Math and Science Education: Another Perspective

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It is a pleasure to participate this evening in your consideration of issues related to public education in the United States.

I think it might be useful if I directed my remarks to those issues which are now receiving widespread public attention as a result of recent reports on the state of our educational system, particularly math and science education. As you know, the conclusions of many of these reports are quite grim. One report concludes:

> Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science and technological innovation is being overtaken by competitors throughout the world.[1]

Another reports:

> The current and increasing shortage of citizens adequately prepared by their education to take on the tasks needed for the development of our economy, our culture and security is rightly called a crisis by leaders in academe, business and government.[2]

Not all observers, however, have been quite so pessimistic. A. Bartlett Giamatti, president of Yale and a member of one of the most publicized

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recent education commissions, recently wrote that he considered making the following remarks to Yale's entering freshman class:

> Ladies and gentlemen of the class of 1987: I am delighted to see you all here. After all the critiques and debate about the American high school this summer, I did not know if anyone could or would show up this fall. You are a very strong group, as strong a freshman class as we have ever had. Your presence here argues for the health of American secondary education.... You have come here not despite but because of school systems and teachers who have taken a battering recently, a battering all out of proportion to their responsibility....3/

Indeed, even one of the most critical of the recent education reports acknowledges the great successes of the American education system by noting that:

> [The schools] now graduate 75 percent of our young people from high school.... The proportion of Americans of college age enrolled in higher education is nearly twice that of Japan and far exceeds other nations such as France, West Germany, and the Soviet Union.4/

It generally has been assumed that math and science education in the United States is deficient in five respects:

- The American education system is not producing adequate numbers of trained scientists, mathematicians, engineers or computer scientists to meet economic or military needs.
- The problems will become even more severe in the next decade when technological advances will increase the need for highly trained personnel in these fields.
- American students are more poorly trained, as measured by science and mathematics achievement tests, than are their peers in other industrialized countries.

- American students are also more poorly trained than were their American predecessors a generation ago.
- These problems result from a general laxity in educational curricula and standards and by a shortage of qualified science and mathematics teachers.

I will discuss (1) the extent to which these conclusions are supported by research findings; (2) the extent to which proposed remedies--such as increasing science and mathematics requirements--will in fact solve whatever problems are identified; and (3) what other issues--trade-offs if you will--which relate to finance, fairness and the social structure of our country--need to be considered in determining whether or how educational changes in these areas should be implemented.

Research Findings

Many of the reports conclude that the American education system is not producing adequate numbers of trained scientists, mathematicians, engineers or computer scientists to meet economic or military needs.

It would seem appropriate straight off to consider some recent findings of the Bureau of Labor Statistics and other organizations.[5/]

These findings show that the current supply of scientists and mathematicians is in fact adequate except in a few subfields of physical and biological science. Indeed, projections indicate that by 1990, the number of new science and mathematics graduates at all degree levels, Bachelors, Masters and Ph.D., will exceed the number able to find jobs in those fields.

Projections indicate, in fact, an overall balance between supply and demand for engineers for the rest of the 1980s. Shortages of engineers

in the past few years have been limited to a few specialties (recent graduates in electronics, computer design and petroleum engineering)--certainly not a circumstance which would justify a massive effort to change basic course curricula. There may be shortages of Ph.D. engineers, but only to fill faculty positions--caused not by any inadequacies in the education system but simply by a lack of financial incentives for young engineers, who are well paid by industry at lower degree levels and who therefore are reluctant to aspire to Ph.D.s and to lower paying university positions. The Bureau of Labor Statistics sums it up this way:

> During the 1980s, the United States will be turning out about twice as many Bachelor's degree graduates in engineering as in the 1960s, a decade of rapid economic growth, high defense spending, and a space program that put an astronaut on the moon.6/

The fact is that we will not need more engineers than the rate now being turned out.

The current demand for trained computer scientists does exceed the supply. However, the numbers of students receiving computer science degrees is increasing so rapidly that by the end of the 1980s, given current rate increases, even these shortages will be shortlived.7/

In general, therefore, labor market projections show that the educational system is in fact producing adequate numbers of scientists, mathematicians and engineers. Any shortages that exist are likely to be short term. Indeed, there will be surpluses in many fields.

The Bureau of Labor Statistics suggests that some of the exaggerated predictions of shortages may result from the methodology used in surveying

the projected business and military demand.[8] In response to surveys of future projected requirements, these institutions overestimate overall industrial growth and their share of the market. Each defense industry apparently assumes that it will receive a disproportionate share of major defense contracts, which in turn multiplies many times the overall requirements of the industry. Only one award will in fact be made. The result is a large overcount of technical staffing needs. There also is evidence that companies report shortages of highly trained personnel when they cannot attract the best students at the salaries they would prefer to pay. Managers under such circumstances too quickly conclude, almost as a defensive gesture, that the fault lies in the lack of top applicants.

A second assumption of the reports is that in the next decade, technological advances will rapidly accelerate the demand for high level scientific and computer personnel.

No one can predict with certainty exactly what these advances or their effects will be. Projections suggest that some computer and engineering fields will be among the fastest growing occupations. However, contrary to popular belief, the greatest number of new jobs will not be in these fields. They will be in low-skilled occupations requiring quite low levels of science and math knowledge and not in high technology jobs.[9] This is consistent with a recent study of college graduates in the mid-seventies which showed that almost half were not in college level jobs, i.e., they were doing jobs in which at least 70 percent or more of their colleagues doing the same job did not attend college.[10]

Not one of the twenty occupations expected to have the largest job growth in the 13-year period between 1982 and 1995 will be in a high technology area.[11] Some examples are relevant. Recent estimates show:

> 779,000 new openings for building custodians; 744,000 new openings for cashiers; and 719,000 new openings for secretaries, compared to 217,000 new openings for computer systems analysts; 205,000 new openings for computer programmers; and 600,000 new openings for all engineering fields combined.

And probably more surprising is the prediction that the number of new kindergarten and elementary teaching positions available--511,000--will be greater than the number of positions for computer systems analysts and for computer programmers combined and not substantially lower than the total number of new openings for engineers.

Compare these numbers with the results of a survey of freshmen entering college in 1983. 3.1 percent of these students planned to become elementary school teachers. 8.5 percent of the students planned to become computer programmers or analysts. And 10.8 percent of the students entering college in 1983 planned to become engineers.[12]

Just as important, it is not at all certain that increased technological innovations in the next ten to twenty years will require increased skill requirements.[13] Some economists argue that high technology is more likely to reduce the skill requirements for jobs rather than to increase them and that the supply of the technically trained will outstrip the demand--a conclusion contrary to the popular assumption that our education

system has failed to produce adequate numbers of qualified scientists and engineers.

Computers offer one example of potential reduction in skill requirements.[14] Before recent advances in computer technology, programmers and operators with complex skills were needed to develop and use computers. Now, the creative and skilled work is done by systems analysts, packaged programs are readily available, and computer programming and operation have become more routine tasks. Look at the drop in prices of home computers--certainly not evidence of an ever increasing need for a high cost labor force for their production and refinement. On the user side, the fact is that no special skills are needed to operate new office computers. Indeed, the newest ones will correct both your spelling and grammar!

This does not say, of course, that our society will not need significant numbers of highly trained scientists, engineers and computer specialists. It does suggest that reports of shortages, poor training, and the proportion of total employment accounted for by these fields have been greatly exaggerated.

I turn now to the conclusion that American students are more poorly trained in science and mathematics, as measured by achievement test scores, than are their peers in other industrialized countries.

Perhaps. The <u>average</u> enrolled American high school student scores lower in international comparisons than the <u>average</u> enrolled high school student in other industrialized countries. The problem with these comparisons is that they do not compare equal proportions of the relevant

high school age groups. Let me be specific. Only about 20 percent of the high school age group children attend upper secondary school in Europe--the highest achieving 20 percent. That compares to about 80 percent in the United States. In Europe, academic schooling for those between 16 and 18, while perhaps not elitist, certainly does not attempt to serve virtually the entire age group. As a result, the international studies compare the average score of over three-fourths of the age group in the United States with the average score of the top 9 percent in West Germany, the top 13 percent in the Netherlands, or only the top 45 percent even in Sweden. However, when the same proportions of relevant age groups are compared, the results are quite different. The top 4 percent of American students score at about the same level in mathematics as a comparable group in most other industrialized countries, though lower than students in Sweden, Japan, or Israel, for example. American students also score at about the same levels in science as compared to students in other industrialized countries--better than students in France, Belgium or Italy, not as well as students in New Zealand, England or Australia.15/ I could go on with comparative data. It is sufficient to note that when equal percentages of age groups are compared, the results do credit to our educational system--particularly when one considers that the system must not only provide an education of high quality for the brightest students but, unlike its European counterpart, must do so in an environment in which

there is an educational responsibility for virtually the entire school age group--not just a small part of it--and in the same classroom.

A fourth conclusion is that American students today are more poorly trained than were their American predecessors. That means that you and I were better trained in high school than are our children. I doubt it instinctively and, more important, the assumption is not supported by the evidence.

The problem again is one of measurement. An advisory panel on SAT scores noted that three-fourths of the decline in scores between 1963 and 1970 could be attributed to changes in the numbers and socio-economic characteristics of the group taking the test, and one-fourth after 1970.16/

This simply means that 15 to 20 years ago the test was taken by a much smaller proportion of the population since fewer students attended college. The more that take the test, the lower will be the average scores. That has nothing to do with the quality of education, and certainly would be an unreliable measure to use for any longitudinal study of the quality of education.

Even given the larger numbers taking the tests, the results are better than the reports would lead us to believe.

Scores on SAT science achievement tests (in biology, physics and chemistry) are as high or higher than they were 6 to 10 years ago. Scores on the ACT natural science test (which represents a better cross section of college bound students than do the SAT

achievement tests) have shown slight increases in the past 15 years.[17] Finally, the National Assessment of Educational Progress (NAEP), which assesses representative samples of students, not just college bound, shows that 9 year olds and 13 year olds have stayed at about the same level in science, while scores for 17 year olds have declined.[18]

Scores on SAT math achievement tests (taken by the top math students among the college bound population) and for simple computational skills have not declined. However, everything in between--particularly math applications like problem solving and computing percentages--has gone down.[19]

These achievement findings are similar to reports of employers who note deficiencies in lower level math skills--and in speaking, writing, reading, listening skills--for a wide range of relatively low-skill occupations. Science and higher level math deficiencies are mentioned far less often.[20] One rarely hears a complaint about inability to do simple algebraic equations; there are, however, widespread complaints that employees cannot write a simple letter. But I will comment more on that later.

The fifth conclusion drawn by the reports is that there is a general laxity of educational curricula and standards across the board, and there is a shortage of qualified science and mathematics teachers.

Again, the actual data show that recent reports exaggerate or inadequately define the problem.

Some general findings:

The training and qualifications of high school graduates who intend to major in science and engineering after high school remains high; the main problems are in the quality of instruction for the general non-science or engineering population.21/

Contrary to public perception, high school students took more mathematics in 1980 than they did in 1972 and about the same amount of science. Among college bound students who took the SAT, the amount of math and science has increased every year for the past 10 years.22/

Turning to teacher quality, there is evidence that students majoring in education have lower academic qualifications than do students preparing for other professional careers. This finding, of course, is not unique to science and mathematics teachers but can be said of education majors generally when compared to other college majors.23/

The well publicized shortage of mathematics and science teachers at the secondary level is more severe for math than it is for science, where it is limited to physics and chemistry. However, the teacher shortage in math and science is not limited to these fields. There are also shortages in vocational/technical fields, special education and bilingual education.24/ Finally, there is a shortage of high quality faculty to teach engineering and computer courses at the college level.25/

A note of irony: Shortages of math and science teachers do not necessarily mean that these teachers can readily find jobs. In April

1983, the same month the National Commission on Excellence released its report noting "particularly severe" shortages of mathematics and science teachers, the Chicago press reported that the Chicago Board of Education had made substantial reductions in math and science teachers during the past several years. Indeed, Chicago had a surplus of math and science teachers compared to available positions. Many of these teachers were working as substitutes and not necessarily in their fields of expertise.[26] The problem is the financial capacity of the states and school districts.

Proposed Remedies

What might be concluded from the research evidence?

First, the data show that the American education system is producing highly qualified scientists, engineers, mathematicians, and computer specialists. Shortages are limited to sub-specialties and generally are temporary.

Further, the achievement of our top students in math and science is respectable both in comparison with their peers in other countries and with their American counterparts of earlier years.

Second, improvements in science and math education are needed for those who are not planning a career in science or math. Achievement results show declines in basic knowledge about science and in math applications such as problem solving.

A number of reforms in math and science education have been proposed. These include strengthening course requirements,

curriculum revisions, and financial incentives for math and science teachers--higher salaries, merit pay plans, and scholarships. I will limit my comments here to proposals for strengthening course requirements. In general, these proposals would require all students to take more algebra, calculus, physics or chemistry. These proposals do not address the needs of the population as a whole--that is, those who are neither science or math majors--who may benefit more from courses that are not designed along narrow disciplinary lines.

The more traditional courses often result in the students parroting chemical terms and doing simple formulas without the vaguest idea of what they are learning about or how it is relevant to scientific methodology or to the world about them. Even the labels are forgotten within six months.

Nor is there any evidence these so called "tough" courses, given at random two or three times in a high school career, create a discipline for doing careful work, act as a foundation for logical thinking, or prepare one for the rigor of the "real world." Instead, it has been suggested that students should receive an understanding of scientific methodology and of major scientific issues in the context of public policy, rather than attempting to teach everything that is known about physics to reluctant high school students.

It is simply not meaningful for most students to cover an entire four year undergraduate college physics curriculum in a high school year by spending a week on each major field of physics.

The result, which we all remember from our own experience or that of our children, is that most students memorize a lot of stuff, cannot place it in context, understand the fields from which the material is derived, where it is leading, or how it is used.[27]

As one observer noted, "forcing students to take the same Chemistry or Algebra II they have been avoiding for the last 20 years is no answer."[28] The General Secretary of the American Association of University Professors summed it up this way: "Requiring courses does not guarantee learning in courses."[29] French essayist Montaigne in 1580, perhaps, best reflects my own concerns:

> But as the steps that we take walking in a gallery may tire us less than if they were taken on a fixed journey, so our lessons, occurring as if it were accidentally, without being bound to time or place, and mingling with all our other actions, will glide past unnoticed.[30]

Financial and Social Implications

There are, of course, other considerations, possibly more fundamental, in determining whether or how education reforms should be implemented.

First, very few of the education reports consider the financial or social costs of their recommendations and the trade-offs that would be faced, nor do they set priorities.[31] The point is that resources spent on a trivial problem takes money that might be better spent for other purposes. Similarly, reforms that do not consider implications for all parts of the society are likely to do more harm than good.

Let me be specific. It is estimated that the total cost of recommendations in recent education reports--that is, increasing teachers' salaries, merit pay arrangements, extending the school day and school year, for example--would be $20 billion to $30 billion each year in new funds.[32/] To put this figure in perspective, the total federal expenditure for elementary, secondary and higher education programs in fiscal year 1983, including student aid at the college level, was $15.4 billion. And each of these recommendations is fraught with controversy. Which subject matters would be rewarded? How would merit be measured? Who would decide? Which courses would be expanded? The recent education reports pay little attention to these issues.

Although some of these reports give passing attention to the impressive role of the American education system in increasing social opportunity, they do not discuss the societal implications of recommendations like stricter course and graduation requirements. What happens to students who cannot pass Algebra II or Physics in terms of drop out rates, tracking, future employment prospects? While we do not pretend anymore to be a classless society, we certainly do not seek an education system which will put roadblocks on upward mobility and access to a more fulfilling and productive life.

We are not a society which is satisfied to educate only the top 10 percent to run the country or business. Forty-seven percent of the age group enter college.[33/] Further, there is no evidence that the brightest are at a disadvantage in fulfilling their academic potential or in the marketplace.

The fact is that a balance is needed; the talk nowadays, prompted by romantic notions about future technology and international competition, is not conducive to a careful consideration of the implications of proposed public policy solutions. My concern is that social science, history, humanities, literature will be diminished in an effort to meet the assumed demands of the future.

A few reports--particularly the Carnegie Foundation study--have stressed the importance of a balance between math and science and other parts of the curriculum.[34]

The fact is that SAT scores, for example, have shown steeper declines in verbal than in math scores. NAEP shows greater declines in political knowledge than in science.[35] The quality of students' writing leaves much to be desired; recent observers suggest that a simple writing requirement is more critically needed than improved science and mathematics instruction.[36] A number of engineering schools are now revising their curriculum to include broader liberal arts courses.[37] In short, that is where the attention and balance are needed. I suggest that it will make for more informed citizens--a particularly desirable objective when there is little doubt that the social sciences and humanities, both in financial terms and in classroom hours, will suffer if an attempt is made to meet a "need" where justification remains, as of now, unproven.

I would like to close with some quotations by Benjamin Stein in Public Opinion magazine based on his conversations with high school and college students in the Los Angeles area.[38]

> [A] student at [the University of Southern California] did not have any clear idea when World War II was fought. She believed it was some time this century... She also had no clear notion of what had begun the war for the United States. ("Pearl Harbor? Was that when the United States dropped the atom bomb on Hiroshima?") Even more astounding, she was not sure which side Russia was on and whether Germany was on our side or against us..
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> A few [students] have known how many U.S. Senators California has, but none has known how many Nevada or Oregon has. ("Really? Even though they're so small?")
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> . . .
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> Of the teenagers with whom I work, none had ever heard of Vladimir Ilyich Lenin. Only one could identify Joseph Stalin. (My favorite answer--"He was President just before Roosevelt.")
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> . . .
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> None [of the students] could name even one of the first ten Amendments to the Constitution or connect them with the Bill of Rights.
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> . . .
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> Only a few could articulate in any way at all why life in a free country is different from life in an un-free country.
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> . . .
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> I have mixed up episodes of ignorance of facts with ignorance of concepts because it seems to me that there is a connection. If a student has no idea when World War II was and who the combatants were and what they fought over, that same human being is likely to be ignorant of just what this society stands for. If a young woman has never heard of the Bill of Rights, that young woman is unlikely to understand why this is a uniquely privileged nation with uniquely privileged citizens....
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> . . .

I think these observations might put the "problem" we face in some perspective.

Footnotes

1. Report of the National Commission on Excellence in Education, A Nation at Risk: The Imperative for Educational Reform (Washington, D.C.: United States Department of Education, 1983), p. 5.

2. Report of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, Today's Problems, Tomorrow's Crises (Washington, D.C.: National Science Foundation, 1982), p.2.

3. A. Bartlett Gramatti, "The Great Education Panic," Washington Post, 13 Sept. 1983, p. A-19.

4. Report of the National Commission on Excellence in Education, p. 34.

5. See, for example, Douglas Braddock, "The Job Market for Engineers: Recent Conditions and Future Prospects," Occupational Outlook Quarterly, Summer 1983; National Science Foundation and Department of Education, Science and Engineering Education for the 1980's and Beyond (Washington, D.C., 1980); George T. Silvestri et al, "Occupational Employment Projections through 1995," Monthly Labor Review, November 1983; Wilson K. Talley, "National Needs for Science and Technology Literacy--the Army as a Case Study," Teacher Shortage in Science and Mathematics (Washington, D.C.: National Institute of Education, 1983); Betty M. Vester, Opportunities in Science and Engineering (Scientific Manpower Commission, Washington, D.C., 1982).

6. Braddock, p. 8.

7. See Alexander W. Astin, The American Freshman: National Norms for Fall 1983 (American Council on Education and University of California at Los Angeles) for estimate of probable career choices, 1983.

8. Braddock.

9. Richard W. Riche et al, "High Technology Today and Tomorrow: Small Slice of Employment," Monthly Labor Review, November 1983.

10. Thomas J. Moore, "The Job Gap," Chicago Sun-Times, 18 Sept. 1983.

11. Riche.

12. Astin.

13. Henry M. Levin and Russell W. Rumberger, The Educational Implications of High Technology (Institute for Research on Educational Finance and Governance, Stanford Univeristy, 1983).

14. Levin and Rumberger.

15. These analyses are based on an article by Torsten Husén, "Are Standards in U.S. Schools Really Lagging Behind Those in Other Countries?," Phi Delta Kappan, March 1983.

16. Lyle V. Jones, "Achievement Test Scores in Mathematics and Science," Science, 24 July 1981.

17. Daniel Koretz, Congressional Budget Office, Personal Communication, 1983.

18. Barbara J. Holmes et al, Reading, Science and Mathematics Trends: A Closer Look (Report of the National Assessment of Educational Progress, Education Commission of the States, 1982).

19. Koretz.

20. Koretz.

21. Koretz.

22. Koretz.

23. Betty Vester, "Supply and Demand for Science and Mathematics Teachers," Teacher Shortage in Science and Mathematics.

24. Koretz.

25. National Science Foundation and Department of Education, Science and Engineering Education for the 1980's and Beyond.

26. George N. Schmidt, "Science Teaching in Chicago: Survival of the Fattest," Reader, 29 April 1983.

27. Ernest L. Boyer, "High School: A Carnegie Foundation Report on Secondary Education in America" (Report of the Carnegie Foundation for the Advancement of Teaching, 1983).

28. Teacher Shortage in Science and Mathematics, p. 7.

29. Jerry G. Gaff, General Education Today (San Francisco: Jossey-Bass, 1983), p. 115.

30. J.M. Cohen, trans., Montaigne Essays (New York: Penguin, 1982), p. 72.

31. For a more detailed discussion of the implications of the proposals, see Harold Howe II, "Education Moves to Center Stage: An Overview of Recent Studies," Phi Delta Kappan, Nov 1983; Paul E. Peterson, "Did the Education Reports Say Anything?," The Brookings Review, Winter 1983.

32. Howe.

33. Unpublished tabulation for the 1981-1982 academic year, National Center for Education Statistics, 1983.

34. Boyer.

35. Holmes; Koretz; Ina Mullis, "Citizenship/Social Studies Achievement: Trends Over Time," National Assessment of Educational Progress, 1978.

36. Gene I. Maeroff, "Teaching of Writing Gets New Push," The New York Times Education Winter Survey, 8 Jan 1984.

37. Gaff.

38. Benjamin J. Stein, "The Cheerful Ignorance of the Young in L.A.," Washington Post, 3 Oct 1983, p. A-15.

30. Michel de Montaigne, Montaigne Essays, J.M. Cohen, trans. (New York: Penguin, 1982), p. 72.

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32. Howe.

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37. Gaff.

38. Benjamin J. Stein, "The Cheerful Ignorance of the Young in L.A.," Washington Post, 3 Oct 1983, p. A-15.