will simply reflect a combination of sampling artifacts and the practical difficulties of implementing a high-quality assessment.

Although the researchers responsible for the studies are trying to address these problems, much of the responsibility to ensure that the sample accurately reflects the school-age population rests with the participating countries. However, as noted above, certain practical and political problems are extremely difficult to control for, even with the best-designed sampling plan.

Many observers have noted that a so-called horse race comparing the science and mathematics achievement of students in various countries is not likely to improve the practice of education in the participating countries. I simply argue here that, if we do conduct such competitions, we are responsible for ensuring that the results are meaningful. An oversampling of elite schools in China would distort the results in the same way as a U.S. sample composed primarily of students from the Bronx High School of Science. The citizens of each of the participating countries deserve clear information about how to interpret the findings. They cannot be expected to review the fine print that tells them that, because of "technical" difficulties, they should not really believe what they have just read.

TOO MUCH EMPHASIS ON TEST COMPARISONS?

Let us assume, however, that the methodological difficulties are resolved and that the test results accurately portray the relative rankings of the participating countries. Let us also assume that the questions are a reasonable measure of mastery of the subject matter. We are still left with the matter of whether the results are a useful measure of those things that are most important to us – or to other nations – in the fields of science and engineering education. I would suggest that even a methodologically sound study of test performance does not address far more important issues with respect to science and engineering education, nor does test performance necessarily correlate with these other matters. Indeed, a preoccupation with test comparisons may lead us to implement "solutions" that are counterproductive to the long-term improvement of science and engineering education. These comparisons clearly do not reflect the breadth of a nation's accomplishments or concerns. For example:

- How productive is the U.S. in basic and applied research fields? What does the marketplace say about the research opportunities in our institutions of higher learning? Where are students from other parts of the world taking their advanced degrees in science and engineering?
- What are our accomplishments in making major technological advances, as measured by patents and their application in products, in such areas as semiconductors, biotechnology, materials development, radiation imagery chemistry, information storage and retrieval, medical research, and pharmaceuticals? Are we successful in turning our scientific and technological advances into products that are competitive in the international marketplace?
- Are the fields of science and engineering attracting high-achieving students? Is there a shortage of students or faculty members in these fields? Are we making progress in attracting women and minorities to these fields?
- Does the teaching environment in our schools and colleges encourage students to select – and continue to study – science and mathematics? Does it give students who do not major in these fields some understanding of key scientific issues and methods?
- Are we providing the general student population with an opportunity to gain the skills that are needed in order to be competitive and productive in the workplace? Are we maintaining the technical expertise of the workforce?

The answers to these questions are mixed, but they are far more meaningful measures of our national accomplishments and problems than are comparisons of test scores. More important, they focus on important policy matters and provide insights into the areas that most need attention. A full analysis of such questions is clearly beyond the scope of this article. However, the discussion below illustrates some of the information that can be used to assess our status in science and engineering. While the discussion is not meant to deal with the full range of issues or to offer definitive conclusions, it is intended to provide some examples of the research data and the anecdotal evidence that bear on these questions and to suggest areas in which we need further research or debate.

"Please, dad, not another sermon."

RESEARCH PRODUCTIVITY

Consider what the U.S. produces in basic and applied research as measured by the number of scientific publications. In 1986 U.S. publications in science and engineering accounted for 35.6% of the world's technical publications, a figure that has remained approximately the same since 1973. The next-highest-ranking nations are the United Kingdom, Japan, and the Soviet Union, at about 8% each. Moreover, the U.S. maintains its leadership position across many disciplines:

- 40% of the world's publications in clinical medicine,
- 38.4% in biomedical research,
- 38.1% in biology,
- 22.2% in chemistry,
- 30.3% in physics,
- 42.6% in earth/space sciences,
- 37.3% in engineering/technology, and
- 40.3% in mathematics.[9]

A further measure of our accomplishments in basic research is the high enrollment of foreign students in U.S. universities. Indeed, it is generally acknowledged that no other nation's system of higher education offers the breadth and quality of the research opportunities available to students in U.S. institutions. As Jean-Jacques Servan-Schreiber and Herbert Simon of Carnegie Mellon University put it, "For the first time in modern history, one country seems to serve, in the advanced sciences, as the university of the world."[10]

COMPETITIVENESS IN HIGH-TECHNOLOGY PRODUCTS

Our success in turning research into marketable products is less clear. The U.S. experienced its first trade deficit in high-technology products in 1986, followed by a small surplus in 1987.[11] An analysis of patents points up specific areas of strength and weakness in U.S. and foreign markets. Our strengths are in such fields as petroleum, biochemistry, semiconductor manufacturing, glass manufacturing, communications, and pharmaceuticals. U.S. corporations, however, give low priority to a number of fields that are emphasized by Japanese inventors who hold U.S. patents: photocopying, information storage and retrieval, photography, radiation imagery chemistry, typewriters, motor vehicles, internal combustion engines, and machine elements and mechanisms.[12]

These patterns are largely a reflection of the global economy and of industrial practices of the nations involved, and they bear little relationship to the quality of education in these fields. The high value of the dollar between 1980 and 1985 led to a decline in

There is no problem with the supply of highly qualified students.

the overseas sales of U.S. manufactured goods. Once lost, these markets are difficult to reestablish. In addition, there has been increasing competition from other nations, while the world debt crisis has shrunk markets for U.S. goods in heavily indebted countries, particularly in Latin America. At the same time, many industries have had little financial incentive to invest in long-term product development, product design, and marketing.[13] In addition, the large volume of Japanese electronic goods imported by the U.S. – sometimes based on U.S. patents licensed to Japan – has contributed to the trade deficit.

The quality of education is not the issue here. The lack of policy initiatives related to global competitiveness may be of far greater significance.

This is not to say that engineering education in the U.S. needs no improvement. There is clearly a need for greater attention to problem solving and practical applications. Students typically receive limited training in designing and managing the manufacturing process. Moreover, these shortcomings are likely to be compounded when U.S. graduates enter industrial settings, where they are less likely than their Japanese and German counterparts to be directly involved in the problems encountered on the factory floor. The sophisticated use of computer technology by U.S. engineers in designing products may not easily translate into quality or price advantages in a competitive world market.[14]

A lot of research needs to be done to explain why U.S. scientific and technological advances are often not applied to the development of marketable products. But again that matter relates not so much to science education or test scores as to far more subtle factors: interactions between the research universities and industry, the use of research findings, business practices, and policies with respect to offshore manufacturing.

The U.S. also spends a smaller proportion of its resources on civilian research and development than do Japan and Germany. Approximately one-third of total U.S. expenditures (and two-thirds of federal expenditures) for research and development go to defense.[15] That resource allocation hurts the competitiveness of the private sector to the extent that the resources could have been used to support research and development leading to marketable products.

SUPPLY OF SCIENTISTS AND ENGINEERS

Another indicator of the future strength or weakness of U.S. scientific research is our success in attracting and retaining highly qualified students of science and engineering. Our record in this area is mixed: bachelor's degrees in engineering showed large increases between 1977 and 1987; degrees in the physical sciences declined.[16] Yet an emphasis on test performance provides little information about the nature of the problem or about the factors that influence students' choices. Nor does a focus on testing tell us why student interest in some basic science fields has declined (or what the implications are), where potential shortages exist, how to increase the participation of women and minorities, or how to provide a better education for the general student population in a world requiring ever-greater technological skills.

Indeed, an analysis of SAT mathematics scores shows that there is no problem with the supply of highly qualified students. These scores have actually improved in recent years. In 1977 the 90th percentile score was 628; in 1986 it had risen to 642.[17] The reason that a smaller proportion of high-achieving mathematics students chose to study the physical sciences or mathematics has nothing to do with any lack of proficiency in these fields. These students are simply aware of projections that show that the physical sciences (with the exception of materials science) are not expected to be high-growth fields in the 1990s.[18] And they are not unaware of the fact that other fields, such as engineering, business, and law, are more financially rewarding. They also want to pay off their student loans.

The fact is that the students who do choose to enter science and engineering fields continue to rank well above the national average on academic measures. Students in the physical sciences, mathematics, engineering, and the biological sciences rank particularly high with regard to both SAT scores and class standing.[19]

A basic question is whether we have "enough" scientists and engineers. Some analysts predict shortages based on declines in student interest in these fields and on the smaller numbers of students now passing through the education system. However, others conclude that any shortages that do occur are part of the normal operation of the labor market and will be remedied over time. Indeed, in engineering – one of the few professional fields in which only an undergraduate degree is required for good job opportunities – students have been highly responsive to the labor market. Bachelor's degrees in engineering awarded to U.S. citizens and permanent residents rose from approximately 46,000 in 1977 to 85,000 in 1987.[20] Economic studies over the past 30 years generally support the assumption that the labor market for scientists and engineers does make the necessary adjustments, although there may be temporary spot shortages because of the time needed to complete the educational process.[21] Nor is there any reliable evidence that the business community is complaining about the numbers or quality of mathematicians, physicists, chemists, or engineers being turned out by U.S. universities.

However, there is evidence of shortages of precollege and college faculty members in certain technical fields and in certain regions of the country. At the precollege level, we know that teachers are often assigned to science and mathematics classes for which they have not been specifically trained and that the number of new graduates prepared to teach in these fields has declined. Although efforts to raise standards and to recruit more teachers appear to be making some difference, the basic fact remains: students who graduate with science degrees have job opportunities in fields that are considerably more lucrative than teaching.[22]

Faculty shortages in higher education are also caused at least partly by the lack of financial incentives for engineers and computer scientists to consider careers in academe. It makes little financial sense for a student to enroll in a costly and time-consuming doctoral program that leads to a relatively low-paid university position when private industry offers greater financial rewards and does not generally require a doctorate. Science and engineering graduate programs have also faced some strong competition from such fields as investment banking, where the rewards can be greater still.[23] Indeed, shortages of doctoral degree candidates in engineering, physics, and mathematics exist for the same reason that shortages of Ph.D. faculty members exist in business schools: salaries are higher outside academe.

Too narrow a definition of the problem may lead us to "solutions" that are trivial.

The future of U.S. science and engineering also depends on our success in increasing the participation of women and minorities. While women have made large gains, they continue to be underrepresented in the physical sciences and engineering. They are also less likely than men to hold senior positions in universities or in industry. Minority students have made gains in engineering over the past decade, but their numbers still remain small. In some fields, such as the physical sciences, their representation is extremely low. Minorities are also seriously underrepresented in faculty positions in all fields.[24]

Many of the factors that contribute to this underrepresentation of women and minorities have little to do with the quality of education. They include, for example, the effects of poverty and discrimination, the increasing costs of higher education, and the decline in the real value of student financial aid. These are important policy issues that need to be addressed. And while none of these problems will be easily solved, we do know that they cannot be alleviated by administering yet another round of standardized tests.

THE TEACHING ENVIRONMENT

We also have evidence – although most of it is still anecdotal – that the teaching environment makes an important difference in student achievement and persistence in science and engineering. Indeed, there have been efforts to make the study of scientific fields more attractive by reducing the emphasis on courses that turn out to be barriers to further study. At both precollege and college levels, interest has been growing in redesigning courses to give greater emphasis to major scientific concepts, scientific issues in the context of public policy, research methodology, and – in the case of mathematics – statistics and problem solving.

These are not easy concepts to teach. Therefore, it is not surprising that traditional teaching remains the norm, with an emphasis on science courses that contain large amounts of superficial information to be memorized and mathematics courses that bear no clear relationship to scientific research or problem solving. The result is that the general student population learns little about scientific concepts or methodology, while many potential science and engineering majors leave the field before they have had an opportunity to take the advanced courses that provide a far better understanding of what science is all about. This problem is exacerbated by the trend for colleges and universities to give lower priority to undergraduate teaching and greater attention to research and a range of other activities.[25]

Moreover, an emphasis on standardized, multiple-choice testing at the precollege level – which has increased even apart from the international assessments – may have a deleterious effect on the quality of teaching and of the curriculum. Such tests generally deal with isolated facts. Thus they are inconsistent with the kind of curriculum changes that would increase students' knowledge of key issues and perhaps their motivation to study science. In addition, the proliferation of tests creates a preoccupation with teaching to the test, reduces the emphasis on concepts, encourages learning by rote, and generally contributes to a less rewarding classroom environment – for both students and teachers. I suggest that curriculum changes that will increase the emphasis on key scientific concepts are highly unlikely until teachers are freed from the pressure of rote examinations on material so limited that it can be measured by multiple-choice items across countries.[26]

TECHNOLOGICAL EXPERTISE OF THE WORK FORCE

I believe that the most difficult challenge may not be improving the quality of education for science and engineering majors, but providing a better education for other students – who represent the large majority – in a world requiring ever-greater technological skills. The reasons are well-known. Our international competitiveness increasingly depends on a highly trained labor force. Moreover, U.S. society will grow increasingly polarized if a significant proportion of our population lacks the skills needed to compete for jobs that provide a reasonable income. The number of traditional manufacturing jobs requiring less than a high school education has declined in large northeastern and midwestern cities. Although inner-city residents with higher levels of education have had access to new job opportunities in high-technology or information industries, those with less education have often remained unemployed or found jobs only in low-paying occupations.[27] Indeed, "America continues to face the very real possibility of the two separate societies envisioned by the Kerner Commission two decades ago."[28] And because poverty correlates so highly with educational problems, these problems are likely to be exacerbated over the years if the current trends continue.

Expenditures on education also greatly favor the most affluent regions, schools, and students. The fact is that low-income and minority students, on average, have less opportunity to study science and mathematics than do other students. They have less access to the most qualified teachers, to adequate facilities and equipment for learning science and mathematics, and to the types of curricula and instructional strategies (e.g., strategies designed to develop inquiry and problem-solving skills) considered particularly effective with all students. Indeed, high-achieving students in predominantly low-income, minority schools appear to have fewer opportunities than do low-achieving students who attend more advantaged schools.[29]

The public perception that the U.S. is falling behind in science and mathematics, embodied in the fourth national goal for education, is based on a narrow criterion that has serious methodological deficiencies. The risk is not simply that we will underestimate our accomplishments. Of far greater importance is the likelihood that too narrow a definition of the problem may lead us to "solutions" that are at best trivial and may indeed be counterproductive to addressing more important problems. It is unlikely that increasing requirements for traditional science and mathematics courses or memorizing facts that can be readily assessed on standardized tests will encourage greater numbers of high-achieving youngsters to become scientists and mathematicians or give young people who do not attend college the skills they will need to compete in the marketplace.

Clearly, we have problems in science and mathematics education. But the bottom line is not so grim as the current rhetoric would have us believe, nor are the problems identified by that rhetoric necessarily the ones that are most troublesome to the welfare and productivity of the society as a whole.

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21. See, for example, Michael G. Finn, *Trends in Science and Engineering Education and the U.S. Labor Market* (Washington, D.C.: National Research Council, 1 June 1989), pp. 6-7, 24-25.
22. Linda Darling-Hammond, Lisa Hudson, and Sheila Nataraj Kirby, *Redesigning Teacher Education: Opening the Door for New Recruits to Science and Mathematics Teaching* (Santa Monica, Calif.: RAND Corporation, March 1989), pp. 5-7.
23. Iris C. Rotberg, "Resources and Reality: The Participation of Minorities in Science and Engineering Education," *Phi Delta Kappan*, May 1990, p. 676.
24. Ibid., pp. 672-79; Sheila E. Widnall, "AAAS Presidential Lecture: Voices from the Pipeline," *Science*, 30 September 1989, pp. 1740-45; and *Women and Minorities in Science and Engineering*, op. cit.
25. See, for example, Iris C. Rotberg, "A New Perspective . . . ," pp. 671-72; and idem, "Resources and Reality . . . ," pp. 673, 678-79.
26. See, for example, *From Gatekeeper to Gateway: Transforming Testing in America* (Chestnut Hill, Mass.: National Commission on Testing and Public Policy, Boston College, 1990).
27. U.S. House of Representatives, pp. 22-25.
28. Ibid., p. 60.
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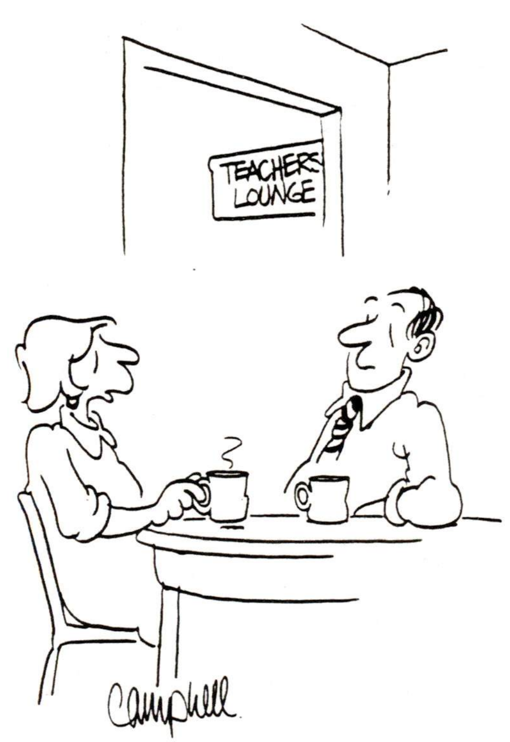

"I have six comedians in fifth period. Every day is 'Saturday Night Live.' "