SCIENTIFIC ILLITERACY: CAUSES, COSTS AND CURES

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6/13/89

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The scientific, mathematical and technical competence of American high school students is generally recognized to be very low. The National Assessment of Educational Progress (NAEP) reports that only 7.5 percent of 17 year old students can "integrate specialized scientific information" (NAEP 1988 p.51) and 6.4 percent "demonstrated the capacity to apply mathematical operations in a variety of problem settings." (NAEP 1988b p. 42)

There is a large gap between the science and math competence of young Americans and their counterparts overseas. In the 1960s, the low ranking of American high school students in such comparisons was attributed to the fact that the test was administered to a larger proportion of American than European and Japanese youth. This is no longer the case. Figures 1 to 4 plot the scores in Algebra, Biology, Chemistry and Physics against proportion of the 18-year old population in the types of courses to which the international test was administered. In the Second International Math Study, the universe from which the American sample was drawn consisted of high school seniors taking a college preparatory math course. This group represents 13 percent of the age cohort, a proportion that is roughly comparable to the 12 percent of Japanese youth who were in their sample frame and is considerably smaller than the 19 percent of youth in the Canadian province of Ontario and the 50 percent of Hungarians who took the test. In Algebra, the mean score for this very select group of American students was about equal to the mean score of the much larger group of Hungarians and substantially below the Canadian achievement level (McKnight et al 1987).

The findings of the Second International Science Study are even more dismal. For example, the 25 % of Canadian 18-year olds taking chemistry know just as much chemistry as the very select 1 % of Americans high school seniors taking their second chemistry course (most of whom are in "Advanced Placement"). The 28 % taking biology know much more than the 6 % of American 17-18 year olds who are taking their second biology course (International Association for the Evaluation of Educational Achievement, 1988).

(Figure 1-4 about here)

The poor performance of American students is sometimes blamed on the nation's "diversity". Many affluent parents apparently believe that their children are doing acceptably by international standards. This is not the case. In Stevenson, Lee and Stigler's (1986) study

FIGURE 1

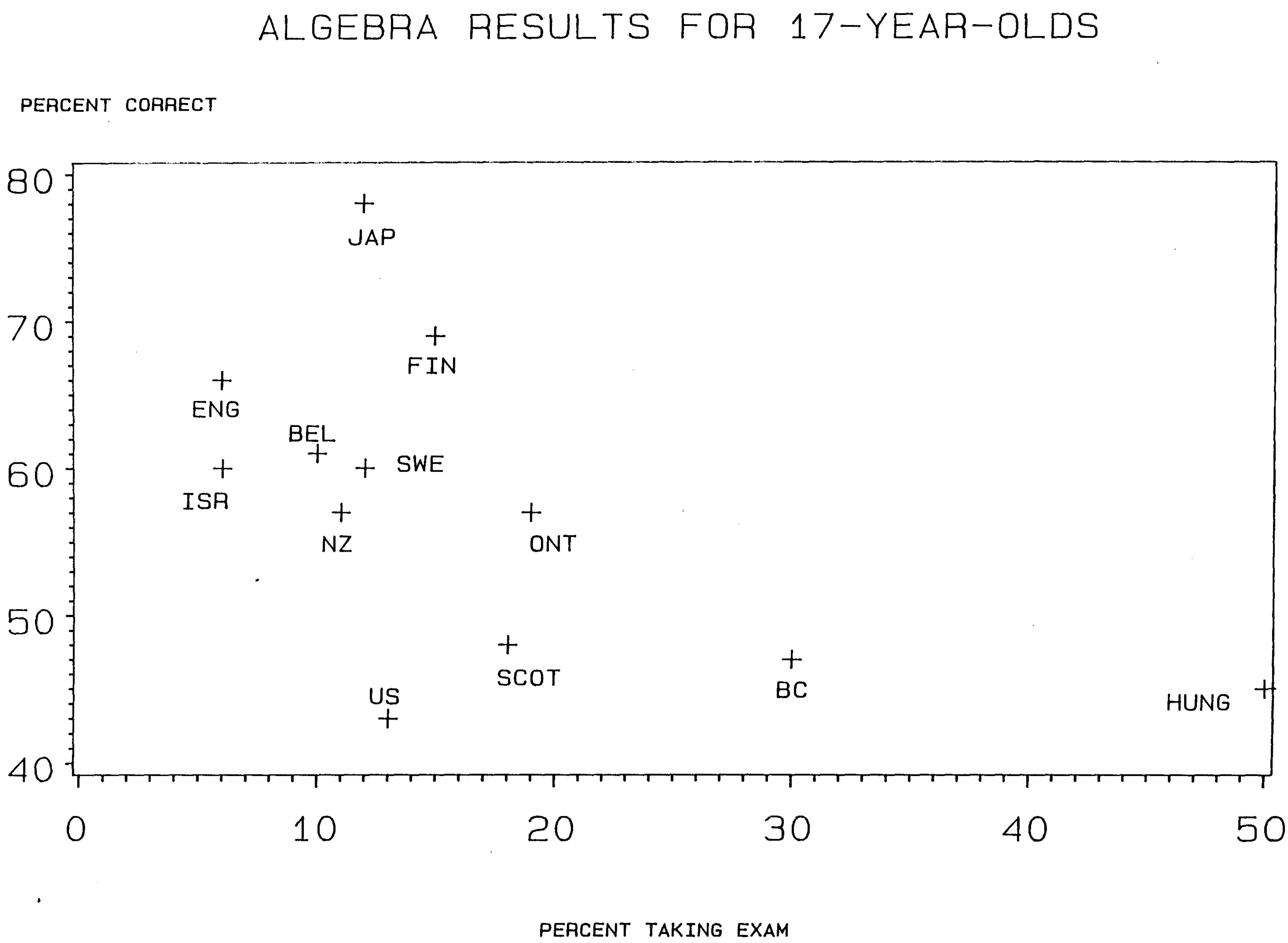

ALGEBRA RESULTS FOR 17-YEAR-OLDS
PERCENT CORRECT
80
70
60
50
40
JAP
FIN
ENG
BEL
SWE
ISR
NZ
ONT
SCOT
US
BC
HUNG
0
10
20
30
40
50
PERCENT TAKING EXAM

FIGURE 2

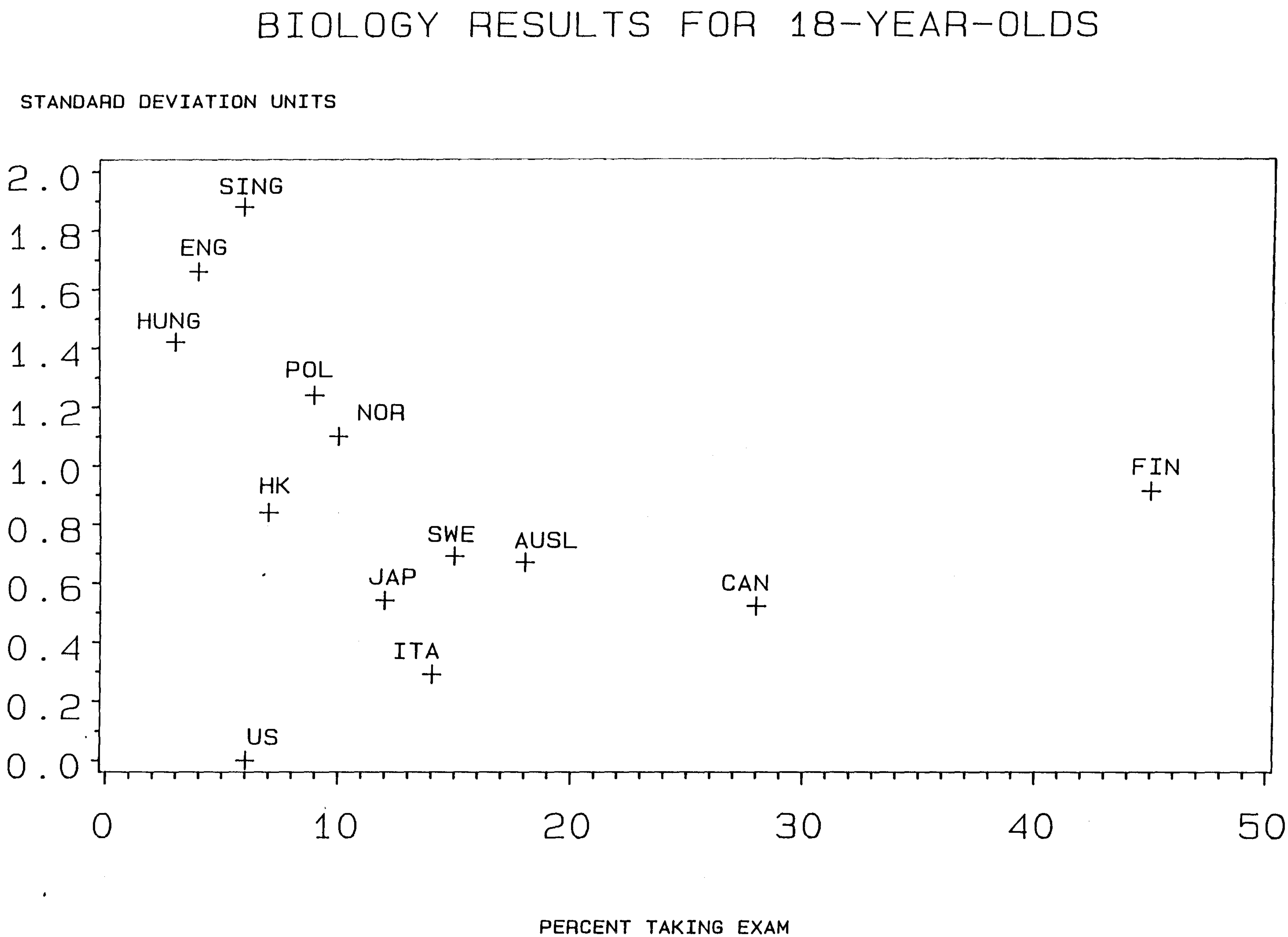

BIOLOGY RESULTS FOR 18-YEAR-OLDS
STANDARD DEVIATION UNITS
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
SING
ENG
HUNG
POL
NOR
HK
SWE
AUSL
JAP
ITA
US
CAN
FIN
0
10
20
30
40
50
PERCENT TAKING EXAM

FIGURE 3

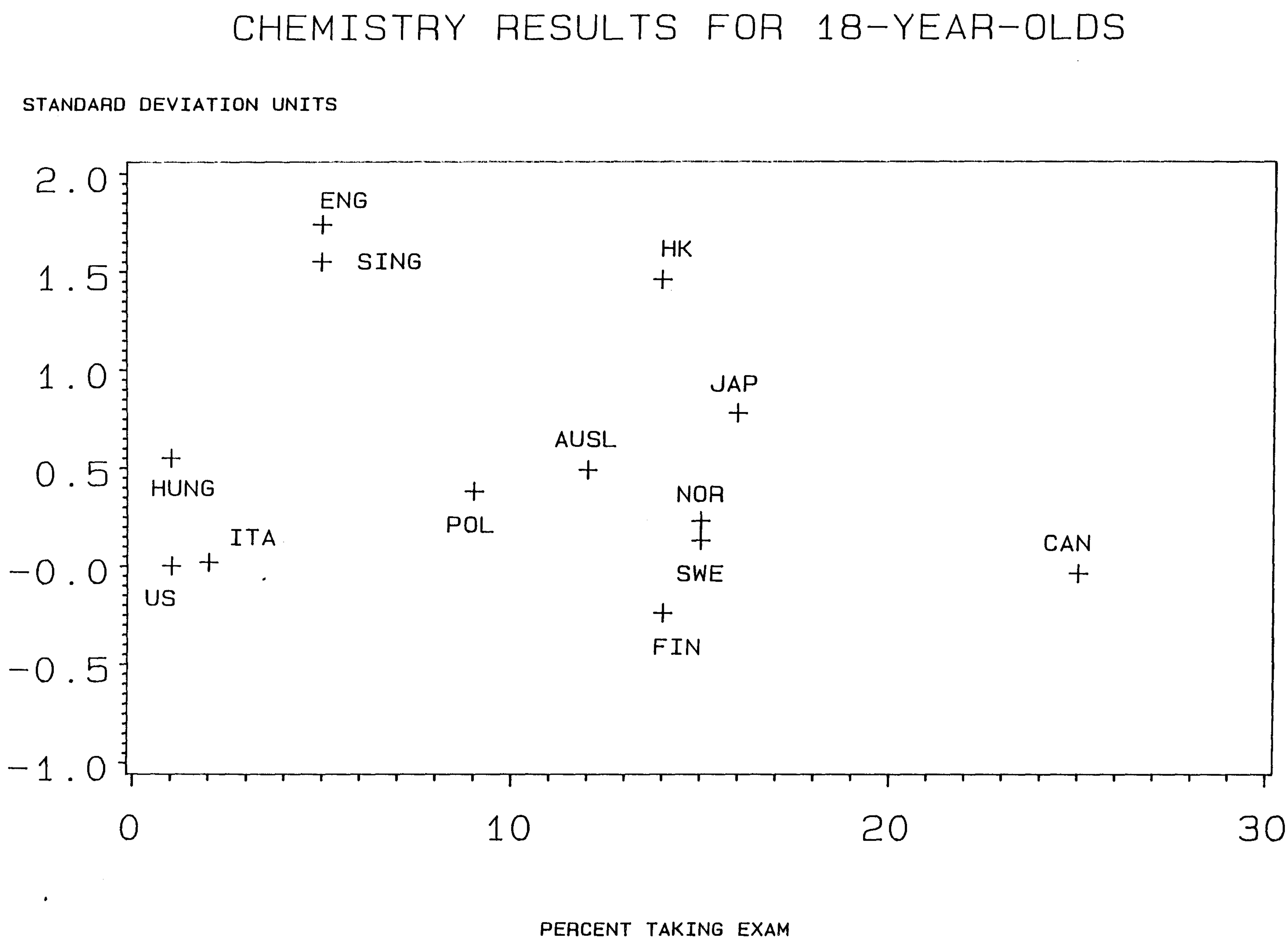
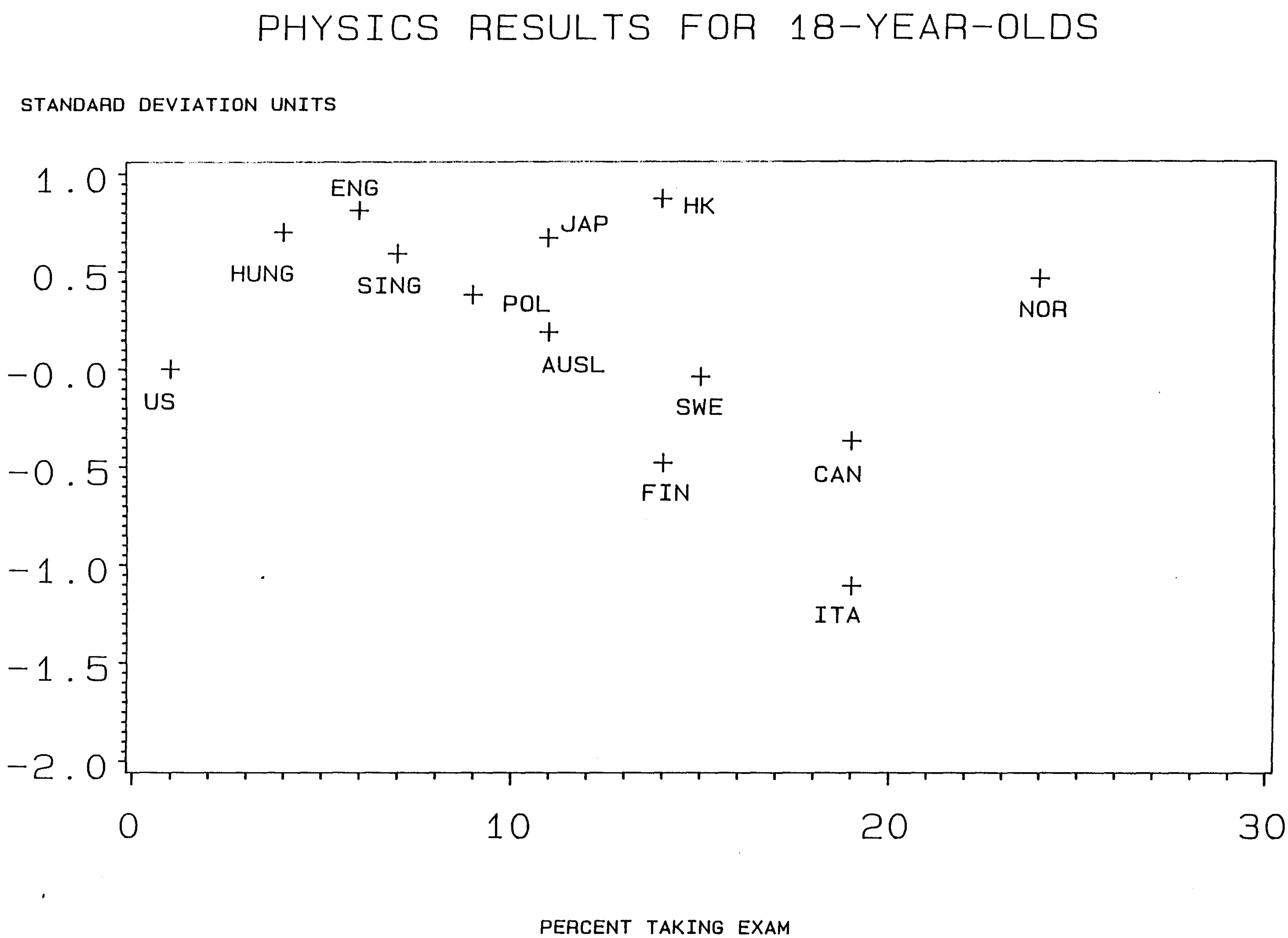

CHEMISTRY RESULTS FOR 18-YEAR-OLDS
STANDARD DEVIATION UNITS
2.0
1.5
1.0
0.5
-0.0
-0.5
-1.0
ENG
SING
HK
JAP
AUSL
HUNG
POL
NOR
ITA
CAN
SWE
US
FIN
0
10
20
30
PERCENT TAKING EXAM

FIGURE 4


PHYSICS RESULTS FOR 18-YEAR-OLDS
STANDARD DEVIATION UNITS
1.0
0.5
-0.0
-0.5
-1.0
-1.5
-2.0
ENG
HK
JAP
HUNG
SING
POL
NOR
AUSL
US
SWE
CAN
FIN
ITA
0
10
20
30
PERCENT TAKING EXAM

by international standards. This is not the case. In Stevenson, Lee and Stigler's (1986) study of 5th grade math achievement, the best of the 20 classrooms sampled in Minneapolis was outstripped by every single classroom studied in Sendai, Japan and by 19 of the 20 classrooms studied in Taipeh, Taiwan. The nation's top high school students rank far behind much less elite samples of students in other countries. At the end of secondary school the gaps in science between white American students and their counterparts in England, Canada, Finland and Japan are as large as the black-white gap in the US and in mathematics the gaps are more than twice as large as the black-white gap. The learning deficit is pervasive.

This article examines the causes of the learning deficits in science, math and technology, evaluates their social costs and then recommends policy measures for remedying the problems identified. Following the American Association for the Advancement of Science's Science for All Americans report, I define the domain of "science" very broadly to include mathematics and technology along with the natural sciences. To avoid confusing readers accustomed to the narrower definition of science, broadly defined science is referred to as science, mathematics and technology.

The paper is organized as follows. Section 1 presents evidence that American students devote considerably less time and energy to studying science, math and technology in high school than their counterparts abroad. Section 2 attributes the apathy of students and parents regarding science, math and technology education to the failure of our society to recognize and reward students who commit the time and energy necessary to master these subjects. Competence in science has **absolutely no** effect on the wages or earnings of people under the age of 30 and very little effect on their chances of admission to more prestigious colleges. Competence in mathematical reasoning has **no** effects on the labor market success of young men and **only very limited** effects on the labor market success of young women. Competence in the technological arena, by contrast, has **very substantial positive** effects on the wages and earnings of young males.

Section 3 examines the social costs of the learning deficits in science, math and technology. Mathematical and technological competencies are found to have substantial effects on hands-on measures of job performance in military jobs which are similar to the blue collar and technical jobs occupied by the majority of male high school graduates. Competence in mathematical reasoning has substantial effects on job performance in clerical jobs. Science knowledge has modest effects on job performance in both types of jobs. This implies that even though the labor market fails to reward most young people who have studied and learned science and mathematics, the nation's future productivity will be enhanced if high school students receive a stronger mathematics and science background, though the effect of science knowledge is not as large as one might hope. For young men and women hoping to obtain blue collar and technical jobs, the empirical analysis suggests that technological competence is a powerful contributor to both productivity and labor market success. The Nation at Risk report recommendation that all students take a course in computers gave some recognition to the need for technology education but computers are only one of technologies we interact with on a daily basis. This is an area of study that needs much more attention than it has been getting. Section 4 sets forth a series of policy recommendations designed to improve student incentives to devote time and energy to learning and to strengthen parental incentives to demand that local schools be upgraded.

I. APATHY: THE PROXIMATE CAUSE OF THE SCIENCE LEARNING DEFICIT

American high school students do poorly in these international comparisons primarily because they devote a lot less time and energy to the task of learning. American students average nearly 20 absences a year; Japanese students only 3 a year (Berlin and Sum 1988). School years are longer in Europe and Japan. Thomas Rohlen has estimated that Japanese high school graduates average the equivalent of three more years in a classroom and studying than American graduates. Studies of time use and time-on-task show that American students actively engage in a learning activity for only about half the time they are in school. A study of schools in Chicago found that public schools with high-achieving students averaged about 75 % of class time for actual instruction; for schools with low achieving students, the average was 51 % of class time (Frederick, 1977). Overall, Frederick, Walberg and Rasher (1979) estimated 46.5 percent of the potential learning time was lost due to absence, lateness, and inattention.

In the High School and Beyond Survey students reported spending an average of 3.5 hours per week on homework. When homework is added to engaged time at school, the total time devoted to study, instruction, and practice is only 18-22 hours per week -- between 15 and 20 % of the student's waking hours during the school year. By way of comparison, the watching television (A. C. Neilsen unpublished data). Thus, TV occupies as much time as learning. Students in other nations spend much less time watching TV: 55% less in Finland, 70% less in Norway and 44% less in Canada (Organization of Economic Cooperation and Development, Table 18.1, 1986). Science and mathematics deficits are particularly severe because most students do not take rigorous college preparatory courses in these subjects. The high school graduating class of 1982 took an average of only .43 credits of Algebra II, .31 credits of more advanced mathematics courses, .40 credits of chemistry and .19 credits of physics (Meyer 1988 Table A.2).

Even more important than the time devoted to learning is the intensity of the student's involvement in the process. At the completion of his study of American high schools, Theodore Sizer (1984) characterized students as, **"All too often docile, compliant, and without initiative** (p. 54)". John Goodlad (1983) described: **"a general picture of considerable passivity among students...**(p. 113)". Sixty-two percent of 10th graders agree with the statement, "I don't like to do any more school work than I have to" (Longitudinal Survey of American Youth or LSAY, Q. AA37N). The high school teachers surveyed by Goodlad ranked "lack of student interest" and "lack of parental interest" as the two most important problems in education.

The student's lack of interest makes it difficult for teachers to be demanding. Sizer's description of Ms. Shiffe's class, illustrates what sometimes happens:

> Even while the names of living things poured out of Shiffe's lecture, no one was taking notes. She wanted the students to know these names. They did not want to know them and were not going to learn them. Apparently no outside threat--flunking, for example--affected the students. Shiffe did her thing, the students chattered on, even in the presence of a visitor....Their common front of uninterest probably made examinations moot. Shiffe could not flunk them all, and, if their performance was uniformly shoddy, she would have to pass them all. Her desperation was as obvious as the students cruelty toward her."(p. 157-158)

Some teachers are able to overcome the obstacles and induce their students to undertake tough learning tasks. But for most, the student's lassitude is demoralizing. Teachers are assigned responsibility for setting high standards but we do not give them any of the tools that might be effective for inducing student observance of the academic goals of the classroom. They finally must rely on the force of their own personalities. All too often teachers compromise academic demands because the bulk of the class sees no need to accept them as reasonable and legitimate.

The Apathy of Parents and School Boards

The second major reason for the low levels of science and math achievement is parental and school board apathy. An NSF funded survey of 2222 parents of 10th graders found that 25 percent thought their child should take only 1 or 2 science classes in high school (LSAY, Q. BH165). When 2829 high school sophomores were asked whether "My parents...think that math (science) is a very important subject," 40 percent said no with respect to math and 57 percent said no for science (LSAY, Q. AA19Q-AA19R). Only 30 percent of 10th graders reported their parents "want me to learn about computers" (LSAY, Q. AA19D).

Japanese families allocate 10 percent of the family's income to educational expenses; American families only 2 percent. If American parents were truly dissatisfied with the performance of their local public schools, they would send their children to tuition financed schools offering an enriched and rigorous curriculum (as so many Australian parents do) or arrange for their children to receive tutoring help (as half of Japanese parents do). Private investment in secondary education is relatively low in the US because parents are satisfied with the education their children are getting at the public schools.

A comparative study of primary education in Taiwan, Japan and United States found that **even though American children are far behind Taiwanese and Japanese children in mathematics capability, American mothers are much more pleased with the performance of their local schools than Taiwanese and Japanese mothers.** When asked "How good a job would you say ___'s school is doing this year educating___", 91 percent of American mothers responded "excellent" or "good" while only 42 percent of Taiwanese and 39 percent of Japanese parents were this positive (Stevenson 1983). Clearly, American parents hold their children and their schools to lower academic standards than Japanese and Taiwanese--as well as European -- parents. Why is this the case?

II. INCENTIVES: THE REAL CAUSE OF THE SCIENCE LEARNING DEFICIT

Incentives for Learning Science in High School

The fundamental cause of student and parental apathy regarding science, mathematics and technology education is the absence of good signals of learning in high school and a consequent lack of rewards for learning science and mathematics. The signals of learning generated by our educational system such as years of schooling and SAT scores generate handsome rewards--better paying jobs and admission to prestigious colleges. Science and technological learning accomplishments in high school are by contrast poorly signaled to colleges. Science and mathematics learning accomplishments are poorly signaled to employers. Learning accomplishments not signaled are not rewarded. The lack of incentives for learning in science, math and technology are a consequence of three phenomena:

* The peer group actively discourages academic effort.
* Admission to selective colleges is not significantly influenced by achievement in science and technology. It is based instead on aptitude tests which do not assess competence in science and on class rank and grade point averages, which are defined relative to classmates' performances not relative to an external standard.
* The labor market does not reward science and math achievement in high school.

The Zero-Sum Nature of Academic Competition in High School

An important cause of high school students' poor motivation is peer pressure against studying hard. Students who enjoy science and work hard in science courses are considered "nerds" by most of their classmates. The primary reason for peer pressure against studying hard is that pursuing academic success forces students into a zero-sum competition with their classmates. Their achievement is not being measured against an absolute, external standard. In contrast to scout merit badges, for example, where recognition is given for achieving a fixed standard of competence, the schools' measures of achievement assess performance relative to fellow students through grades and class rank. When students try hard to excel, they set themselves apart, cause rivalries and may make things worse for friends. When we set up a zero sum competition among close friends, we should not be surprised when they decide not to compete. All work groups have ways of sanctioning "rate busters." High school students call them "brain geeks," "grade grubbers," and "brown nosers."

The second reason for peer norms against studying is that most students perceive the chance of receiving recognition for an academic achievement to be so slim they have given up trying. At most high school awards ceremonies, the academic recognition goes to only a few--those at the very top of the class. By 9th grade, most students are already so far behind the leaders, that they know they have no chance of being perceived as academically successful. Their reaction is often to dismiss the students who take learning seriously and to honor other forms of achievement--athletics, dating, holding their liquor, and being "cool"--which offer them better chances of success.

College Selection Criteria

In Canada, Australia, Japan, and Europe, educational systems administer achievement exams in science, mathematics and other subjects which are closely tied to the curriculum. With the exception of Japan, all of these exams use an extended answer format. Performance on these exams is the primary determinant of admission to a university and to a field of study and good grades on the toughest exams--physics, chemistry, advanced mathematics--carry particular weight. In the United States, by contrast, the national tests which influence college admission decisions--the SAT and the ACT--are multiple choice exams that do not assess the student's knowledge and understanding of science and technology.[1] The American exams that are similar to those administered in Canada, Australia and Europe--the Advanced Placement exams--are taken by only 6.6 percent of high school seniors and have little impact on college admission decisions.

High school grade point averages and class rankings have substantial effects on who is admitted to the most prestigious colleges. Since most classes are graded on a curve, **taking more rigorous science and math courses lowers the student's grade point average.**[2] Many college admission officers try to factor course difficulty into their evaluations, but most high school students still believe that A's in regular classes are better than B's in honors classes. The result is that many students avoid taking the more demanding courses such as chemistry, physics and calculus. The second problem with the use of GPA and class rank as college admission criteria is that it results in zero-sum competition between classmates and consequently contributes to peer pressure against studying and parental apathy about the quality of teaching and the rigor of the curriculum.

<u>**The Absence of Major Economic Rewards for Effort in High School**</u>

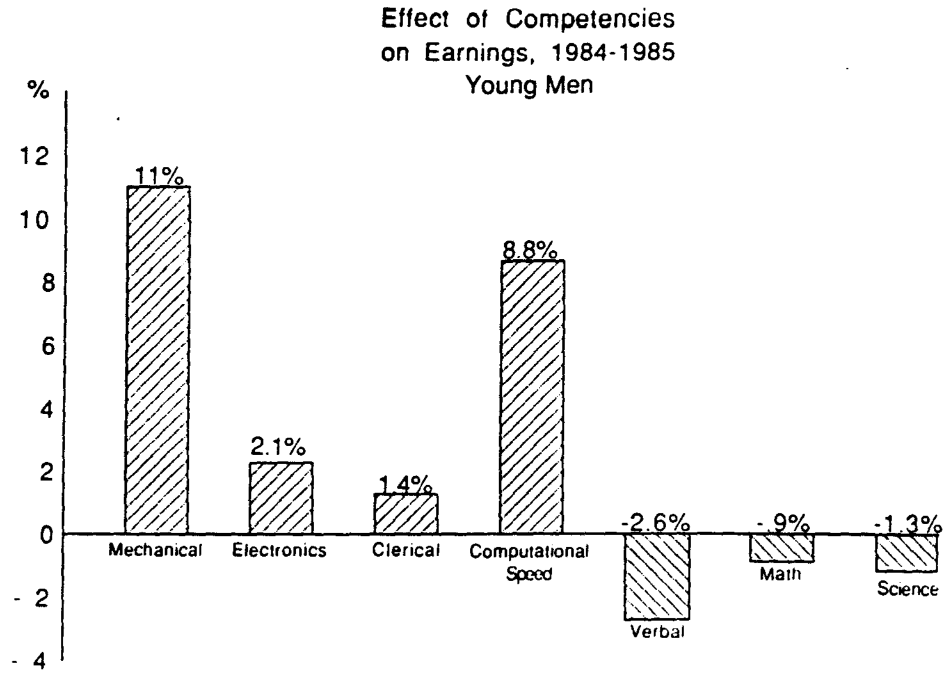
Students who plan to look for a job immediately after high school typically spend considerably less time studying science and mathematics than those who plan to attend college. In large part, most see very little connection between how much they learn and their future success in the labor market. When 10th graders are asked "Which of the following math [and science] courses will you need to qualify for your first choice of job," only 23 percent check geometry, 29 percent check algebra, 18 percent check trigonometry, and only 20-21 percent check biology, chemistry and physics (Longitudinal Survey of American Youth 1988, Quest. BA24B-BA25D). Statistical studies of the youth labor market confirm their skepticism about the benefits of taking tough math and science courses and studying hard.

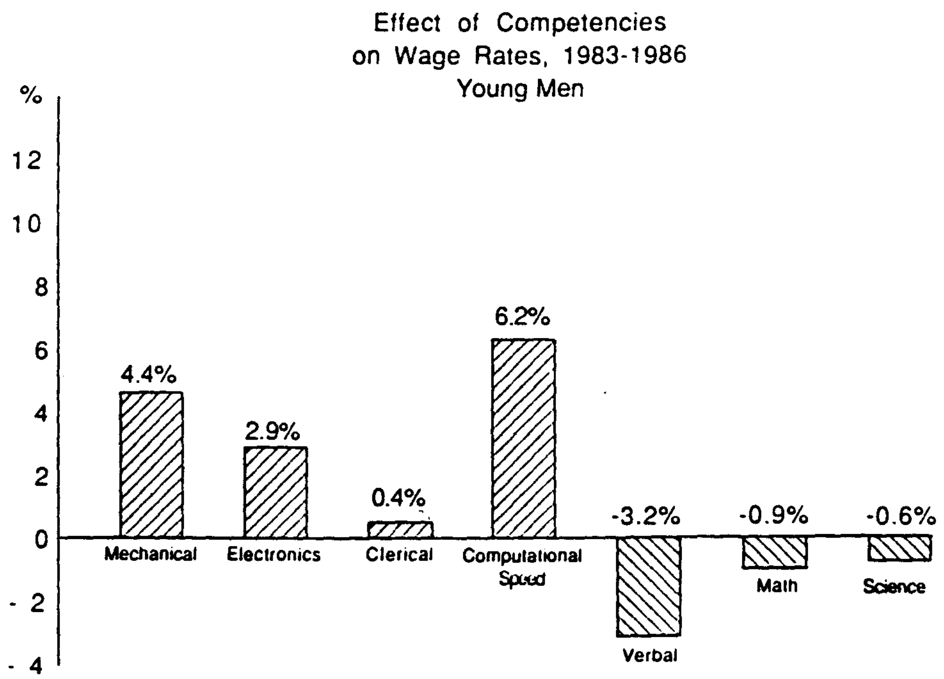
A study of 1972 high school graduates by Joseph Altonji (1988) for the National Center for Education and Employment found that when family background and years of schooling are controlled, the number of science courses taken in high school had no effect on wage rates in the first 14 years after graduating from high school. Science courses were associated with higher rates of wage growth, however, so there may be more substantial benefits coming when the individuals reach the age of 40. By contrast, both math courses and industrial, trade and technical courses had significant positive effects. The effect of two additional full year math courses on wage rates was between .88 percent and 3.4 percent depending on specification. One full year course in an applied technology field raised wage rates by 2.5-2.8 percent.

[Figure 5 and 6 about here]

Results of an analysis of the ability of subtest scores of the Armed Service Vocational Aptitude Test Battery (sample questions for each sub-test are provided in Appendix A) to predict the labor market success of men and women in the Youth Cohort of the National Longitudinal Survey are summarized in figures 5 and 6 (Bishop, 1988b). <u>It was found that, holding years of completed schooling and college attendance constant, that young men received **no** rewards from the labor market for developing competence in science, language arts and mathematical reasoning during the first 8 years after leaving high school</u>. The only competencies that were rewarded were speed in doing simple computations (something that calculators do better than people) and technical competence (knowledge of mechanical principles, electronics, automobiles and shop tools). For the non-college bound female, there

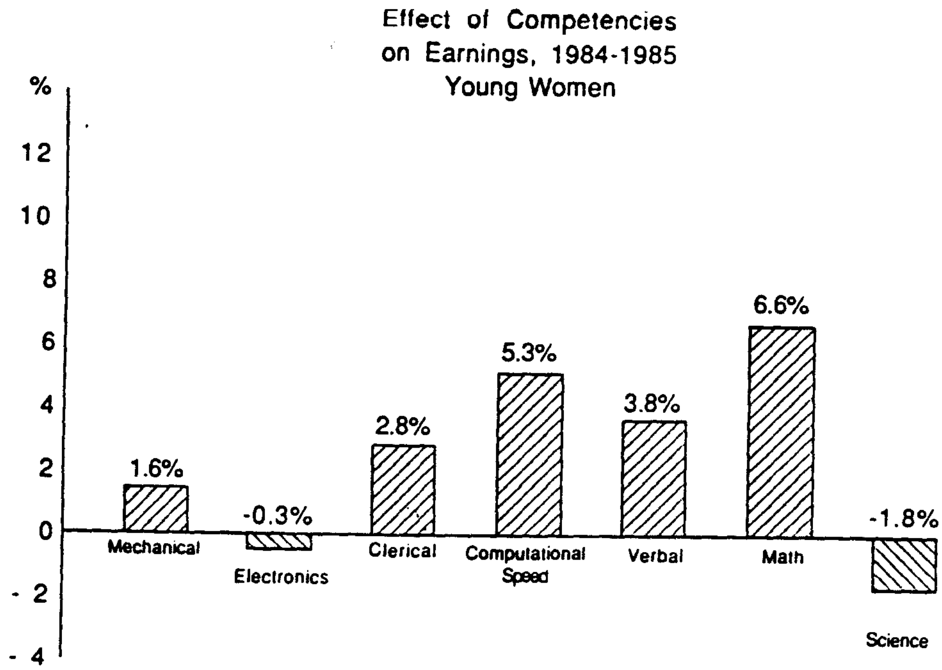
Figure 5

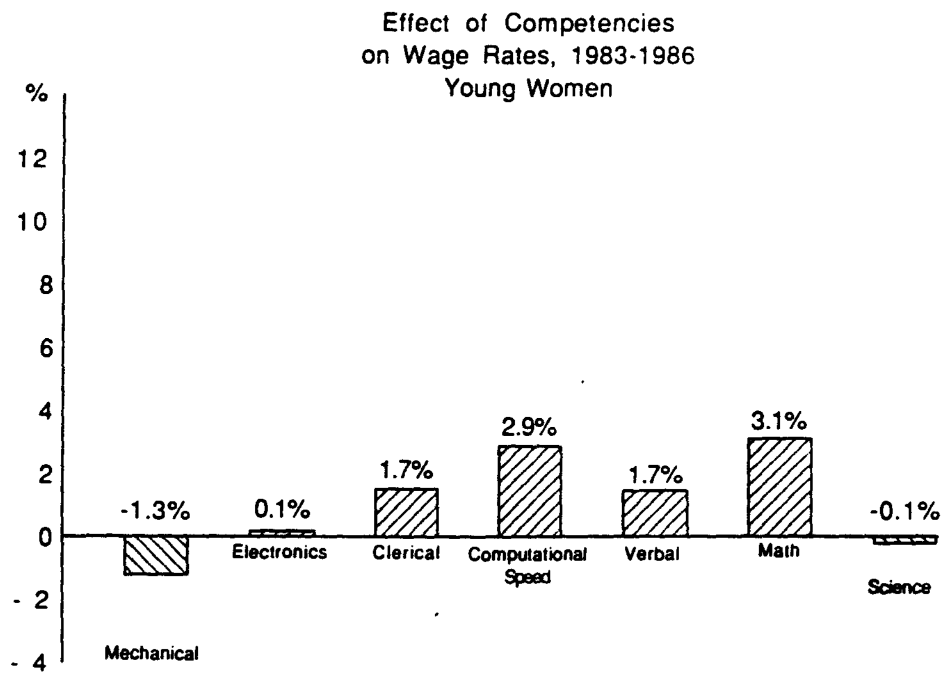




Source: Analysis of NLS Youth data. The figure reports the effect of a one population standard deviation increase in Armed Services Vocational Aptitude Battery subtest while controlling for schooling, school attendance, age, work experience, region, SMSA residence and ethnicity.

Figure 6





Source: Analysis of NLS Youth data. The figure reports the effect of a one population standard deviation increase in Armed Services Vocational Aptitude Battery subtest while controlling for schooling, school attendance, age, work experience, region, SMSA residence and ethnicity.

were both wage rate and earnings benefits to learning advanced mathematics but no benefits to developing competence in science or the technical arena. Competence in language arts did not raise wage rates but it did reduce the incidence of unemployment. The payoff to verbal, scientific and mathematical reasoning competencies did not appear to rise with age or labor market experience.[3]

The absence of rewards for science and math learning achievements is due in large part to the lack of objective information available to employers on the learning accomplishments of recent high school graduates. Tests are available for measuring competency in reading, writing, mathematics, science, and problem solving, but EEOC guidelines resulted in a drastic reduction in their use after 1971 (Friedman and Williams 1982). A 1987 survey of a stratified random sample of small-and medium-sized employers who were members of the National Federation of Independent Business [NFIB] found that aptitude test scores had been obtained in only 2.9 % of the hiring decisions studied.[4]

Other potential sources of information on learning achievements are referrals from teachers who know the applicant and high school transcripts. Both are under-used. In the NFIB survey, only 5.2 percent of the high school graduates hired had been referred or recommended by vocational teachers and only 2.7 percent had been recommended by someone else in the high school. Transcripts had been obtained prior to the selection decision for only 14.2 percent of the high school graduates hired. If a student or graduate has given written permission for a transcript to be sent to an employer, the Buckley amendment obligates the school to respond. Many high schools are not, however, responding to such requests. The experience of Nationwide Insurance, headquartered in Columbus Ohio, is probably representative. The company obtains permission to get high school records from all young people who interview for a job. It sent over 1,200 signed requests to high schools in 1982 and received only 93 responses. Clearly, hiring selections and starting wage rates often do not reflect the competencies and abilities students have developed in school.

The situation is very different in Europe and Japan. Grades on school leaving exams are requested on job applications and typically included on one's resume. Exhibit 1 reproduces a resume used by Irish secondary school graduate applying for a clerical job. Exhibit 2 is an application form for a clerical job in the United Kingdom. Exhibit 3 is an application filed by a 33 year old university dropout seeking a managerial job. While

CURRICULUM VITAE

Exhibit 1

Name ;

Address ;

Date of Birth ;

Place of Birth ;

Nationality ;

Marital Status ;

Occupation ;

Father's name ;

Occupation ;

EDUCATION :

August 1980 - June 1985.
(All five years were spent learning through Irish.)

U.C.D.

QUALIFICATIONS :

Subject:	Intermediate Cert. (June 1983)	Leaving Cert. (June 1985)
Irish	C (H)	C (H)
English	D (H)	C (H)
Mathematics	B (H)	A (P)
French	D	C (P)
German	D	---
Science	A	---
Chemistry	---	C (H)
Physics	---	C (H)
History	B	C (H)
Geography	B	---

Exhibit 2

Tarmac

APPLICATION FORM A-F

CONFIDENTIAL

POSITION APPLIED FOR	**RETURN TO**

Surname	Permanent Address
Forename(s)	
Date of Birth	
Place of Birth	
Nationality	Telephone No.
Marital Status	Next of Kin
No. of Children	Relationship
Sex and Year of Birth of Children (under 18 yrs)	Address
Do you own a car or motorcycle?	Do you hold a current driving licence?

MEDICAL HISTORY

Please state any serious illness, disability, allergy or operation..........

Are you registered as disabled?.......... If yes, state number..........

EDUCATION since the age of 11yrs

School	Dates From	To	Qualification	Subject and Grade

FURTHER EDUCATION –Give details of any qualifications gained since leaving school.

College/Evening Classes etc.	Dates From	To	Qualification	Subject and Grade

EXHIBIT 5

APPLICATION FOR AN APPOINTMENT HANDLED BY MVP

MVP

16, Highfield Road, Edgbaston, Birmingham, B15 3DU Tel: 021 455 9765/0559

3319

Appointment applied for DISTRIBUTION PROJECTS MANAGER (B&Q) Ref.No. ....

PERSONAL DETAILS: (block capitals)

Surname [illegible] Title MR Forenames MERVYN JOHN

Address 7, CAERNARVON GARDENS, [illegible]

.... Postal Code [illegible] Tel.No.Home [illegible] Work [illegible]

Marital Status M Children/Dependants (with ages) 1 x 4 YRS, 1 x 1 YR

Age 33 Date of Birth 5.8.55 Nationality BRITISH Place of Birth ILFRACOMBE, DEVON

State of health OK Height 6' Weight 13 ST. 12 LBS

Any disabilities/recurrent medical problems? — Regd.disabled —

Driving Licences CAR Car Owner ✓ Company Car —

Endorsements, convictions, accidents, etc NONE

Leisure activities and offices held in clubs and societies CYCLING/WALKING

EDUCATION:

Secondary Education

From	To	School	Exams Taken (inc. grades)	Other achievements
1966	1972	BARNSTAPLE GRAMMAR	'O' LEVEL:- ENG. LANG. (2), MATHS (3), FRENCH (3), GEOGRAPHY (1), STATISTICS (3), CHEMISTRY (3), ADDL. MATHS (6), HISTORY (6), PHYSICS (6) 'A' LEVEL:- CHEMISTRY (E), PHYSICS (E), MATHS (O)	MIDDLE SCHOOL GAMES CAPTAIN

Further Education

From	To	College/University	Course & results (inc.class/grades)	Other achievements
1972	1973	UNIVERSITY OF BRADFORD	APPLIED CHEMISTRY – LEFT AFTER 1 YEAR – DOMESTIC REASONS	

Other training and qualifications (inc. in-company and external courses, etc.)

From	To	Establishment	Training/Qualifications
1979		FARNLEY COLLEGE, LEEDS	CERTIFICATE OF PROFESSIONAL COMPETENCE (TRANSPORT OPS)
1983	1984	BRADFORD COLLEGE	INSTITUTE OF INDUSTRIAL MANAGEMENT CERT.
1984	1989	IN-COMPANY	NUMEROUS MANAGEMENT COURSES.

Membership of professional bodies

Date	Association/Institute	Grade of membership	Offices held
1988	I.P.D.M.	A.M.	

employers report they pay less attention to exam grades when hiring workers who have been out of school for many years, it is nevertheless significant that the information remains on one's resume long after graduation from high school. In Japan, clerical, service and blue collar jobs at the best firms are available only to those recommended by their high school. The most prestigious firms have long term arrangements with particular high schools to which they essentially delegate the responsibility of selecting the new hire(s) for the firm. The criteria by which the high school is to make its selection is, by mutual agreement, grades and exam results (Rosenbaum and Kariya 1987).

Because information on school performance is available to employers, recent secondary school graduates in these countries are hired into primary labor market jobs that offer considerable training and access to career ladders at high paying firms. In the United States recent high school graduates are never even considered for these high quality jobs.

Incentives to Upgrade Local Schools

The lack of external standards for judging learning achievement in science, the resulting zero sum nature of academic competition in the school and the lack of economic rewards for science learning also influences parents, school boards, and local school administrators. Parents can see that higher standards in science classes or hiring better science teachers will not on average improve their child's rank in class or GPA. Improving the teaching of science at the local high school will have only minor effects on how my child does on the SAT, so why worry about standards? Scores on AP exams and other achievement tests have little effect on admission to better colleges.

The parents of children not planning to go to college have an even weaker incentive to demand high standards at the local high school. They believe that what counts in the labor market is getting the diploma, not learning chemistry. They can see that learning more will be of only modest benefit to their child's future, and that higher standards might put at risk what is really important--the diploma.

In our system, locally elected school boards and the administrative and teaching staff hired by these boards make the decisions--teacher salaries, teacher hiring selections, availability of AP courses, grading standards, homework assignments--which determine the quality of education in local schools. If substantial grassroots pressure for higher standards does not come from parents, state mandates designed to upgrade the quality of instruction will not have a lasting impact.

III. THE SOCIAL COSTS OF THE LEARNING DEFICIT

Will the deficit in science, mathematics and technology have major consequences for the nation's standard of living? In the view of the National Commission on Excellence in Education, it will:

> If only to keep and improve on the slim competitive edge we still retain in world markets, we must dedicate ourselves to the reform of our educational system....Learning is the indispensable investment required for success in the information age we are entering (p 7).

Behind their call for higher standards and more class time devoted to studying math and science is an assumption that most jobs require significant competency in these fields.

At least with respect to science, however, there is controversy about these claims. Morris Shamos, an emeritus professor of physics at New York University, argues that "widespread scientific literacy is <u>not</u> essential to... prepare people for an increasingly technological society" (Education Week, Nov. 23 1988. p. 28). About 24 percent of the high school sophomores who are planning to attend college report they are interested in pursuing a scientific or technical career (Office of Technology Assessment, 1988, Figure 1.1). Shamos does not dispute the need for these students to receive a thorough science education in high school. He argues, however, there is no need for most citizens and workers to become scientifically literate. A similar argument could also be made regarding the necessity of most students taking algebra, geometry, trigonometry and statistics.

At least with respect to workers in non-technical occupations, his view might appear at first glance to be supported by the findings cited above that achievement in science has no effects on wage rates, earnings or unemployment of young men and women when other competencies are held constant. Further support for the Shamos position would appear to come from a survey of small and medium sized employers who are members of the National Federation of Independent Business. When asked how frequently the employee most recently hired by their firm needed to "use knowledge gained of chemistry, physics or biology" in their job, 74 percent reported that such knowledge was never required and only 12 percent reported such knowledge was used at least once a week. Asked how frequently the new employee had to "use algebra, trigonometry or calculus", 68 percent reported that such skills were never required by the job and only 12 percent reported they were used at least once a week.

The skills used by entry level workers at NFIB firms, however, are not decisive evidence regarding employer needs for three reasons. First, the low levels of scientific and mathematical competence in the work force may have forced companies to put off technological innovations such as statistical process control that require such skills and to simplify the functions that are performed by workers who lack technical training. If better educated workers were available, entry level workers might be given greater responsibility and become more productive. Second, the NFIB sample does not tell us what is happening at large firms and in the jobs occupied by long tenure employees at small firms. The CEOs of many large technologically progressive companies such as Motorola and Xerox are insisting that their factory jobs now require workers who are much better prepared in math and science than ever before. Third, employers may not realize how the knowledge and skills developed in high school science and mathematics classes contribute to productivity in their jobs. Not knowing which employee possesses which academic skill, they would have no way of learning from experience which scientific and mathematical skills are helpful in doing a particular job. Science and mathematics are thought to teach thinking, reasoning and learning skills applicable outside the classroom and the laboratory. If these skills are indeed successfully developed by these courses, productivity might benefit even when there are no visible connections between job tasks and course content.

The lack of wage and earnings responses to scientific and mathematical knowledge is also not decisive evidence in favor of the Shamos position for research indicates that differences in worker productivity do not result in proportional differences in wage rates. When people hired for the same or very similar jobs are compared, someone who is 20 % more productive than average in the first weeks on a job receives only a 1.6 % higher starting wage. After a year at a firm, better producers received only a 4% higher wage at nonunion firms with about 20 employees, and they had no wage advantage at unionized establishments with more than 100 employees or at nonunion establishments with more than 400 employees (Bishop, 1987a).

Employers have good reasons for not varying the wage rates of their employees in proportion to their perceived job performance. All feasible measures of individual productivity