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ABSTRACT

Many feel that the number of high school students electing to enter careers in science and engineering is shrinking and that the United States needs to improve the potential pool in order to remain competitive in the international technology and research areas. This report attempts to describe the dimensions of the problem this nation faces in producing enough scientists and engineers, and how images of science may affect whether American students choose careers in science. Literature is surveyed in various areas including: (1) "Images of Science"; (2) "Measuring Attitudes to Science"; (3) "Structural (Non-Attitudinal) Factors in Science Career Choice" (including tracking, family factors, and factors affecting career choice); (4) "Media, Youth and Career Choice"; (5) "School Achievement in Science and Mathematics" (including the math crisis, and peers, academic aptitude and academic achievement); and (6) "Excellence, Academic Achievement, and Mathematics." A bibliography including 47 books and reports, and 118 articles is appended. (CW)

IMAGES OF SCIENCE: FACTORS AFFECTING THE CHOICE OF SCIENCE AS A CAREER

by

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INTRODUCTION

> The Nobel Prizes were announced recently and, once again, the United States did well. We should take pride in the fact that our system continues to produce such successes. Unfortunately, the Nobel Prizes are a better measure of the success of past policies than they are an indicator of the future. We will do poorly in science and engineering in the future if we do not train the people that we need. Recent data suggest that we are not doing this well enough.... We are attracting a smaller fraction of our best students to the sciences, and the size of the relevant age groups is declining. (Bloch:1987,595-596)

The crisis to which Bloch alludes is the subject of this report. The report is admittedly ambitious, because in addition to attempting to describe the dimensions of the problem this nation faces in producing enough scientists and engineers, it will also attempt to describe how "images" of science may affect whether American students choose careers in science.

There is no dearth of research examining science, science education, mathematics education, factors affecting science education, career choice, career education, media, media education, attitudes, attitude formation, and media impact on attitudes. Nor is there any lack of research examining various permutations and combinations of these topics. It quickly becomes apparent that this literature, therefore, is nothing if not voluminous. The strategy pursued in the preparation of this report, as a result, was to look for breadth, rather than depth. Thus, studies that attempted to summarize and synthesize large bodies of relevant research were eagerly reviewed and their analysis received considerable attention in the preparation of this report.

In the course of its preparation well over 200 articles and reports were reviewed. In some respects, however, only the surface of this broad topic was scratched. However, the outlines of "the forest" did emerge from among the many "trees" that were examined.

The assumptions that motivated this effort were reasonable. Television is a part of virtually every American home, and a wide variety of "images of science" find their way into our living rooms each day. Television presents scientists as figures in the news and as characters in melodrama; we see them inventing the weapons that may ultimately destroy us and, conversely, foretelling our doom if we don't mend our ways. In the movies they are our favorite villians, and, on occasion, our most revered heroes. With so many conflicting images, isn't it reasonable to wonder how these images affect our young?

The question is certainly reasonable, but the relevant research, unfortunately, is far from helpful in providing us with answers. If anything, the search for answers to the question -- do images of science affect whether or not students choose careers in science? -- only turns up more questions. Perhaps what the question really reveals is the limitation of social science research as a tool for resolving and responding to complex questions. Certainly, what the research literature continually reveals is: (1) how little of variation in complex behavior we are able to explain using traditional survey research methods; (2) how often methodological issues cloud our ability to measure the behaviors and the variables that we are interested in understanding; and (3) how difficult it is to convert research findings into effective policies and/or programs that can remedy the problems that the nation faces in producing more scientists.

What the literature review for this report revealed, more than anything else, was how much becoming a scientist depends on doing well in mathematics and science in school. For example, minority students -- most particularly black students -- continually report that they like science, that they like mathematics, that they would like to do well in science, and that they understand the value (and the importance) of careers in science. Yet despite these positive attitudes, their achievement in science and mathematics courses and their participation in science careers lags far behind that of whites and Asians. Student attitudes, we conclude, are not the problem.

As this report hopes to demonstrate, the way to reverse the trends cited by Bloch is to create the conditions in the schools that will maximize the opportunities of students -- all students -- to do well. Prototypes of programs and instructional strategies exist that have promoted high levels of achievement among the very students that are believed by many to be the most hopeless. In addition to highlighting these prototypes in this report, an attempt is made to discuss the manner in which television might be used to enhance the efforts of the schools to improve science and mathematics instruction. But first, some effort to describe the current crisis in science education and in the preparation of American students for science careers is in order.

The Problem

> The size of the 18 -19 year-old group will decline significantly in the next decade. Unless education in mathematics, engineering, and the sciences is made more effective for all students and more attractive to potential faculty members, and especially to the presently underrepresented (women, minorities, and the physically handicapped), both the quality and number of newly-educated professionals in these important fields will fall well below the Nation's needs -- with predictable harm to its economy and security. (from Undergraduate Science, Mathematics and Engineering Education, National Science Board, 1986, p. 2.)

The supply of scientists and engineers is threatened by a number of factors; first, there is evidence of a decline in the proportions of students entering college prepared to major in or graduate with degrees in science; secondly, the nation's changing demographic profile suggests that the future science/technology workforce will increasingly come from the ranks of its nonwhite school children whose academic preparation leaves much to be desired; thirdly, the academic preparation of all students, irrespective of race, is poor, particularly in the areas of science and mathematics; and fourthly, the prospects for an improvement in these trends appears bleak because students show less interest in and little preference for science the further along the educational pipeline they progress.

The Evidence

In 1986 the annual survey of American college freshmen (Astin et al., 1986) conducted as part of the Cooperative Institutional Research Program (CIRP), found declining interest among those surveyed in pursuing careers in engineering and computer science. Specifically, 3.5 percent of the respondents to the 1986 survey indicated an interest in computer science careers; 9.7 percent of those responding expressed an interest in engineering. These percentages represent, respectively, declines of 60 and 19 percent from the proportion of students expressing an interest in careers in these fields in 1982.

Similarly, the National Science Board reported for the period 1973-83 that the number of undergraduate science majors fell by about 15% and that the number of baccalaureate degrees awarded between 1960-1980 in the natural sciences, engineering and mathematics just barely managed to keep pace with the increase in the proportion of 22 year-olds in the general population during this period (NSB,1986). Tressel (1987) observes: "Most students who take high school science do so only because it is required for college; only one in ten has any plan to pursue science further, and in fact only one in thirty will actually do so and complete their undergraduate studies. And of these, less than one in four will go on to higher studies."

The picture for minority students is even bleaker. They comprise an ever dwindling proportion of students in the educational pipeline, and even those who manage to persist to college find that the going, if anything, gets tougher. This pattern is typified by the experience of black students in engineering. As reported by Garrison (1986), for example, "Blacks comprised 6.1 percent of the first year engineering students in 1981. This figure fell to 4.9 percent of the second year students in 1982, 3.8 percent of the third year students in 1983, and 3.2 percent of the fourth and fifth year students in 1984." (1986, p. 42)

To add to this litany, recent assessments of the academic preparation of the nation's students from elementary school to graduate school suggests that US students do not compare favorably with their peers from other industrialized nations. To cite a few of the most widely reported results:

- Stevenson and colleagues (1986), in a study of scholastic achievement among schoolchildren in Taiwan, Japan and the US, report that American first and fifth graders are severely overrepresented among children receiving low scores in mathematics and are severely underrepresented among those with high scores in math.
- The Second International Science Study found that American student performance in science had improved over that reported in 1983 but was well below that attained in 1970 when the first international study was undertaken; moreover -- and perhaps more significantly -- the study found that students in England, Japan, and six other countries outperformed the top American students, despite the fact that the Americans had had advanced coursework in physics, chemistry, and biology (Rothman, 1987).
- As Steen reports in his analysis of mathematics education in the US "Non-US citizens who take the Graduate Record Examination in mathematics average 100 points higher than US students. The

performance gap is twice as high in mathematics as in any other field -- the next highest being in physics, the most mathematical of the sciences." (1987, p. 251)

The less-than-stellar academic performance of American students in mathematics and science is mirrored by their very evident dislike of these subjects. The 1982 National Science Assessment found among 13 year-olds:

• slight, but nonsignificant, declines in science achievement between 1976 and 1981;

• levels of achievement that were below 1969 levels; and

• little change in generally lukewarm opinions toward science careers.

Among 17 year-olds the Assessment reported:

• continued, significant declines in science achievement;

• major declines in students' willingness to support science research and to use science information; and

• declines in students' perceptions of themselves as change agents for socio-scientific problems (Hueftle et al., 1983).

The report's authors caution:

> ...News of waning science achievement cannot be accepted without concern -- particularly when it is coupled with eroding student attitudes.... Perhaps young adults do not have enough science knowledge to face complex technological problems, and feel less certain that they -- or anyone else -- can solve these problems as a result. If so, we may be moving dangerously away from the enlightenment Jefferson felt was so critical for citizens to maintain if society was to preserve control over its processess. (Hueftle et al., p. 98)

In subsequent sections of this report an attempt will be made to summarize the literature in a number of widely varied fields in an effort to understand the relationship between public images and perceptions of science and choosing a career in science or engineering. Along the way, a number of related topics are examined. We begin with a look at how science is portrayed in the media and how it is perceived by students and the general public. Structural factors that affect career choice are examined, followed by a discussion of media and its impact on career choice. Recent research on science and mathematics achievement is discussed next, followed by a detailed look at the work of mathematics educator Uri Treisman. Finally, in a concluding section, a modest proposal to measure attitudes and school behavior is made.

I. IMAGES OF SCIENCE

Hueftle and colleagues suggest that the images of science that US schoolchildren possess -- particularly from non-school sources such as radio, TV and other popular media -- contribute to the relatively low esteem in which science and scientists are held. The public image of science has been studied in a number of separate settings over the years. Some of the more notable of these include the following.

•Gerbner (1987) studied the content of network prime-time dramatic programs for the 10-year period between 1973 and 1983. Among the results reported he cites the following: (1) images of science and technology appear in 7 of every 10 dramatic programs: the average viewer will see, therefore, one dozen doctors and two other kinds of scientists each week. (2) Doctors are more positively portrayed than other scientists. (3) There is an imbalance with respect to the successes that television characters achieve: "for every scientist in a major role who fails, two succeed. But for every doctor who fails, five succeed, and for every law enforcer who fails, eight succeed." (1987, p. 111)

Gerbner notes that one of the causes of the higher failure rate of TV scientists is that roughly 5 percent of the scientists portrayed on television kill someone and about 10 percent managed to be killed -- the highest victimization rate of any occupational group seen on prime time (including private eyes, policemen, and members of the army).

Gerbner also found evidence that heavy television viewing had a negative effect on the responses of viewers to an attitude survey designed to assess science attitudes. The more people watch television, the more they think of scientists as odd and peculiar, and this image is particularly pronounced among viewers who report watching little or no public television. Gerbner reports, "Exposure to science and technology through television entertainment appears to cultivate a generally less favorable orientation toward science, especially among higher status groups whose light-viewer members are its greatest supporters." (1987, p. 112)

• In a nationwide study sponsored by the American Association for the Advancement of Science in which high school students were asked to compose essays describing scientists, Mead and Metraux (1957) constructed a composite description of science and of scientists from over 35,000 student responses.

Overall, science was perceived as a man's province in which women did not figure. The field was described by respondents in a variety of forms: as a "very broad field" for some, as a single entity for others, and for still others, as a melange ("medicine and gas and electric appliances"). The goals of science could be described in humanitarian terms ("working to better mankind, finding cures, making new products"), or in individualistic terms ("making money, gaining fame and glory..."), or destructive terms ("dissecting, destroying enemies, making explosives").

The common image of the scientist that emerged from these essays portrayed him as a man "who wears a white coat and works in a laboratory," and who "spends days doing experiments...with plants and animals, cutting them apart, injecting serum into animals." He is perceived in a positive sense as "a very intelligent man -- a genius...[with]

long years of expensive training....He works for long hours in the laboratory, sometimes day and night, going without food and sleep." But on the negative side, "his work is uninteresting, dull, monotonous...and though he works for years, he may see no results or may fail...He has to keep dangerous secrets; he is endangered by what he does...He may sell secrets to the enemy...He may not believe in God or may lose his religion...He neglects his family .... He is never home."

The authors offered a number of observations of this composite.

> The number of ways in which the image of the scientist contains extremes which appear to be contradictory -- too much contact with money or too little; being bald or bearded; confined work indoors, or traveling far away; talking all the time in a boring way, or never talking at all -- all represent deviations from the accepted way of life, from being a normal friendly human being, who lives like other people and gets along with other people. (1973, p. 318)

• Following the work of Mead and Metraux, Chambers (1983) reports the results of the Draw-A-Scientist Test (DAST) that was administered to 4807 children from kindergarten to grade five in Montreal over a period of 11 years (1966-77). As the title of the test suggests, the DAST requires students to draw a picture that best portrays their image of a scientist. Each drawing is analyzed and scored according to the degree to which "standard images" of a scientist are present (e.g. lab coat, eyeglasses, beards, etc.). The average number of standard images present in the drawings ranged from .31 per student (among kindergarten students) to 3.26 per student (among fifth graders). Chambers concluded from the study "(1) The stereotypic image of the scientist, which Mead and Metrux examined in high school students, was found to appear among students at the grade school level. (2) The evidence indicates that the various elements of the stereotype appear with greater frequency as students advance through the grades." (Chambers, p. 264)

• Etzioni and Nunn (1975) surveyed national public opinion polls and attitude surveys to examine the attitudes of Americans toward science. Among their findings were: (1) most Americans value science and see it as the means through which this nation enjoys a high standard of living; (2) similarly, Americans hold generally favorable opinions of scientists and trust their judgement; and (3) opinions and attitudes toward science vary significantly by age, education, region, socioeconomic status, and personality type. The authors note that although a large number of people approve of science as a "technological golden goose," they have much less appreciation for it "as an approach to the world, as an exciting or aesthetic experience, or as a great puzzle solver." (Etzioni and Nunn, p. 239) In general, they conclude, science is among the least understood of American institutions.

• In a similar analysis, Komarnicki and Doble (1986) examined public opinion surveys of attitudes to science, conducted during the period between 1972 and 1986. Their findings largely mirror those of Etzioni and Nunn (1975); for example, the authors found, as did Etzioni and Nunn, that there is widespread public support for science, technology and engineering as the source of the nation's unprecedented high standard of living. Among the 35 distinct findings they report from their review, they observe: (1)

the public believes that technology has increased economic productivity, but are uncertain whether technology creates more jobs than it takes away; (2) the public is moderately interested in science and technology but confesses to a lack of adequate information to make informed judgements about such matters; (3) the majority of Americans would recommend a career in engineering, computers, or electronics if asked by a young person for advice about what career to choose; and (4) although public support for science/technology is generally high, there appears to be evidence that this support has slipped in recent years.

Significantly, public attitudes toward science become more favorable as the level of education of respondents increases. As reported by Komarnicki and Doble, for example, when a 1983 survey asked "how much interest do you actually have in scientific and technological matters", responses were highly correlated with the level of education of respondents--the greater the amount of education, the greater the level of interest expressed. Unfortunately, even among the best educated within the sample, only a small fraction (15%) rated itself as well informed about new inventions, new technologies, and scientific discoveries. Among the least well educated of this sample, only 5% admitted to being well informed about these issues (Kamornicki and Doble, 1986).

Summary

I have suggested throughout this review that the images of science and of scientists, are complicated by a variety of factors. In general, the surveys of attitudes and images do not lend themselves to simple characterization. Public responses to questions about science and technology vary tremendously, according to what questions are asked, when they are asked (e.g. after a scientific triumph or after a technological disaster), and who is asked. It does seem clear, however, that the science education that the average American has received (either in school or through other information media) has only partially succeeded in promoting an appreciation for science or an ability to keep abreast of technological developments.

The assumption of many commentators on these attitudes is that public opinions about science provide us, as Etzioni and Nunn observe, with "an indicator of the changing status of rationality." The authors claim that positive attitudes toward science reflect the degree to which "institutions embodying rationality" are accepted by the general public as well as the degree to which the public will support their continued growth and development. However, it seems equally clear that these attitudes also reflect the degree to which science and mathematics education in the schools have been successful in providing the public with a foundation for understanding and appreciating these fields. Results suggest that such a foundation has not been laid and that critical developments in these fields are only dimly understood by a large sector of the American public.

II. MEASURING ATTITUDES TO SCIENCE

When scientists and mathematicians describe their work, they frequently speak of its beauty or of the awe that it inspires. Hammond (1978), for example, quotes the mathematician Hans Bers on the subject of beauty in mathematics:

> I think the thing which makes mathematics a pleasant occupation are those few minutes when suddenly something falls into place and you understand....Some people have it only once or twice in their lifetime. But the quality of this experience--those who have it know it--is really joy comparable to no other joy. (1978, p. 27)

At the heart of our objectives for science education lies the hope that students will begin to see glimpses of the beauty of Nature's harmony through their studies and will become inspired to learn more. Moreover, we assume that if students develop positive attitudes toward science our science education programs will have been at least partially successful.

Measuring such attitudes, however, is far from straightforward. Hugh Munby's 1983 study, "An Investigation into the Measurement of Attitudes in Science Education" examines some of the difficulties encountered in defining attitudes to science and in correlating achievement in school science with student science attitudes. His report contains a review of 56 instruments used for measuring attitudes to science that were culled from over 200 dissertations and more than 100 published studies.

Munby observes that these studies offer many definitions as to what constitutes an attitude to science, "and the range extends from scientific attitudes, through attitudes to science courses and activities, to career interests and preferences." (p. 142) Moreover, there are a large number of attitudinal "targets" described in these studies that include: scientists, science courses, the difficulty of doing science in school, knowledge of science, science teachers, science experiments, and the ability to use the scientific method in thinking. Munby concludes that the confusion about what constitutes an attitude to science undoubtedly accounts for "conflicting research reports" from studies exploring the relationship between attitudes and science achievement.

Of critical importance here is Munby's notion that the very concept "attitude to science" is ambiguous and difficult to measure. "Science, it could be argued, is so much a part of western thinking that its meaning and its implications for society might get lost behind the more obvious and superficial (if not newsworthy) ways in which its presence is felt." (1983, p. 146) It is almost impossible, he contends, to "unpack" the concept of "attitude to science" so that it becomes a useful explanatory variable in research. He suggests that the inconsistent results reported in many studies examining the relationship between attitudes to science and subsequent achievement in science may be attributable to our inability to adequately define or measure these attitudes.

For example, the components of an "attitude to science" -- at least as the term is used in the studies Munby reviewed -- might include: (1) knowledge of science , (2) awareness of science facts, (3) ability to reason scientifically, (4) opinions of the people who are involved in science, and (5) our attitudes toward the products of science and technology (ranging from computers to toxic waste and acid rain). There is considerable overlap among these topics and attempting to represent them in some comprehensive manner--e.g. by adding up subscale scores to create an "attitude to science score"--may not produce a valid measurement. We run the risk of defining the variable too broadly (so that the attitude we measure is meaningless) or of defining it too precisely (so that we overlook valuable information).

More difficult still is the task of using a variable purporting to measure "attitudes toward science" to explain the variation in such complex behavior as achievement in science courses or the choosing a career in science. The voluminous literature on attitudes and their relationship to beliefs, intentions, and behaviors suggests that there are considerable methodological hurdles to overcome.

Attitudes: Research and Theory

The seminal work in the area of attitude research is that of Ajzen and Fishbein (1980). The Fishbein/Ajzen attitude-behavior model is the object of considerable comment and criticism in the research literature (e.g. Liska, 1984), and there have been numerous attempts to test its validity (Liska et al., 1984; Chaffe and Roser, 1986; Carpenter and Fleishman, 1987). What is clear from this body of literature is that there is no simple linear relationship between an attitude and a behavior, particularly if a long period of time elapses between when attitudes are measured and when behaviors occur. Thus, the attitudes that children of five express toward careers are unlikely to have any relationship to the careers they ultimately choose.

The literature similarly suggests that little or no relationship will be observed between an attitude and a behavior that is not directly under the control of the individual. Becoming a scientist or an engineer falls into this latter category since -- it goes almost without saying -- entering these career fields involves more than simply having positive attitudes toward these career fields.

More useful, perhaps, are efforts to assess the relationship between *intentions* -- since by definition an "intention" implies a predisposition to behavior -- to perform a particular behavior and one's resources for carrying out one's intentions. This relationship was the subject of research by Carpenter and Fleishman (1987) concerning the intentions of Australian high school students to attend college.

Specifically, the authors sought to test the Fishbein-Ajzen model of attitude-behavior to determine how intentions to attend college, as measured in the senior year of high school, were related to actual college attendance of Australian students two years later. Their findings supported some aspects of the Fishbein-Ajzen model. Specifically: (1) favorable attitudes toward higher education, parental encouragement, and the college attendance plans of friends and peers were significantly correlated with the intention to attend college; (2) intentions to attend college were significantly correlated with actual college attendance ($r=.620$ for boys; $r=.490$ for girls). But the authors also found support for Liska's (1984) suggested revisions of the Fishbein/Ajzen model.

Liska contends that intentions mean little if an individual does not have the wherewithal to bring intentions to fruition. Thus, social-structural opportunities, that is, having the money to attend college, attending a school that promotes college attendance, having the grades to compete for college admissions, and so on which are necessary conditions for converting the intention to attend college into actual college matriculation. Accordingly, (and consistent with Liska), the Carpenter and Fleisman study found that social-structural opportunities and resources were significantly related to actual college attendance (as were attitudes to college and intention to attend college).

Summary

From the foregoing, it seems reasonable that choosing a career in science involves more than simply having favorable attitudes toward science. As suggested in Munby's work, the methodological problems inherent in developing appropriate measures of attitude are considerable and not easily overcome. Research investigating the relationships between attitudes and behavior suggests that, at the very least, attitudes must be examined in concert with other variables (e.g. measures of intention) in order to explain a significant portion of the variation in such complex behavior as making a career choice. Certainly, structural factors must be examined with at least as much interest as those related to attitudes and intentions.

III. STRUCTURAL [NON-ATTITUDINAL] FACTORS IN SCIENCE CAREER CHOICE

On a gross level the structural factors affecting the choice of science as a career may be classified on two levels: personal and systemic. At the personal level we include grades, financial resources, family background, and knowledge of careers. At the system level, we include the quality of school that a student attends and how a student is tracked in school. These factors, it seems clear, are likely to explain more of the variation in college attendance, science course enrollment, and entry into science/engineering careers than students' attitudes to science (however these attitudes are measured).

Tracking

There is a growing body of literature that has examined the issue of tracking, some of which is summarized in a review of the literature on tracking provided by Rosenbaum (1980). The weight of the studies cited there strongly supports the notion that the way students are grouped and tracked in school will significantly affect their academic careers:

•With respect to the impact of ability grouping on student achievement, Rosenbaum found conflicting, even contradictory, claims for grouping:

> NEA's (1968, p. 42) careful tabulation of the results of the 50 best controlled studies [on ability grouping] published since 1960 dramatically shows the inconclusiveness of this literature.... It shows that for each study exhibiting a net gain

> in achievement, a comparable study recorded a net loss (for all ability levels except the lowest, which had slightly more losses than gains). (1980, p. 365)

•Rosenbaum also found evidence that "grouping separates students into distinct, hierarchically ordered groups and these groups tend to endure over fairly long periods of time." There is also some evidence that students' self perceptions are affected by such grouping and that the effects are particularly harmful for those who are placed in lower tracks. Rosenbaum was particularly impressed by the self-reported feelings of students in lower tracks that suggest dramatically (and in ways that statistics could not possibly convey) how severely stigmatized the experience of being in a low-rated group can be. He cited a statement made by a student in a mid-Western high school in 1949 as evidence:

> If you take a college preparatory course, you're better than those who take a general course. Those who take a general course are neither here nor there. If you take a commercial course, you don't rate. It's a funny thing, those who take college preparatory set themselves up as better than the other kids. Those that take the college preparatory course run the place. [from Hollingshead, 1949, p. 169]

•The large body of literature published since Rosenbaum's review suggests that similar findings continue to be reported by a variety of researchers. Felson and Reed (1986), Felmlee et al. (1985), Dar and Resh (1986), and Sorensen and Hallinan (1986), for example, conducted research examing the effects of grouping on academic performance, self-appraisal, and classroom attention. In each, evidence is presented that there are negative consequences that issue from ability grouping, particularly for students in groups that are perceived as having low esteem.

•Ability grouping has significant effects that persist beyond school and that affect the student's placement in the workforce. Hare (1987) is prominent among social critics who suggests that the American economy cannot accomodate blacks and members of other non-white minority groups and that the schools play a critical role in enforcing the social order. Specially, Hare suggests that tracking in schools is an efficient way to assign "undesireables" to inferior social roles and positions. Those who fail in school will attribute their failure to achieve higher status in later life to their inability to "make the grade" in school, and will not question a socio-economic system that assigns high status to high academic achievers.

> The myth of equal opportunity serves as a smoke screen through which losers will be led to blame themselves, and be seen by others as getting what they deserve. One might simply ask, for example, how can both inheritance of wealth for some and equal opportunity for all exist in the same social system? (1987, p.101)

Colclough and Beck (1986) found significant empirical support for Hare's assertions. They found that curriculum tracking had a significant impact on the reproduction of social class--that is, the likelihood that a student would complete school and enter the workforce in the same social class as that into which he or she was born. Specifically,

> Curriculum tracking was shown to be the critical

> determinant of reproduction. We find that students from manual class backgrounds are over twice as likely to be placed in a vocational track, and students who have been assigned to a vocational track have an eighty-nine percent chance of being channeled into a manual class destination. Similarly, students with a mental class origin are 1.6 times more likely to be placed in a college-bound track, and 61.56 percent of the college track students are channeled into mental class destinations. (p. 470)

Moreover, the authors note that males who were from manual class backgrounds but were placed in a college-bound track in high school had a different experience that their peers in the vocational track. "As expected, for males in the manual class, being allocated to a vocational track significantly increases the odds of class reproduction, but being assigned to a college-bound track has the opposite effect, enhancing the likelihood of class mobility." (pp. 467-468) Thus, although social class has a strong relationship to the track to which one is assigned, there do appear to be signficant opportunities available to students who show early promise in school and who escape the "traps" of non-college tracking in high school.

Family Factors

Two surveys of the largely male Westinghouse Science Talent Search (WSTS) winners conducted at very different points in time (Edgerton, 1961; Science Service, 1985) suggest that a parent, a close relative, or a teacher may play a critical role in the decision to become a scientist. In both surveys the influence of males -- fathers, brothers, and uncles -- receives prominent mention as a factor in the choice of career.

The WSTS is one of America's oldest high school competitions in the sciences. Since 1942, Westinghouse has awarded $2 million to 1,760 young scientists. Among this group are included five Nobel Prize winners, two Fields Medal winners, and four MacArthur Founda' ı Award winners. Although they are not a random sample of the scienc community, WSTS winners clearly merit interest.

In a 1985 survey of WSTS winners, the 58% who responded to the survey had become an extremely accomplished group. Most were invclved with a college or university: 27% reported that they taught in institutions of higher education, 24% reported that they were doing research at a college or university, and another 2% listed jobs in college or university administration.

The fathers of 35% percent of those surveyed were professionally involved in science, mathematics, engineering, or medicine; 23% reported brothers and 21% reported uncles in these professions. Fully 48% of those surveyed were the oldest child; another 16% were only children. Sixty-two percent of the sample cited a professor or a teacher as playing a major role in their decision to select their careers. Forty-four percent reported that they became interested in their current professional field in high school.

The disproportionate concentration of only and first children in the sample was of particular interest. On the assumption that birth order is a random effect, and that scientists are no more likely to be first born children than they are to be the middle or youngest child, this author did a chi-square goodness-of-fit test on sample responses to examine the degree to which the observed sibling order reported by respondents deviated from expectation. The results ($X^2 = 253.7$, with 3d.f., $p<.001$) suggest that there is a disproportionate concentration of first and only children in the sample. Is there a relationship between the creativity and career achievement of this group and their sibling order?

Sibling configurations of scientists and other eminent persons have been studied frequently (e.g. Altus, 1966), but findings have been consistently disputed because of the suspected presence of methodological artifacts arising both from the manner in which appropriate samples are drawn and the manner in which data analysis is conducted (Datta, 1968). West (1960), using a sample of persons engaged in research (their professional eminence was not studied) and testing his data against a number of hypotheses related to the expected distribution of birth order among such data, found, nonetheless, a disproportionate number of first and only children in his sample. Datta (1968), however, using a sample of Science Talent Search winners and applicants, found no significant difference in the scores of subjects on the Test of Potential Scientific Creativity and subject's birth order, separation from next oldest sibling, family size, and sex of next oldest sibling. "Birth order," she concludes,"considered as simple ordinal position, does not appear to be a very powerful factor within the [Science Talent Search] sample." (1973, p. 45)

Results of these and other studies (e.g. Terman, 1954) suggest that there is no simple, direct relationship between choosing a career in science, family size, birth order, and/or parental influence. These factors are undoubtedly important, but attempts to measure their influence yield inconsistent results that arise from methodological problems that are not easily overcome.

Factors Affecting Career Choice

Perhaps the most extensive study of the factors affecting occupational selection conducted to date was completed by Wagenaar (1984) using data collected as part of the High School and Beyond (HSB) study. To examine the factors influencing occupational selection, a variety of models of vocational choice were tested with an assortment of variables related to aspiration, SES, ability, academic achievement, and parental influence. However, these models only explained, at best, approximately 16% of the variation in career selection. Wagenaar concludes, "The results indicate clearly that selection of a given occupation is largely a product of factors that were not included in the equations. Such factors might include actual experience in an occupation, occupation held by a parent or a close friend, occupational knowledge, other values and beliefs, and psychological traits." (p. 253)

In his own extensive review of the literature on occupational choice, Wagenaar is led to conclude that, whatever their information source, students are not particularly knowledgeable about occupations or about what is required to pursue a particular career. He cites studies in which (1) only 45% of surveyed ninth graders had the same occupational preferences two years later and only 27% had the same occupational preferences one year after high school graduation; (2) high school students demonstrate little knowledge of occupations or of occupational structures;

and (3) that only a small proportion of entering college students are sure about their major or have any clear sense of the career implications of their undergraduate majors. He concludes, "The thrust of these and other research findings is that adolescents know little about the occupational structure and that most make occupational choices in incremental fashion based on personal opportunity situations negotiated within the larger social structure. Also, adolescents are unrealistic in predicting their own job selections and success." (p. 11)

IV. MEDIA, YOUTH AND CAREER CHOICE

One is tempted to ask whether media images of occupations influence the "occupational knowledge, other values and beliefs" that Wagenaar describes. To what extent do television and other media contribute to occupational choices and the images that students have of occupations? The literature on the impact of media on viewers' attitudes, knowledge, and behavior is both dense and complex. Television, as Beniger (1983) observes, has transformed the "shared symbolic environment" of the nation; it has become such an integral part of the American consciousness that "unpacking" its impact on our thinking and behavior popses tremendous difficulties.

As Singer and Singer (1983) comment, for example: "Television is a member of the family. Ensconced in 99% of American homes, the television set claims the attention of school children for approximately 4 1/2 hours per day reaching a peak of 5 1/2 - hours a day by age 12 (Lyle and Hoffman, 1972). Poor children watch more than middle-income children (Greenberg, 1976), and black children watch more than white children (Greenberg and Dominick, 1970)."

Media research is not confined, of course, to television. The American public is "tuned in" to more than television and is receiving messages from a variety of media. Larson and Kubey (1983), for example, found that music programming on the radio has a tremendous impact on young people, demonstrating greater powers than television to engage adolescents emotionally. Similarly, Christenon and DeBenedittus (1986) found that viewing television was an activity that children and adolescents shared with their parents; listening to the radio, however, particularly for young adolescents, was something done in private as a means of "eavesdropping" on the teenage/adult world.

Christenson and Roberts (1983) suggest, that much of the research on media and young people has been motivated by a fear that television and radio threaten the information monopoly of parents and the schools. These fears arise, they point out, because children are vulnerable; they lack both the information processing skills and the sophistication of adults, and are more susceptible to being manipulated and misled. Christenson and Roberts conclude, however, that the effects of television on behavior are complex and cannot be understood simply by analyzing the content of what is viewed. Exhibiting violent behavior, for example, cannot be shown to bear a simple, linear relationship to viewing television shows with a high violence content.

Nonethless, research findings relating attitudes to the content of what is viewed on television continue to be reported. Atkin (1977), for example, found no relationship between viewing television news and children's attitudes toward political candidates. He did, however, find modest correlations between self-reported viewing of political commercials for presidential candidates and their ratings of candidates. Similarly, Atkin and Ganz (1978) found modest correlations between television news viewing and interest in political affairs among children aged six to eleven. However, Rubin (1978) in a survey of somewhat older children and adolescents, found almost no relationship between either public television viewing, general television viewing, and attitudes toward the American president and the American government.

These results -- suggesting that television impact on attitudes and values depends partially on the age of the viewer -- support findings reported by Collins (1982) and Roberts (1982). As the child becomes more mature, the ability to judge the information/entertainment content of what is viewed becomes more sophisticated. Children's attitudes toward what is seen will be influenced, in other words, by what they have seen and learned of the world. Christensen and Roberts (1983) suggest, as a result, that young children are more susceptible to manipulation than older children. "A child of five years will have fewer prior attitudes on fewer topics than will a ten-year-old, who in turn, is likely to have fewer than a fifteen-year-old. We also expect that what attitudes the young child has will be less firm, less well integrated within a total cognitive map. For these reasons, then, attitude formation and change should be easier to accomplish among younger children." (1983, p. 93)

As children grow older, however, television is particularly critical in the formation of an understanding of social relationships and of the social forces that govern adult life. Peterson and Peters (1983), in their review of the literature of the impact of television on the social reality of adolescents, suggest that television provides adolescents with glimpses of adult life and adult roles that are not otherwise available to them.

> Television may function as a window into the world of social actions extending far beyond the teenager's more restricted range of daily experiences. That electronic

> images can expand the youth's world is especially important because adolescence is a period of "age segregation" in which few social contacts occur outside one's age group. Except on television, adolescents have few opportunities to observe adult role models in a wide variety of careers.... Thus, although "media culture" may offer somewhat stylized versions of reality, television also introduces adolescents to aspects of roles that lie outside their daily experiences. (1983, p. 72)

The authors suggest that adolescents observe televised role behaviors and experiment with them; these roles include how to interact with peers (by providing a glimpse of expected, age-appropriate behaviors -- e.g. how to be cool), how to exhibit age/gender-appropriate behavior, how to assume an appropriate sexual identity, and, in terms of our interests here, how to acquire an understanding of adult occupations. Similar observations are made by Ellis (1983), Noble (1983), and Bontinck (1986).

Some television viewing is associated with negative attitudes, particularly in promoting racial and sexual stereotypes (Graves, 1975; Seiter, 1986). A number of observers (e.g. Morgan and Rothschild, 1983; Durkin, 1985; Harris and Stobart, 1986; Seiter, 1986; Livingston and Green, 1986) have commented that television programs and advertising consistently portray women as submissive to men and as holding jobs that are typically defined as "female" roles. Durkin (1985) and Graves (1975) also present evidence that television can be influential in changing attitudes toward women and/or members of another race, depending on how images of them are presented to the viewer.

Is it clear from this research, however, that we know how to affect attitudes and behavior using television? Messner (1986) and Gunter and Furnham (1984) suggest that viewers make "highly differentiated judgements" about television content depending on their personality characteristics, the form of the television presentation and its content. Christensen and Roberts (1983) conclude that it is difficult, if not impossible, to determine from available research how, and to what degree, television affects children. Similarly, Baggley (1985), in his review of the literature of media impact on promoting positive health behaviors, concludes that media can be effective in promoting public awareness but does not appear to have much impact on changing behaviors. "The public," he concludes,"is immensely resistant, or even oblivious, to attempts made by media to persuade it of new beliefs or a new course of action."

Thorton and Voight (1983), in their examination of television and juvenile delinquency, conclude that family, school, and peer factors exert a stronger impact on deliquency than television viewing. Similarly, Messner (1986) found little evidence to support the claim that high levels of exposure to television violence are related to high levels of crime.

Heavy television viewing has, however, been associated with low levels of academic performance (Felter, 1983; Ward et al., 1983) and has been cited as one of the possible causes for the decline in the SAT scores of America's college-bound students (College Entrance Examination Board, 1977).

Summary

It is important to understand that how a television message is received is dependent on a variety of factors related to the viewer and not to the message. Goldberg and Gorn (1983) in their review of the impact of television advertising on children, are critical of many of the studies assessing the relationship between viewing habits and children's purchasing behavior. They cite, for example: (1) the inability of many -- particularly very young children -- to answer questions accurately; (2) the unwillingness of some subjects to answer questions honestly; (3) the problems associated with the wording of survey questions so that children understand what they are being asked; (4) the problem posed by experiments in which subjects are exposed to television content in ways that differ from their normal viewing habits; and (5) experiments which attempt in one experimental setting to examine behavior that is typically influenced by a season of television viewing. These views are important because they suggest that research attempting to 'unpack' the attitudes and the behaviors that are attributable to television viewing is severely limited. It suggests that there is something of a Heisenberg principle in operation here -- that what we observe and measure is largely contaminated by the tools we use to conduct the observations and take the measurements.

Finally, Christenson and Roberts (1983), in their review of the literature on television in the formation of children's social attitudes, observe: "There is no such thing as a 'television message'. People perceive the same material in different ways.... The attitudinal effect of a given program or of a certain steady diet will vary according to the relationship between the 'television view' and the view given by the various other agents that supply information to the child." (pg. 96) They conclude, "As a practical matter, if one is truly concerned about the effects of television on children, it may prove more feasible to improve children's information processing skills than it is to effect any broad, socially significant changes in the television diet that is offered." (p. 96)

V. SCHOOL ACHIEVEMENT IN SCIENCE AND MATHEMATICS

Cole and Cole (1973), in *Social Stratification in Science*, point out that the stratification observed in the sciences is not a function of social class or political power but rather intellectual attainment. In their study of the careers of research physicists, social origins appear to play an insignificant role in the career attainments of sample subjects.

Rather, their results suggest that intellectual ability ,talent, and individual achievement carry far more influence and explain much more of the variance in science career attainment than family background or social origins. "In almost all cases where science departs from the ideal [of a strictly meritocratic system] we find the process of accumulative advantage at work. People who have done well at time1 have a better chance of doing well at time 2, independently of their objective role-performance; the initially successful are given advantage in subsequent competition for rewards."

Undeniably, however, this "accumulative advantage" seems to favor white men. Women and non-Asian minority students fall behind white males in mathematics and science almost from the beginning of their school careers and they don't catch up. The literature on academic achievement and test performance by race and gender (see, e.g., Kahle and Matyas, 1987; Ethington and Wolfe, 1986; Moore and Smith, 1986) makes the point abundantly clear: females and minority students do not compete equally with white (and Asian) males academically, and their failure to achieve at an early age has a greater impact on their lack of representation in the science and engineering workforce than any single factor (Kahle et al., 1985; National Science Foundation, 1986). In *Women and Minorities in Science and Engineering*, the authors assert, "One major cause of the underrepresentation of women and minorities in science and engineering is the different patterns of participation they exhibit compared to men and the majority at all educational levels." (1986, p. 32)

The most clearly marked differences between men and women and between whites and non-whites emerge in mathematics. Interest in science remains relatively high for all students, irrespective of race and gender, through the early years of school. However, differences in mathematical proficiency gradually become more pronounced until, at the time the second year of high school is completed, a significant portion of all women and the majority of minority students have dropped out of mathematics and, for all intents and purposes, have given up their options for entering a mathematics-based career (Marrett, 1982; Gordon, 1986).

The suggestion is repeatedly made in the studies reviewed for this report that we will not be able to increase the numbers of scientists produced in this country until mathematics education in the schools at all levels has been improved. In the subsequent discussion, mathematics and mathematics education are examined.

The Math Crisis

> Since mathematics is the foundation discipline for science, the state of mathematics education is a crucial predictor of future national strength in science and technology. Evidence suggests

> that our mathematics classrooms, like our smokestack industries, no longer provide adequate support for modern society. They deliver neither the mathematical foundation required for scientific research nor the quantitative literacy necessary for a democratic society. (Steen:1987, p. 251)

Mathematics education--like science education--has been the subject of intense national interest for many years, and efforts aimed at promoting mathematics education reform have been a high priority for the nation's educators (Usiskin, 1985). Few topics have generated more heat and less light, however. As Steen (1987), Stevenson and colleagues (1986) and numerous others have documented, concern to improve mathematics education has not resulted in a more quantitatively literate public -- rather, that concern has coincided with steadily worsening reported levels of mathematics performance by American schoolchildren at all levels of the educational system. These declines have appeared despite reams of research into the factors that influence performance and achievement in mathematics.

Steen (1987), for example, argues that mathematics classrooms in American no longer provide the nation with the quantitatively literate workforce that is necessary to maintain national strength in science and technology. "Because of its widespread utility in industrial, military, and scientific applications, mathematics is a crucial indicator of future economic competitiveness. The evidence is overwhelming, however, that the mathematics yield of US schools--the sum total of mathematics learned by all students--is substantially less than that of other industrialized nations." (1987, p. 251)

Steen cites Stevenson and colleagues (1986) in support of this contention. In their comparative study of the mathematics and reading achivement of 720 Chinese, Japanese, and American students they report:

> The data indicate that among the 100 top scorers on the mathematics test at grade1, there were only 15 American children. At grade 5, only one American child appeared among the top 100 scorers from the total sample of approximately 720 children. On the other hand, among the children receiving the 100 lowest scores at each grade, there were 58 American children at grade 1 and 67 at grade 5. (Stevenson et al., 1986, p. 695)

The authors found significant differences in the schools they observed as well as in the school habits of students, and in parental expectations of student performance. Specifically, they note: 1) American students in the study were engaged in academic activities far less frequently than Chinese and Japanese children; 2) Less time was spent in mathematics instruction in American schools and in mathematics homework in American homes than in Chinese or Japanese schools and homes; 3) American mothers valued homework far less than Chinese or Japanese mothers; 4) American children were most likely to express unhappiness with school and schoolwork; 5) American teachers were more likely to be engaged in non-academic, non-instructional activities than were Chinese or Japanese teachers.

The authors conclude:

> The comparatively low levels of achievement of the American children in mathematics appear to be attributable in part to the fact that they are not receiving amounts of instruction comparable to those received by children in Taiwan and Japan. These cross-national differences become even more profound when they are extended over the school year.... Taken together, these data point to enormous differences in amounts of schooling young children receive in the three countries.

In addition to citing significant, alarming differences in the mathematics performance of US and Asian school children, recent national examinations of academic performance have also dramatized equally significant, and equally alarming differences in the mathematics achievement and aptitude of females, non-Asian minority students, and white male students in the US (NAEP, 1980; Matthews et al., 1984; National Science Board, 1986). As these and other studies have indicated, since the first administration of the National Assessment of Educational Progress (NAEP), women and minority students have earned mean scores in mathematics that have been consistently below the mean of white males.

Similar results have been reported from data collected in the National Center for Education Statistics National Longitudinal Study (NLS) and the High School and Beyond Study (HSB) (see, e.g., Wagenaar, 1984; Ethington and Wolfe, 1986; Goggins and Lindbeck, 1986; Moore and Smith, 1986).

In her review of published research conducted with these data, Marrett (1986) identifies four themes that figure prominently in reported findings: (1) the first is that there is evidence that black and Native American students have made significant strides in mathematics and science; (2) that despite these gains, the performance of minority students lags far behind that of white students; (3) the factors that influence performance on standardized examinations of mathematics and science affect both minority and non-minority students alike; and (4) there is a need to improve, not just diagnose, minority student mathematics and science achievement. Of particular importance, she notes, is the finding that for minority and non-minority students alike, scores on the NAEP (and the mathematics achievement as measured in the HSB) are strongly correlated with the amount of coursework a student has taken in mathematics.

It is highly significant therefore, that the amount of coursework in mathematics and mathematics-related subjects taken by women and minority students is much lower than that of white males (Johnson, 1984; Jones et al, 1986; Marrett 1986; Nettles, 1986; Jones, 1987). Jones and colleagues (1984), in their study of mathematics achievement on the NAEP, note, "The average score for students who had not taken Algebra 1, Algebra 2, or Geometry was 47%, whereas the average for students who had taken all three courses was 82% correct for the same mathematics exercises. The relation of mathematics achievement to courses taken is strong and clear." (Jones et al., 1984, p. 161). One clear implication of these findings is that the poor performance of minority students in mathematics achievement tests might be substantially improved if schools encouraged (or required) students to continue their studies of mathematics beyond algebra (Jones et al., 1984; Marrett, 1986; NAB, 1986).

Significantly, however, Jones and colleagues also found that the *type* of school attended was strongly related to both the number of mathematics courses taken and performance on the NAEP. They found, for example, that in schools with less than a 70% white enrollment, the mean number of semesters of algebra and geometry was significantly below national means. "Note that 73% of all black students, but only 8% of the white students, were attending such schools. In contrast, 66% of all white students, but only 7% of the black students, were attending schools that were at least 90% white." It is significant, therefore, that the mean number of years of algebra and geometry taken by 1980 NAEP seniors in predominantly (90%) white schools was 1.8, while among those in schools with a 70% or less white enrollment, the mean was 1.3. There is, in other words, a strong link between the lower NAEP scores of black students and their overrepresentation in schools where they were less likely to take advanced mathematics courses.

However, Moore and Smith (1986), Benbow and Minor (1986) and Ethington and Wolfe (1986) have all determined in separate studies that diffential coursework enrollment does not completely explain all of the difference in male/female mathematics performance. Benbow and Minor (1986), using data collected as part of the Study of Mathematically Precocious Youth (SMPY), found that mathematically gifted males and females in high school did not differ in the number of mathematics courses taken or in their attitudes to science and mathematics. Nonetheless, males performed better on tests of mathematical reasoning, were more likely to take and score highly on college-level science achievement tests, and were more likely to cite an intention to major in a quantitatively oriented field (engineering and physics) in college than females.

Ethington and Wolfe (1986), using data drawn from the first follow-up of the High School and Beyond study (HSB), found that mathematics aptitude and greater exposure to mathematics had a greater positive impact on the overall mathematics achievement of men than it did on the mathematics achievement of women. Expressed in other terms, controlling for mathematics aptitude and the number of math courses completed did not eliminate (nor fully explain) differences in the performances of males and females on tests of mathematics ability. Similarly, Moore and Smith (1986), in an effort to explain sex and race differences in mathematics knowledge and arithmetic reasoning using data from the National Longitudinal Study, report, "Course work was found to affect sex differences significantly in mathematics knowledge but not arithmetic reasoning." (p. 94) Similar findings emerged in their analysis of racial differences in mathematics knowledge. "The positive effects of high shool grades in [mathematics] courses is much stronger for whites than for blacks. Still, differences in mathematics knowledge shrink significantly when course-work experiences are controlled." (p. 93)

As Marrett (1982,1986) observes, however, many minority students fail to progress beyond elementary mathematics because they fail to earn the grades and fail to acquire the skills to tackle higher level mathematics coursework. Making higher-level coursework mandatory for women and minority students may not be sufficient, therefore, to improve the quality of their mathematics preparation. Given the hierarchical nature of mathematics, unless students possess the requisite foundation, advanced work is unlikely to be useful and is unlikely to change the patterns of achievement that are described in these studies.

There is evidence, however, that reforms in the elementary and secondary school mathematics curriculum are responsible for some of the gains observed in the achievement of Black and Hispanic students on the NAEP. In his examination of the past 20 years of curriculum reform in mathematics education, for example, Usiskin (1985) lends support for the thesis that the "back-to-basics" movement in elementary and secondary school mathematics was principally responsible for the increase in performance of black and Latin students of all ages of the NAEP. Because this movement promoted the establishment of minimal competence standards for promotion or graduation in many states, minority students and students of all races at the bottom of the ability distribution have begun to improve their performance on paper-and-pencil tests that emphasize computation skills. Accordingly, the improvements in NAEP performance reported for minority students occurred precisely in the area of basic computation skills.

As Usiskin notes, however, "These successes have been gained at great cost. The performance of the top 25% of students on the NAEP declined from 1977-78 to 1981-82. Overall performance on applications and problem-solving items dropped from 1972-73 to 1977-78 and did not improve in 1981-82." (1985, p. 7) He concludes that the only remedy for this situation is a tightening of graduation requirements and a major updating of the elementary and secondary school mathematics curriculum. Specifically, he notes, there needs to be a shift from rote manipulation to problem solving; moreover, "estimation, applications, computers, and statistics and probability all should play important roles in secondary school mathematics study." (1985, p.15)

Other research is not particularly illuminating. In a review of 24 studies concerning minorities in mathematics, Matthews (1984) observes that a significant portion of this literature is concerned with explaining why minority students fail in mathematics; while this attitude is understandable, it is hardly helpful. She observes: "One of the greatest difficulties with past research (and with the prevention or intervention programs subsequently developed) is its emphasis on minority students who are *unsuccessful* in mathematics. Findings of poor performance do not explain the causes of that performance." (1984, p. 92).

Additional research -- cited in a special edition of the Journal of Research in Mathematics Education -- consistently points to cultural and linguistic differences between minority and majority students in an effort to explain the observed differences in their mathematics achievement. Much of this work has suggested that a greater understanding of a student's culture and language might promote improvements in their mastery of mathematics (Bradley, 1984. Valverde, 1984; Cuevas, 1984; Duran, 1986). These factors, these authors suggest, have particular relevance for the curriculum and for the manner in which key concepts are presented to students:

> Not all cultures interpret the physical world nor generalize about it in consistent ways.... The way mathematics concepts are presented in textbooks may be inconsistent with how immigrant Hispanic students have already been introduced to certain concepts. This inconsistency may cause confusion and delay understanding. (Valverde, 1984, p.126)

Significantly, however, the attitudes of black and Latin students to science and mathematics do not appear to differ dramatically from those of white and Asian students (Duran, 1986; Walker and Rakow,1985). Duran, for example, in his review of the literature on the science and mathematics achievement of Hispanic students, concludes that the socialization of Hispanics may hinder the development of the requisite skills for success in mathematics and science, despite survey findings suggesting that they hold positive attitudes toward science in general and science careers in particular.

There is much evidence that part of the socialization process for adolescents signficantly affects academic achievement. Studies by Jones (1979), Paul and Fischer (1980), Hock and Curry (1981), Ishiyama and Chabassol (1985), and Felson and Reed (1986) all note that as young people mature, their self-awareness, their relationships to their peers and their academic achievement become intricately connected. Felson and Reed, for example, found that students' self-appraisals and their perceptions of their academic performance are significantly affected by the friendship networks to which they belong.

Peers, academic aptitude, and academic achievement

Throughout much of the history of this nation, the findings described in these studies would have been explained by some as the function of genetic differences between whites and non-whites (Lawler, 1978). Jensen (1968), in a much publicized study of IQ and academic achievement, for example, concluded that environmental factors such as social class, schooling, and exposure to middle class culture, contributed less to IQ scores than inherited characteristics. Jensen's work, not surprisingly, is frequently cited to explain the persistent differences in performance between whites and non-whites that are consistently observed on virtually every standardized test of academic performance available.

Moore (1987), in an important study of class, race, and IQ, provides strong evidence that socio-cultural forces are at the heart of these differences in test performance. The objective of her study was to test the hypothesis that when equalitarian relationships between blacks and whites exist, these relationships will positively influence black children's performance on standardized tests. To test this hypothesis, a unique research/sample design was created. Specifically, a sample of 46 adopted black children was selected; 23 were adopted by white families (transracially adopted children); the remaining 23 were adopted by black families (traditionally adopted children).

Moore's research was based on earlier studies by Blau (1981) that suggested that being raised by a white family would facilitate the adopted black child's integration into a "mainstream cultural orientation" by introducing the child into a white friendship network. One measure of such a mainstream orientation, Moore reasoned, would be reflected in higher IQ scores for transracially adopted children than for traditionally adopted children.

The sample families were largely similar with respect to socio-economic status but differed with respect to the racial composition of their neighborhoods and with respect to the friendship networks of the children. The families with transracially adopted children tended to live in white or integrated neighborhoods and reported having more white friends than traditionally adopted children. Of particular significance were the patterns of academic achievement and IQ scores reported for each group: transracially adopted children had higher reading scores on the Iowa Tests of Basic Skills than traditionally adopted children and reported a higher mean IQ score (117.1) on the Wechsler Intelligence Scale for Children (WISC) than that reported for the traditionally adopted children (103.2). The author observes, "Although traditionally adopted children achieved scores that placed them in the average range for the WISC, the transracially adopted children showed an advantage of nearly one standard deviation in their performance." (1987, p. 47)

The racial composition of the child's friendship network was highly correlated with IQ (r=.61) as was the average reading level of peers (r=.51). Moore concludes that these results suggest why such a significant difference is consistently observed in the IQ scores of white and black children, even when they are from similar social class backgrounds. "The larger cultural milieu in which the child is socialized, not just parents' education and income, should also be viewed as a factor in ethnic group differences in children's development of skills and performance orientations measured by instruments such as the WISC." (1987, pp. 51-52) these schools produced such a significant number of black achievers -- why, for example, 5 percent of the high schools in Bond's study generated 21 percent of the later Ph. D.'s, or why four of the six schools cited produced such notables as Wilson Riles (first black state superintendent of schools), Thurgood Marshall (first black Supreme Court justice), Robert C. Weaver (first black Cabinet member), and Edward W. Brooke (first black US senator since Reconstruction), to name just a few.

Sowell discovered that in their academic heyday (roughly the period prior to *Brown v. Board of Education*), test scores at these schools (IQ as well as achievement tests) had been higher than at black schools in general, and were higher than those of the general school population of the US. He found further that a no-nonsense "law and order" policy characterized their operation: there were few, if any, discipline problems, and high standards of conduct and academic achievement were maintained. Students were expected to strive for excellence. The high academic standards of these schools had the support of the entire community to ensure that the schools had the resources to maintain their commitment to academic excellence.

Finally, each of these schools was located in an urban setting, a fact that Sowell found particularly interesting.

> This is remarkable because, during the academic heyday of most of these schools, most American Negroes lived in rural and small-town settings. This suggests that the rise of such prominent blacks as those who came from these schools was--which is to say, most of the top black pioneers in the history of this country--seems a matter less of innate ability

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> and more of special social settings in which individual ability could develop; and that the settings from which such black leadership arose were quite different from the social settings in which the mass of the black population lived. (1986, p. 36)

Desegregation changed the face of black education, however. Many of these excellent institutions changed drastically in the post-*Brown vs Board of Education* decades that followed. Nowhere, Sowell notes, did desegregation have a more dramatic impact than on higher education enrollments, which saw a doubling of black student enrollment at predominantly white colleges between the 1960s and the 1970s.

This change, Sowell observes, created as many problems as it solved. While more students have managed to enter these schools, their persistence has been far below that of non-black students and their academic performance has been markedly sub-par. Their academic preparation has often been cited as the cause of these problems, but, Sowell contends, the finger of blame must instead be pointed at institutional admissions policies.

Under pressure to pick minority students, top rank colleges (e.g. the Berkeleys, the Michigans, and the Ivies) recruited the best minority students available. Those who were admitted, however, were totally unprepared to meet the academic demands they would confront, and the schools, in turn, were totally unequipped to provide for the educational needs of these students. What has resulted, Sowell concludes, is a "widespread mismatching of individuals with institutions."

> When black students who would normally qualify for a state college are drained away by Ivy League colleges and universities, then state colleges would have little choice but to recruit black students who would normally qualify for still lower level institutions--and so the process continues down the line. The net result is that in a country with 3,000 widely differing colleges and universities capable of accomodating every conceivable level of educational preparation and intellectual development, there is a widespread problem of "underprepared" black students at many institutional levels, even though black students' capabilities span the whole range by any standard used. (1986, p. 131)

This mismatching would not have such grave consequences were the programs created to meet the needs of these students successful. The statistics suggest that, with few exceptions, they have not managed to assist minority students to graduate from college at rates comparable to those of whites and Asians. Worse, the dominant theme of the programs created to assist these students is remedial -- their emphasis is on assisting students to survive, not excel.

A significant departure from this trend was reported by Treisman (1981,1985) in his creation of the Mathematics Workshop Project, a component of the University of California, Berkeley's Professional Development Program (PDP). Since 1978, black and Latin undergraduates in this honors program have earned higher mean grades in calculus at Berkeley than non-workshop minority students and have graduated from the university at rates roughly comparable to those of white and Asian students. The program was created in response to concerns about the low achievement of black undergraduates at Berkeley in mathematics, and like many student affirmative action programs, the Mathematics Workshop program had its origins in research that was undertaken by Treisman to explain why black students were having such intense problems in their adjustment to University life.

Treisman's research departed significantly from the typical educational research paradigm, however. The major question he sought to answer was not, "Why do blacks do so badly in mathematics?", but rather, "Why are Chinese students so successful in a subject that non-Chinese minority students find so daunting?" He assumed, quite plausibly, that the successes of the Chinese might be duplicated for blacks if a means to promote successful study habits and a productive approach to mathematics could be determined.

For many years, these two groups have been at very different points in the academic pecking order at Berkeley: Chinese students have traditionally been the most accomplished mathematics students at the university while blacks have been the least. For example, in 1975 only two of the twenty-one black students who enrolled in first-term calculus (Math 1A) completed the last term in the calculus sequence (Math 1C) with a grade higher than C. Since calculus is required for most of the academic majors that minority students at Berkeley pursue (e.g. architecture/environmental design, business, engineering, all of the natural sciences, and pre-medicine), this pattern of failure for blacks has typically had devasting consequences for their academic persistence and graduation.

In 1975 Treisman first interviewed 20 black and 20 Chinese students

> coupled with the unexpected social isolation they encountered prevented many of them from getting their bearings or developing adequate study habits; thus, few did well in their courses. (1985, p. 22)

• The twenty Chinese students in his study, by contrast, almost immediately upon their matriculation at the University, found friends and classmates with whom they studied regularly. Twelve of the 20 formed informal study groups that became a vehicle for mastering mathematics and for becoming acquainted with the ways and means of life in the university.

> Composed of students with shared purpose, the informal study groups of Chinese freshmen enabled their members not only to share mathematical knowledge but also to "check out" their understanding of what was being required of them by their professors and, more generally, by the University. These students learned quickly, for example, that the often-quoted rule of thumb for estimating the number of hours that one should devote to study--two hours for each class hour--was seriously misleading. The blacks whom I had interviewed devoted approximately eight hours per week to homework and study for their four-unit math course; the Chinese devoted roughly fourteen hours per week to these same tasks. (1985, p. 13)

Treisman was particularly struck by the efficiency with which Chinese students within these groups mastered critical concepts in the course, concepts that, by contrast, left many of the black students in his study bewildered. Black students, Treisman observed, were frequently stumped

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The Chinese students, when confronted with a similar problem, were quickly able to consult others in their study group. Typically, if no one in the group had come up with a solution, group members concluded that the problem was difficult enough and significant enough to warrant consulting the teaching assistant for assistance.

Black students, by contrast, almost never sought out such assistance, particularly from the TA, because they were fearful that they would be exposing an embarassing weakness that would cause them to lose face in the eyes of others in the class.

It became apparent to Treisman that group study offered many options that would be particularly useful to black students at the University. First, study groups would provide an efficient vehicle for mastering the challenges of calculus. The interaction of students as they struggled with difficult, challenging problems appeared to have clear benefit for students who were prone to getting stuck. Secondly, study groups would provide students with an opportunity to combine their social and academic lives, and in so doing, combat much of the social isolation that Treisman had observed among the black students in his study.

In order to avoid the appearance of being "just another remedial program", Treisman and the staff of the Professional Development Program billed their Mathematics Workshop program as an honors program. The "honors" label was not difficult to sell. PDP is sponsored by the university's Academic Senate under the auspices of a standing committee of the Senate, the Special Scholarships Committee. Created in 1964, this committee has counted some of the university's finest scholars (including two Nobel prize winners) among its members. Having such a committee sponsor an honors program, therefore, was absolutely consistent with student expectations of how the university functions.

The workshop's honors focus was not meant to suggest that its participants were selected because their superior academic credentials: rather, the workshops would require that each student would strive to earn honors-level grades as a condition of a his or her participation.

One clearcut benefit has been derived from this emphasis on honors. The workshops attract highly motivated students who see a direct relationship between working for high grades and achieving their career or graduate school objectives. Thus, since the creation of the Mathematics Workshops, PDP students typically put twice as much time into studying each night as is suggested by conventional campus wisdom. This increased "time-on-task" is believed to explain, in part at least, why workshop students do so well.

The work that students are asked to complete in each workshop is intended to be of a more formal nature than the work Treisman observed among the study groups of the Chinese students in his study. However, the basic principles that made these informal groups so successful -- the intense discussion and debate between students around difficult problems in mathematics -- were retained and elaborated upon. These features remain a distinct component of the program today.

The current version of the program centers around workshops that enroll approximately 20-25 students each. Each workshop meets for two hours twice a week. Each workshop session consists of both individual and group work that is centered on the problems contained in a "worksheet". Worksheet problems typically include:

> (1) old chestnuts that appear frequently on examinations but rarely on homework assignments; (2) monkey wrenches -- problems designed to reveal deficiencies either in students' mathematical backgrounds or in their understanding of basic course concept; (3) problems that introduce students to motivating examples or counterexamples and that shed light on, or delimit, major course concepts or theorems; (4) problems designed to deepen the student's understanding of and facility with mathematical language; and (5) problems designed to help students master what, in workshop parlance, is known as "street mathematics" -- the computational tricks and shortcuts known to many of the best students, but which are neither mentioned in the textbook nor taught explicitly by the instructor. (1985, pp. 42-43)

Students work on these problems alone at first, then together in a group of four or five other students, all of whom have been working with the same problem(s). The major objective of the group work is to have students communicate with other about their efforts to develop solutions. This communication may be facilitated in a number of ways: (1) students may be asked to present their problem solutions to others in their group (or if the situation warrants it, to the entire workshop); (2) two or three students may be asked to edit another student's work, paying particular attention to issues of mathematical accuracy (e.g. was the correct form followed?), and to the elegance and clarity of the student's conclusions;

and (3) students who appear to be well advanced in their work may be asked to tutor slower students until everyone in the group has arrived at the same level of expertise.

The advantage of these approaches is that the art of communicating complex ideas and concepts is an important means through which students organize and clarify their thoughts. As Treisman observes, "By continually explaining their ideas to others, students acquire the same benefits of increased understanding that teachers themselves regularly experience." If students find it difficult to express themselves, they become immediately aware of the inconsistencies in their understanding. Moreover, their efforts to make themselves understood -- particularly in the face of pointed, thoughtful probing by the listener(s) -- may also lead them to explore facets of a particular concept that might not otherwise have occurred to them. Discussing the solutions to worksheet problems also provides students with an opportunity to practice the skills and to exhibit the mastery of course concepts that they are expected to demonstate on quizzes and examinations.

Students are not alone in the workshops, however. A workshop leader -- typically a graduate student in mathematics or physics or some other similarly quantitative field -- will be responsible for the preparation of the worksheets and for directing the activities of workshop students. Leaders are taught to be unobtrusive. Their major task is to ensure that students are communicating effectively about the work at hand. "Towards these ends, the leader circulates among the students and listens carefully to their discussions. When he suspects that students are not listening carefully to one another, he intercedes, perhaps asking a student to restate something he has said more precisely or to explain in more detail the steps by which he arrived at the solution to a certain problem." (1985, pp. 44-45)

One clearcut advantage of the group study format used in the workshop is that anyone listening to the conversations students are having about their work has a unique glimpse of the mathematical thought processes of each of the speakers. As students discuss their struggles with the material, they are literally making their problem-solving algorithms public. At the same time, these conversations provide the workshop leader with numerous opportunities to determine the degree to which students have mastered important material and key ideas. If students are unclear about the work, their problems will quickly become manifest in their verbal interactions. As leaders overhear what students are saying, they can pinpoint the nature of the difficulty and respond accordingly.

The workshop, therefore, is an ideal instructional setting: it offers students an opportunity to practice the skills they will be expected to demonstrate in quizzes and examinations; it forces students to communicate with each other in a fashion that promotes greater mastery of difficult concepts as well as familiarity with the language and syntax of mathematics; and finally, it provides instructors with a vehicle for monitoring the progress of students as they master course materials.

Data on student achievement suggests that the program has been extremely successful:

•Black students at Berkeley are at greater risk of academic failure and are more prone to leave college before graduation than any comparable group of students. Significantly, 55% of the 231 black students who were enrolled in the workshop program between 1978 and 1985 earned grades of B- or better in calculus; only 21% of the 284 non-workshop black students who took calculus during this period earned comparable grades. The mean final grade for workshop students was 2.6 (N=231); the comparable mean for non-workshop blacks was 1.9 (N=284).

• The workshops also had a dramatic impact on student failure in mathematics: during the period between 1978-85, only 8 black workshop students in 231 (3%) failed calculus; by comparison, 105 of 284 (37%) non-workshop black students failed the course.

• Perhaps the most significant impact of the workshops was on the mathematics achievement of poorly prepared students (that is, students who entered the university with SAT Mathematics scores in the lowest tercile [200-460] of the score distribution). The mean final grade in calculus for black workshop students with poor mathematics preparation (2.2; n=56) was four-tenths of a grade point higher than that of non-workshop black students (1.9; n=42) with "strong preparation" in mathematics (defined as students with a SAT Math score above 550).

• Participation in the workshops was also associated with high retention and graduation rates. Approximately 65% of all black workshop students who entered the university in 1978 and 1979 (47/72) had graduated or were still enrolled in the spring semester of 1985. The comparable rate for non-workshop black students entering the university in those same years was 47% (132/281). The proportion of workshop students earning degrees in science and/or mathematics-related fields was 44% -- the comparable rate among non-workshop students was 10%. Comparable rates of achievement and persistence have been reported for Hispanic workshop students as well.

The persistence of these students is consistent with the model proposed by Tinto (1975) and later elaborated upon by Pascarella and Terenzini (1980) and Fox (1986). The "Tinto model" asserts that students are most likely to persist at colleges where they find an appropriate social and/or academic niche within the campus community. Significantly, therefore, the social circles that PDP workshop students form in workshops frequently become the nexus for social networks that will persist through the student's senior year, and in some cases, beyond.

Treisman's success with this approach extends beyond the boundaries of the Berkeley campus. Successful adapations of the workshop program -- defined as programs whose black and Hispanic students have earned final mean grades in calculus of 2.7 or better -- have been created at UCLA, UC San Diego, UC Santa Cruz, and Cal Poly Pomona. Similar secondary-level adaptations have been created for high school students in Albany, Richmond, Stockton, and Orange County, California.

These adaptations are by no means exact clones of the Mathematics Workshop program at Berkeley, but they all share key features in common. Treisman was interviewed for this report and made a number of observations about his work and his approach to the creation of programs for minority students in mathematics that are presented below.

First and foremost, he noted, there is much to be learned by studying successful students. As he demonstrated in his observations of Chinese undergraduates at Berkeley, successful students typically have a "bag of tricks" for dealing with institutional bureaucracies (e.g. how to navigate the financial aid mess. how to locate helpful TAs, which faculty members can be approached if you have a "dumb" question), as well as useful strategies for succeeding academically (which campus classrooms are open all night, which questions always appear on so-and-so's examinations, etc). Where possible, Treisman comments, these pieces of received wisdom need to be incorporated into the design of programs that serve students (at all educational levels) and should be integrated into the academic and personal advising that students are given by program staff.

> What should not be overlooked here is the fact that every minority student who gets an "A" in a mathematics course that other equally (or better) prepared students failed may have learned something that we should pass on to others. Too much educational research concentrates on explaining the variance in performance when, in reality, it is the unexplained variance -- typified by the kids whose success can't be explained by race, SES, prior levels of preparation for mathematics, or time-spent-on-task -- that may hold the answer to some of our knotty questions about how to design programs that promote student success.

Treisman's second observation was related to the mathematics curriculum and to the philosophy that guides successful instruction. The most successful teaching techniques, he claims, are those that attempt to have students approach mathematics the way mathematicians do, by looking for and examining patterns.

In too many instances, mathematics instruction fails to provide students with an opportunity to explore mathematics or to play with the patterns that fascinate and entrance mathematicians. Instead, the curriculum concentrates on rote procedures and on getting the right answer. "Students are taught, in other words, to focus on one of the end products of mathematics -- the answer -- and not on the potentially fascinating process we engage in to generate that answer."

In the Stockton Summer Math Institute, a project that Treisman directed in 1987 with support from the Hitachi Foundation, the search for pattern was placed at the core of the curriculum of a summer program for 9th graders. For example, in one of the courses offered, students were introduced to variables as "pattern generalizers" and were given an opportunity to see variables used in understanding arithmetic progressions.

> Students had hands-on experience counting the number of elements in individual entries in a progression and in all entries up to a certain point in the progression. Then the power of variables was illustrated by showing how to find general expressions for the nth term and for the sum of the first n terms of the progression. (Stanley, p. 3)

Not surprisingly, the program involves working with interesting problems and working in small groups of the type used in PDP's Mathematics Workshops. Preliminary reports of the achievement of Stockton Summer students, the majority of whom were minority students, strongly suggests that there is considerable merit to this approach. The mean percentile score of participating students on a test of mathematical problem solving skills at the beginning of the program was 27, at the end of the program the mean was 78. Student attendance and morale were described as "excellent," and observers feel that the model has tremendous potential as a tool for assisting students to make a successful transistion from middle school mathematics to high school college track algebra.

Treisman's final observation is related to teachers and their role in mathematics instruction. He points out that in all too many schools with predominantly minority enrollments, mathematics is taught by teachers who are not trained for it and who may well be teaching the subject against their will. Efforts to reform teaching techniques and the content of the curriculum pass these teachers by, Treisman observes, because they have neither the time, the opportunity, nor the interest in learning how to teach the subject well. If change is to occur, a number of important alterations must be made in the way we try to affect how teachers teach mathematics.

The Stockton Summer Math Institute provides key insights to the nature of these changes. For example, teachers who participated in the institute were actively involved in the development of the institute's curriculum and in the preparation of teaching materials. In many teacher training programs, teachers are treated as "students": they become passive learners who have little or no opportunity to bring their own classroom expertise to bear as they learn new techniques and ideas. Stockton Institute teachers, however, adapted the materials they would use in the classroom from a variety of texts and teaching materials, guided in large part by their own sense of what they knew to be effective methods for presenting topics to their students. "In many of the previous efforts at mathematics teaching reform, instructional material sat on the shelf unused because teachers weren't given an opportunity to adapt the stuff for the unique circumstances they confronted in their own classrooms. If curriculum materials are developed on the assumption that they should be 'teacher proof' -- that is, able to be used without any direct involvement of the teache r-- is it any wonder that teachers ignore them?"

Organizing students into study groups also proved to be an effective means of assisting both students and teachers. For students, it provided the same opportunities to discuss problems and to critique work that undergraduates in the Mathematics Workshops experience. Similarly, for teachers, the opportunity to observe students as they attempted to complete classroom assignments provided a means for determining both how well the curriculum was working and how well individual students were doing.

From these observations, Treisman concludes: (1) mathematics is something that students must do, not as a set of rules that they must mermorize, but rather as an activity in which they must be actively engaged; and (2) instruction works best when students are given an opportunity to communicate with each other about their work and when teachers are in a position to observe, and, where necessary, intervene, in that communication.

Treisman is a mathematician first and a teacher second. His philosophy of teaching relects a desire to provide students with opportunities to do the things that mathematicians do, viz., to search for and examine patterns. As W. W. Sawyer writes:

> ...to make mathematics you must be interested in mathematics. The fascination of pattern and the logical classification of pattern must have taken hold of you. It need not only be the only emotion in your mind; you may pursue other aims, respond to other duties; but if it is not there, you will contribute nothing to mathematics.

Similarly, Scheffler (1976) notes the importance of "the logical, or normative, analysis of mathematical operations and methods, as helping to set the aims of mathematics education."

As a consequence, one sees in these programs a greater concern with the process of *doing* mathematics -- designing classroom opportunities to observe what students are doing with mathematics problems -- and less focus on the *products* of students' labors -- i.e. the answers that they come up with. Secondly, there is a concern with maximizing opportunities for teachers to observe students at work, doing the kinds of problems and exercises that elicit the skills and abilities we are most interested in having students acquire. Finally, group work has the potential to influence the dynamics of peer groups within the schools. At present in all too many schools, academic achievement, particularly in mathematics and science, is not valued. If mathematics classrooms succeed in making large groups of students successful, not simply a few, select individuals, we stand a chance of doing away with "nerds" and of reversing the negative attitudes toward mathematics that too many students bring with them to high school and college.

Treisman's work by no means represents the only successful effort to improve the performance and achievement of underrepresented students in mathematics and science. Reviewed for this report were studies by Morning and colleagues (1980), Campbell and Schwartz (1986), and Gordon (1986) examining programs that encourage minority students and/or women to enter careers in mathematics, science, and engineering. Programs are cited in each that have managed to promote high levels of achievement in science, engineering and mathematics for underrepresented students. These programs share many features in common with Treisman's efforts and with each other, not the least of which is an attempt to build on students' strengths and not to concentrate exclusively on students' weaknesses.

Moreover, Treisman is not the only innovator to use study groups successfully to influence student achievement (see, e.g. Webb, 1982). Friederson (1984,1986) reports success in using cooperative learning techniques to improve the test taking performance of minority medical students and minority nursing students; similarly, Carmichael (1979) and Whimby (1980) report success in improving mathematics and science problem-solving skills among students at many levels (and in a variety of subjects) using group study approaches.

Finally, and most significantly perhaps, Treisman's work helps to place much of the research in mathematics education in some much needed perspective. Much of what has been reviewed here has focused on the personal and systemic structural barriers that inhibit (or promote) student success in science and mathematics courses. What has been suggested here (1) is that students succeed when the proper conditions for success are provided and (2) that we do, in fact, know something about what those conditions must be.

It has been suggested, for example, that the most important factor in promoting the success of students in mathematics may very well not be race, gender, SES, aptitude, school attended, or number of mathematics courses taken. Students of all races, from a variety of schools and social backgrounds, and at all levels of the mathematics ability distribution have done well in math workshops. The issue in their success, Treisman has noted, is not the student's background or "native ability" for mathematics, but rather our ability to design instructional settings that promote excellence. Workshops students, Treisman is fond of saying, provide us with an "existence proof" -- they demonstrate how much can be achieved if the proper conditions are created and maintained.

Creating such conditions is largely the province of the schools. The virtues of creating collaborative learning/group study opportunities, for example, have certainly been extolled at great length here. Are there other measures -- specifically related to the use of media -- that can assist in the quest to improve the science and mathematics preparation of the nation's students?

VII: CONCLUSION: MEDIA AND ATTITUDES TO SCHOOLWORK

Earlier in this report, considerable attention was devoted to the impact of the media on attitudes. The problem of understanding how television or any other medium affects students' attitudes to science, it was noted, begins with the difficulty of defining the exact nature of such an attitude. As Munby notes, surveying attitudes to science is partially a measurement issue (how can we design appropriate instruments?) and partly an issue of definitions (how are we to define attitudes to something as vast and complex as science?). As a solution Munby suggests:

> We ought to ask if the affective domain itself is a useful basis upon which to construct a fresh analysis of the concept "attitude of science." It might be more useful to start with the view that whatever personal preferences and attitudes people might have, these ought to be formulated wisely and thus grow out of the knowledge and understanding of science which is the business of science education to foster (1983, p.156)

If the use of media is to have any significant impact on efforts to increase the participation of women and minority students, a campaign to change "attitudes to science" is probably unlikely to succeed. (1) Students' attitudes are not the problem, it is their failure to succeed in acquiring the skills in school -- particularly in mathematics -- that will put them "on track" (literally) to science and engineering careers. (2) When students are successful in school, those positive experiences typically promote positive attitudes to school and to schoolwork. These attitudes become the foundation for future school successes since students are motivated to do well. If students are motivated, they are likely to work hard, and if they work hard, they are likely to continue to succeed. If they continue to experience success in their efforts, that success has a high probability of persisting throughout their school careers.

The foregoing fits Liska's (1984) description of a reciprocal model of the relationship between attitudes, intentions, and behaviors. As he wrote: "Clearly, a reciprocal effects model is warranted, theoretically and empirically, where behavior directly affects attitudes, attitudes directly affect intentions and behavior, and intentions directly affect behavior."

I would propose that we test a reciprocal impact model using viewers of the TV show 3-2-1 Contact as subjects. That series appears to be a useful example of a way to utilize the media in support of science education. Its objectives are modest. It aspires to make kids curious about science in the hopes that their curiosity will translate into greater attention to science subjects in general and science schoolwork in particular (Mielke, 1987). The techniques used to ensure that the program would appeal to the target audience were well thought out and rigorously carried out (Chen, 1981; Mielke and Chen, 1983). The show is supported by science clubs (Contact Science Clubs) and a magazine and generally seems to serve as the perfect complement to the science education students receive in school.

The attitudes it seeks to influence are comparatively modest (to incite curiousity), but can have significant impact on school-related behaviors. If students are inspired to read more or to ask questions or to be more attentive, then the ultimate impact should be felt in the academic achievement of Contact viewers in science classes.

A longitudinal look at these viewers would answer a variety of questions, particularly if, following Liska (1984) and Liska et al. (1984), there is a reciprocal relationship between attitudes formed by viewing 3-2-1 Contact and grades in school science and mathematics. There are a number of reasons why I believe this is the most reasonable study for OTA to consider:

•Cross sectional studies will not provide a means for determining how attitudes and school behaviors change over time. Since 3-2-1 Contact is a series that is consciously designed to build up a faithful viewing audience, its impact is likely to be greater than one shot movies and shows (e.g. a dramatic presentation about the life of the Curies). Such shows may impress students and favorably dispose them to seek more information about a particular topic, but it is unlikely that one will observe a long-term impact on school behavior.

•The literature describing health education campaigns that seek to promote such behaviors as dieting, exercise, or smoking cessation (see for example, the research cited by Salmon,1985; Chaffe and Roser, 1985; and Baggaley,1985) all suggest that media effects are modest. In and of themselves, they do not appear to drive viewers into health spas or away from the cigarette habit. As Baggaley wrote "The public is resistant, or even oblivious, to attempts made by the media to persuade it of new beliefs or a new course of actions." (p. 236) Rather than seeking the means to "change attitudes to science" on the part of students who have a history of to keep students interested in science will be won in the classroom ultimately, not on the TV screen.

to keep students interested in science will be won in the classroom ultimately, not on the TV screen.

Bibliography

BOOKS AND REPORTS

Ajzen, Icek and Fishbein, Martin, Understanding Attitudes and Predicting Social Behavior (Englewood Cliffs, NJ: Prentice-Hall, 1980).

American Council on Education, Office of Minority Affairs, Minorities in Higher Education (Washington, DC: 1985).

Asher, Herbert B., Causal Modeling, (Beverly Hills, CA: Sage Publications, 1976).

Astin, Alexander W., et. al., The American Freshman: National Norms for Fall 1986 (Los Angeles, CA: The Higher Education Research Institute, UCLA, December 1986).

Brandwein, Paul F., The Gifted Student as Future Scientist (New York, NY: Harcourt, Brace, 1955).

Cole, J. R. and Cole, Stephen, Social Stratification in Science (Chicago, IL: University of Chicago Press, 1973).

College Entrance Examination Board, Advisory Panel on the Scholastic Aptitude Test Schore Decline, On Further Examination: Report of the Panel (New York, New York: CEEB, 1977).

Dix, Linda S. (ed.), Women: Their Underrepresentation and Career Differentials in Science and Engineering: Proceedings of a Workshop (Washington, DC: National Academy Press, 1987).

Doble, John, and Mary Komarnicki, Engineering and Technology: The Public's Perspective, Parts I and II (Washington, D.C., The National Academy of Engineering, 1986).

Edgerton, Harold A., Science Talent: Its Early Identification and Continuing

Development (Washington, D.C., Science Service, Inc., 1961).

Eiduson, B.T. and Beckman, Linda (eds.), Science as a Career Choice: Theoretical and Empirical Studies (New York, NY: Russell Sage Foundation, 1973).

Freeman, Andrew A. (ed.) Brainpower Quest (New York, NY: Macmillan, 1957).

Gordon, Edmund W., et. al., A Descriptive Analysis of Programs and Trends in Engineering Education for Ethnic Minority Students, (New Haven, CT: Yale University, Institution for Social and Policy Studies, October 1986).

Gornick, Vivian, Women in Science: Portraits from a World in Transition (New York, NY: Simon &Shuster, 1983).

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

Hömberg, Erentraud, ed., Pre-school Children and Television: Two Studies Carried Out in Three Countries, (New York, New York: K. G. Saur Publishing, Inc., 1978).

Howe, Michael (ed.), Learning from Televion: Psychological and Educational Research (New York, NY: Academic Press, Inc., 1983).

Hueftle, Stacey J., et. al., Images of Science (Minneapolis, MN: University of Minnesota, 1983).

Keynes, Harvey B., and Watson, Steven R., The University of Minnesota Talented Youth Mathematics Project (UMTYMP): Its Implementation for Education of the Gifted, (Minneapolis, MN: University of Minnesota, School of Mathematics, August, 1984).

Komarr' 'i, Mary and Doble, John, Public Attitudes Toward Engineering and Technology (Washington, DC: National Academy of Engineering, 1986).

Lawler, James M., IQ, Heritability and Racism (New York, NY: International Publishers, 1978).

MacCorquodale, Patricia, Social Influences on the Participation of Mexican-American Women in Science, (Washington, DC: National Institute of Education, May, 1983).

Manning, Kenneth R., Black Apollo of Science (New York, NY: Oxford University Press, 1983).

Mielke, Keith W. and Milton Chen, Children, Television and Science: An Overview of the Formative Research for 3-2-1 Contact (New York, New York: Children's Television Workshop, September 1981).

Morning, Carole, et. al., Factors Affecting the Participation and Performance of Minorities in Mathematics (New York, New York: Ford Foundation, March, 1980).

Munby, Eric, An Investigation into the Measurement of Attitudes in Science Education (Columbus, Ohio: Ohio State University, Center for Science and Mathematics Education, December, 1983).

National Assessment of Educational Progress, Attitudes Toward Science (Denver, CO: Education Commission of the States, October 1979).

National Assessment of Educational Progress, Changes in Student Performance by Achievement Class and Modal Grade: A Different Lok at Assessment Data in Reading, Science and Mathematics (Denver, CO: Education Commission of the States, December, 1982).

National Resource Council, Outlook for Science and Technology (San Francisco, CA: W. H. Freeman, 1982).

National Science Board, Task Committee on Undergraduate Science and Engineering Education, Undergraduate Science, Mathematics and Engineering Education (Washington, DC: March 1986).

National Science Foundation, Women and Minorities in Science and

Engineering (Washington, DC: January 1982)

U. S. Congress, Office of Technology Assessment, "Preparing for Science and Engineering Careers: Field-Level Profiles," Washington, DC: Office of Technology Assessment, January, 1987).

Pais, Abraham, 'Subtle is the Lord...' The Science and the Life of Albert Einstein (New York, NY: Oxford University Press, 1982).

Papert, Seymour, Mindstorms: Children, Computers, and Powerful Ideas (New York, NY: Basic Books, 1980).

Rossiter, M.W., Women Scientists in America: Struggles and Strategies to 1940 (Baltimore, MD: Johns Hopkins University Press, 1982).

Sawyer, W. W., Prelude to Mathematics, (Middlesex, England: Penguin Books, 1966).

Science Service, Inc., Survey of Westinghouse Science Talent Serach Winners, (Washington, D.C.: Westinghouse Electric Corporation, November, 1985).

Smith, Bruce L. R. (ed), The State of Graduate Education (Washington, DC: The Brookings Institution, 1985).

Sowell, Thomas, Education: Assumption Versus History (Stanford, CA: Hoover Institution Press, 1986).

Stevens Institute of Technology, Office of Special Programs for Women, An Investigation of Women in Engineering Education, (Hoboken, NJ: Stevens Institute of Technology, December, 1986).

Treisman, Philip Uri, A Study of the Mathematics Achievement of Black Students at the University of California, Berkeley (Berkeley, CA: unpublished doctoral dissertation, 1985).

Turkle, Sherry, The Second Self: Computers and the Human Spirit (New York, NY: Simon and Shuster, 1984).

Usiskin, Zalman, "We Need Another Revolution in Secondary School Mathematics," in The Secondary School Mathematics Curriculum (New York: National Council of Teachers of Mathematics, 1985).

von Wright, G. H., et. al. (eds.), Ludwig Wittgenstein: Remarks on the Foundations of Mathematics (Cambridge, MA: MIT Press, 1983).

Wagnenaar, Theodore C., Occupational Aspirations and Intended Field of Study in College (Washington, DC: National Center for Education Statistics, 1984).

Ward, Barbara, et. al., The Relationship of Students' Academic Achievement to Television Watching, Leisure Time Reading and Homework (Wahington, DC: National Institute of Education, September, 1983).

Wolfe, Richard G., A Comparative Analysis across Eight Countries of Growth in Mathematics Achievement; The Effects of One Year of instruction, (Toronto, Canada: The Ontario Institute for Studies in Education, April, 1987).

ARTICLES

Allen, Richard L. and Hatchett, Shirley, "The Media and Social Reality Effects: Self and System Orientations of Blacks," Communication Research, vol. 13, No. 1, January 1986, pp. 97-123.

Atkin, C. K., "Effects of Campaign Advertising and Newscasts on Children," Journalism Quarterly, vol. 54, 1977, pp. 503-508.

Atkin, C. K. and Gantz, W. "Television News and Political Socialization," Public Opinion Quarterly, vol 42, 1978, pp. 183-198.

Baggaley, J., "From Ronald Reagan to Smoking Cessation: The Analysis of Media Impact," New Directions in Education and Training Technology, Alloway, B. S. and Mills, G. M. (eds.) (New York, NY: Nichols Publishing Company, 1985).