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ABSTRACT

This report examines issues in the low achievement of American students in mathematics, with emphasis on the low representation of minority students in this field. American myths about mathematics which emphasize the importance of innate ability rather than hard work are seen as reinforcing racial and gender stereotypes about who can do mathematics. Examples of prominent mathematicians and physicists whose lives counter these myths are offered. Comparisons are made showing that American students at all levels lag behind their foreign counterparts in mathematics achievement. Details of these comparisons and how they have influenced reform efforts in mathematics education are considered. Specific barriers to mathematics achievement experienced by minority students are identified and statistics showing minority underrepresentation in this field are detailed. The Strengthening Underrepresented Minority Mathematics Achievement (SUMMA) Consortium Program led by the Mathematical Association of America is described. Specific guidelines for teachers are offered, including: (1) communicate to students that hard work is the key to long lasting accomplishment in mathematics; (2) be familiar with the National Council of Teachers of Mathematics Standards; (3) utilize multicultural materials; (4) encourage mathematical talent in minority students through mentorships and other programs; and (5) strive for both high quality teaching and approachability by students. (Contains 41 references.) (DB)

Constructing a Secure Mathematics Pipeline for Minority Students

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Washington, DC

March 1995
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Dr. William Anthony Hawkins, Jr. earned his Bachelor's degree in mathematics and Master's degree in physics from Howard University. He subsequently earned a Master's degree and a Doctorate in mathematics from the University of Michigan. Since 1969 when he had a short stint as a high school mathematics teacher, he has been involved in the education of minority mathematics students. He was chair of the Mathematics Department of the University of the District of Columbia for five years. His area of research interest is Arithmetic Algebraic Geometry. In 1990, he took leave from the university to work for the Mathematical Association of America as Director of the Office of Minority Participation and its Strengthening Underrepresented Minority Mathematics Achievement (SUMMA) Program.

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ABSTRACT

American myths about mathematics which emphasize innate ability rather than hard work reinforce racial and gender stereotypes about who can do mathematics. The author gives several examples of prominent mathematicians and physicists whose lives contradict the common conception that all prominent contributors to the progress of mathematics and science were geniuses whose talent was apparent virtually from birth.

International comparisons show that all American students lag behind their foreign counterparts. Details of these comparisons and how they have influenced reform in mathematics education are considered. Focusing on minority students, barriers to achievement in mathematics are discussed as well as statistics on minority underrepresentation.

After a description of efforts of the Mathematical Association of America to increase the representation and participation of minorities in mathematics-based fields, the report closes with suggestions for teachers of mathematics at the precollege and collegiate level.

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EXECUTIVE SUMMARY

INTRODUCTION

Who are these minority students and why is it important to recruit them into mathematics and science? Underrepresented minorities (African Americans, Hispanic Americans, and American Indians) formed 21.9% of the population according to the last census. The White male population is no longer sufficient to provide adequate numbers of the technically trained personnel America needs to compete effectively. To produce the best mathematicians, scientists, and engineers, we must encourage all segments of society to achieve to the limits of their abilities in these fields. Since these abilities are randomly distributed among the population, exclusionary policies are bound to miss "diamonds in the rough." The country cannot continue with these failed policies if it is to prosper in the 21st century.

To compete internationally, we need to marshal our human resource base in new ways. MIT economist Lester Thurow (1992) gives a rationale for this in a recent book:

> While technology creates man-made comparative advantage, seizing that man-made comparative advantage requires a work force skilled from top to bottom. The skills of the labor force are going to be the key competitive weapon in the twenty-first century. Brainpower will be the arms and legs that allow one to employ—to be the low-cost masters of—the new product and process technologies that are being generated. In the century ahead natural resources, capital, and new-product technologies are going to move rapidly around the world. People will move—but more slowly than anything else. Skilled people become the only sustainable comparative advantage. (pp. 51-52)

American Attitudes About Mathematics

The Success Myth

The most dangerous, yet most pervasive, myth associated with education in mathematics at every level is that **"Success in mathematics depends more on innate ability than on hard work"** (National Research Council, 1991, p. 10). Since many American educators have expressed doubts historically about the overall intellectual ability of minorities and women, the myth that *"Women and members of certain ethnic groups are less capable in mathematics"* (p. 11) is a conclusion to which many leapt. Such misconceptions are the first and foremost obstacle to be overcome if a secure mathematics pipeline for minority, female, handicapped, and other students is to be constructed.

The Fallacy of the Success Myth

Since many subjects including mathematics and science are taught without reference to historical context, few students know any details about the human beings who created significant portions of the subject they are learning and whose lives illustrate the importance of hard work for success. Unfortunately, many believe that all prominent contributors to the progress of mathematics and science were geniuses whose talents were apparent virtually from birth. But, what evidence is there that hard work is more important to success in mathematics and science than innate ability? Let me give one example from physics.

In a major biography of the two-time Nobel Laureate in Physics and Chemistry, Pflaum (1989) states that Marie Sklodowska Curie (1867-1934) entered the Sorbonne in 1891. She earned the Master's degree, *licence ès sciences physiques* (summa cum laude)—the first woman to receive such a degree at the Sorbonne; the *licence ès sciences mathématiques* (magna cum laude); and the degree, "Doctor of Physical Sciences - summa cum laude"—the first woman to earn a Doctorate in France. When starting her course of study, she found she "lacked the mathematics necessary for a basic understanding of the physical sciences on a university level . . . her French was also inadequate" (p. 27). She and her husband Pierre Curie began their research on radioactivity (a term she coined) in 1897 with uranium and later thorium, and discovered polonium and radium—in an unheated, damp, glass-paneled artist's workshop, much like a greenhouse. "They were to learn the hard way, by the most drudging sort of toil, that radium was less than 1/1,000,000 of a part, and that it would require about fifty tons of water and five to six tons of chemicals to treat one ton of pitchblende and obtain five to six grains of radium—about three hundred to four hundred milligrams" (p. 74), less than 0.02 ounces.

The Problem With American Mathematics Education

International Comparisons

What do international comparisons show about America's best and brightest? The Second International Mathematics Study, reported by McKnight, Travers, and Dossey (1987), was conducted in 1981-82. Twenty school systems around the world participated at grades 8 and 12. Twelve thousand American public and private school students took part (7,000 in grade 8; 5,000 in grade 12) from 250 schools. The first group of students selected were 13 years old in the middle of the school year, i.e., 8th grade in the U.S. The second group consisted of "those students in their last year of secondary school who were still engaged in the serious study of mathematics" (p. 17). This group represents 12th grade students in the U.S.

American mathematics students ranked 14th out of 20 at grade 8 and 12th out of 15 at grade 12. The students in grade 12 did worse than those in grade 8. Japan scored at or just below the top at both grades. In addition, the Japanese students who took the 8th grade test were actually in the 7th grade, taking the test one year earlier than the rest of the international students. The 8th grade test covered arithmetic, algebra, geometry, statistics, and measurement. The 12th graders were tested on number systems, sets and relations, algebra, geometry, elementary functions and calculus, and probability and statistics. American 8th graders were about average in arithmetic, algebra, and statistics, but near the bottom in geometry and measurement. U.S. 12th graders scored below the international average in all topics.

It is important to recognize that all the older students were enrolled in advanced mathematics classes, were college preparatory mathematics students, and were "the cream of the crop." It is **not** the case that average American 12th graders were compared to elite groups in other countries—a common misconception.

As one might expect, à variety of reasons are given for these striking international comparisons. Attitudes differed between American and Japanese teachers regarding mathematics education. American mathematics teachers said the subject was easy to teach; Japanese thought it was hard to teach. Teaching loads were heavier in the U.S. than in many other countries. Mathematics teacher meetings in Japan dealt more with teaching content and strategies and much less with managerial, administrative, and school policy matters, the primary topic for U.S. 12th grade teachers.

Low Expectations

A study of American, Taiwanese, and Japanese elementary children by Stevenson, Lee, and Stigler (1986) investigated attitudes about success in school. Mothers were asked to rate the importance of four factors: effort, ability, task difficulty, and luck. All the mothers indicated that effort was the most important factor, but the Asian mothers gave it higher rankings. Asian mothers rated ability much lower than effort. American mothers rated ability almost as highly as effort.

Similar findings emerged in a follow-up study (Stevenson, Chen, & Lee, 1993). Eleventh graders and their teachers were asked to respond to a question about the relative importance of "a good teacher, innate intelligence, home environment, and studying hard" on students' performance in mathematics. More than 60% of Chinese and Japanese students said studying hard was the most important compared to less than 30% of American students who responded similarly. Among teachers, 93% of Japanese teachers indicated studying hard was important, compared to less than 30% of American teachers. "In contrast, the first choice of 41% of American teachers, but of only 7% of the Japanese teachers was innate intelligence" (p. 57). American students and their mothers believed less than the Chinese and Japanese that "'Everyone in my class has about the same natural ability in math'" (p. 57). Clearly, more Americans believe in the importance of innate ability.

Performance of Minorities

According to the 1990 U.S. Census, African Americans formed 12.1% of the total population, Hispanics constituted 9.0% of all Americans, and American Indians totaled 0.8% of the U.S. population (i.e., altogether these minorities comprised about 21.9% of the total American population). Statistical theory indicates that when large amounts of data are collected at random about participation in a given societal activity that similar percentages of all population groups should occur. For example, whether looking at 8th grade mathematics students, college freshmen majoring in mathematics, or mathematicians in industry or university settings, one would expect 9% of the individuals to be Hispanic. "All things being equal," one would likewise expect that minority student norms would be statistically indistinguishable from those of majority students. Unfortunately, the reality differs considerably.

Barriers to Minority Achievement in Mathematics

Why is the reality so markedly different for minorities in mathematics? A recent study by Oakes, Ormseth, Bell, and Camp (1990) for the RAND Corporation has identified barriers to mathematics opportunities in high school. Minority access to high-track mathematics classes diminished as minority enrollment increased, i.e., as the proportion of minority students increased, the relative proportion of college preparatory or advanced course sections decreased. In a racially mixed school, minority students were more likely than their White peers to be tracked into low-level classes. There tends to be less access for minorities to "gatekeeping" courses such as algebra, geometry, and high school calculus (pp. 35-42).

Moreover, low-income and minority students have less access to the best qualified mathematics teachers (Oakes et al., 1990, pp. 57-62). As the percentage of White students increases within a school, the percentage of certified mathematics teachers increases as does the percentage of those with Bachelor's or Master's degrees. A striking finding was that low-ability students in more advantaged schools (high socioeconomic status, predominantly White, suburban) had a higher percentage of qualified teachers on each of these measures than students in high-ability classes in less advantaged schools (low socioeconomic status, minority, inner-city).

Tracking

The negative effects of tracking in mathematics suggested by the College Board study of Pelavin and Kane (1990) are strongly supported by the data reported by the National Center for Education Statistics (NCES, 1992) on characteristics of drop-out students and those scoring below proficiency in basic mathematics and reading. The NCES study examined the demographic variables of gender, ethnicity, and socioeconomic status (SES) as well as other characteristics and adjusted the data for these characteristics. It is important to note that minority 8th graders, after adjusting for gender and SES, were **not** statistically more likely to drop out by grade 10 than White students. However, students attending remedial mathematics classes were almost 2.5 times more likely to drop out than students attending regular mathematics classes, while those eighth graders attending algebra classes (i.e., advanced mathematics classes) were 60% less likely to drop out than those attending remedial classes.

Slavin and Braddock (1993) argue that low-track students suffer in comparison to low achievers in untracked schools in a number of ways. They have less opportunity to learn; they perform more poorly on achievement tests in reading, mathematics, science, and social studies; their classes are more segregated by race and socioeconomic class; they have less self-esteem and more feelings of inferiority; they are more likely to be delinquent and to drop out. On the other hand, in terms of achievement test scores," . . . there was no consistent corresponding benefit of ability grouping for high or average achievers" (p. 3).

Minority Underrepresentation in Advanced-Level Mathematics

The first Ph.D. degree in mathematics to an African American man was awarded in 1925 to Elbert Frank Cox at Cornell University—one of only 28 Ph.D.s awarded that year. The first Ph.D.s in mathematics to African American women were awarded in 1949 to Marjorie Lee Browne at the University of Michigan and Evelyn Boyd Granville at Yale University. The magnitude of this latter accomplishment is revealed by the fact that only 9 Ph.D.s in mathematics were awarded to women of all races in 1950. The first Hispanic American Ph.D. recipient was Joaquin B. Diaz who received his degree in 1945 from Brown University. Anecdotal information suggests that the first Native American was Thomas Storer who graduated from the University of Southern California in 1964.

To put these dates in perspective, the first White male to receive a Ph.D. was J. H. Worrall in 1862 from Yale University; the first White female was Winifred Edgerton Merrill in 1886 from Columbia University. Interestingly, the first African American to receive a Ph.D. in any field was Alexander Bouchet in 1876 from Yale University in the field of Mathematical Physics.

Since 1973 (the first year that statistics included ethnic background), African Americans have earned 1.45%, Hispanics 0.89%, and American Indians 0.33% of the mathematical sciences Doctorates awarded in the United States, according to annual surveys conducted by the American Mathematical Society, the Institute of Mathematical Statistics, and the Mathematical Association of America.

Why are minority students less successful in reaching the end of the pipeline? While the data show differences between genders when it comes to pursuing mathematics, science, or engineering in college (the percentage of males, 31%, choosing these majors is twice that of females, 16%), ethnic differences are minor. Specifically, about 25% of college graduates from the high school class of 1980 majored in these fields whether they were White, African American, or Hispanic. Thus, the problem of underrepresentation stems from the low college attendance and the graduation rates experienced by minorities (National Center for Education Statistics, 1990). The 1993 National Collegiate Athletic Association Division I graduation rates were 32% for African Americans, 41% for Hispanics, 30% for Native Americans versus 56% for Whites (Carter & Wilson, 1994).

In examining the undergraduate and graduate education of minority mathematics majors, it is important to note the impact of historically Black colleges and universities (HBCU) and historically Hispanic institutions (HSI). The historically Black colleges and universities enrolled only 18% of all African American undergraduates in the fall of 1991, which actually represented an increase during the decade (Boulard, 1993). Yet, in the fall of 1989 they produced 48% of the African Americans earning Bachelor's degrees in mathematics (Hill, 1992a, p. 48-49). Even more striking is the statistic that 31% of Ph.D.s awarded to African Americans in mathematics were earned by HBCU graduates during the years 1985-1990 (Hill, 1992b, p. 12). Between 1986 and 1989, 17 of the top 20 Baccalaureate institutions for African Americans earning Ph.D.s in all fields were HBCUs. For that same period, 10 of the top 20 Baccalaureate institutions for Hispanics were HSIs (Office of Scientific and Engineering Personnel, 1990). This contradicts the assumption often made that minority institutions are not academically competitive. Thus, the question to be addressed by majority institutions is why they cannot accomplish similar results with minority students.

What Can Be Done

Curriculum and Assessment Standards

It is clear that we need an educational system that encourages each child to develop his/her potential. In the area of school mathematics, the National Council of Teachers of Mathematics (NCTM, 1989) has promulgated new curriculum and evaluation standards. It is worth noting that the NCTM *Standards* are the model for new science standards in the areas of curriculum, evaluation, and assessment developed under the aegis of the National Research Council for publication in draft form in 1994.

The NCTM *Curriculum Standards* are designed to address the concern that all students learn significant mathematics, hence a core curriculum. High expectations are to be maintained for all. No longer will the curriculum consist of years of arithmetic, followed by algebra and geometry for only the select few. Many of the curriculum strands persist over several levels, but the approach involves fewer topics in greater depth and increasing sophistication.

The SUMMA Program

The NCTM *Curriculum and Evaluation Standards* and the prototype assessments represent the efforts of mathematics educators to begin changing school (K-12) mathematics. The members of the Mathematical Association of America (MAA) are college and university faculty, precollege and college students, high school teachers, and mathematicians outside of academia. This organization focuses on undergraduate mathematics education. It has undertaken a program to address the problem of minority underrepresentation in mathematics-based fields.

The Strengthening Underrepresented Minority Mathematics Achievement (SUMMA) Program of the MAA is a national effort focused on increasing minority participation in mathematics at every level, from elementary through graduate school and beyond. The goals of SUMMA are to improve the mathematics education of minorities and to increase the representation of minorities in the fields of mathematics, science, and engineering.

A series of projects have been developed to implement the goals of SUMMA. Oversight of the SUMMA Program is provided by the MAA Executive Director and the MAA Committee on Minority Participation in Mathematics. The SUMMA Program has eight project components designed to address the underrepresentation of minorities at each stage of the pipeline in ways appropriate to a professional organization.

The components are:

- Mathematics-Based Projects for Minority Students
- A SUMMA Consortium of Intervention Projects
- Attracting Minorities Into Teaching Mathematics
- Mainstreaming Projects for College Students
- A National Collaborative for Mathematics Departments at Minority Institutions
- A Minority Graduate Student Mentoring Project
- An Archival Record of Minority Ph.D.s in Mathematics or Mathematics Education and a Directory of Minority Mathematicians
- A Collaborative With the Bureau of Indian Affairs (BIA) to Create a New Vision of Mathematics in BIA Schools.

To facilitate implementation, SUMMA collaborates directly with a variety of mathematics-related organizations, such as the American Indian Science and Engineering Society, the American Mathematical Association of Two-Year Colleges, the Alliance to Involve Minorities in Mathematics of the Mathematical Sciences Education Board, the Benjamin Banneker Association, the National Association of Mathematicians, and the Society for the Advancement of Chicanos and Native Americans in Science.

Conclusion

The need for changes in attitudes and practices in mathematics education is clearly evident by examining the poor American performance in international comparisons. It is being said more and more often that making mathematics work for minorities will also make it work for other students as well, thus developing a secure mathematics pipeline for **all** students. Hopefully, the SUMMA Program is encouraging the members of the MAA and the mathematics community to move in this direction. It is clear that only by utilizing the mathematical ability of all of our citizens can we hope to address the problems of the 21st Century.

Guidelines for Teachers

Guideline 1: Mathematics is no different from any other human endeavor. Hard work is the key to longlasting accomplishment.

Discussion: This is not to minimize the obvious talent possessed by certain persons in given areas such as literature, painting, sculpture, music, dance, science, and even mathematics. Nonetheless, a high level of attainment in mathematics is accessible to all students.

Guideline 2: Familiarize yourself with the NCTM *Standards* so your students can take advantage of the tremendous changes taking place in the K-12 mathematics curriculum.

Discussion: Since the lecture method is not effective with many students, you can use a variety of methods such as cooperative learning, projects and hands-on learning. You can use more open-ended problems, classroom-based assessments, and portfolios. You can take advantage of opportunities for in-service workshops for calculator and computer use. You can become teacher-leaders in the mathematics reform movement.

Guideline 3: Access multicultural materials detailing the mathematical accomplishments of non-Western societies.

Discussion: Major publishers such as Dale Seymour and Carolina Biological have materials discussing Benjamin Banneker and Omar Khayyam, for example, as well as African, Mexican, and American Indian mathematicians. Minority students cannot be expected to be interested in subjects to which they are told their ethnic group has made no past or present contribution.

Guideline 4: Encourage mathematical talent among minority middle and high school students through mentorships and advanced intervention programs.

Discussion: Most students can point to only a handful of teachers who made a memorable difference in their lives. Efforts to mentor students and involve them in mathematics enrichment activities during the academic year and summer provide powerful incentives to all students to persevere.

Guideline 5: The number one concern of all science, mathematics, and engineering students (whether still pursuing a degree or having changed to a nonquantitative major) was the "poor teaching and unapproachability" of their faculty (Seymour, 1992a, p. 234).

Discussion: "The worst teaching ratings often went to mathematics faculty, where small departments were portrayed as struggling to 'process' very large numbers of introductory-course students across the whole range of engineering and science majors" (Seymour, 1992b, p. 286). The importance and difficulty of mathematics changing from a critical filter to a pump is masked by the simplicity of the metaphors. Without improvement in the teaching of collegiate mathematics, there can be no significant change in the small numbers of students completing quantitative majors, however great the country's need for technically trained personnel.

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Constructing a Secure Mathematics Pipeline for Minority Students

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Introduction

Who are these minority students and why is it important to recruit them into mathematics and science? Underrepresented minorities (African Americans, Hispanic Americans, and American Indians) formed 21.9% of the population according to the last census. The White male population is no longer sufficient to provide adequate numbers of the technically trained personnel America needs to compete effectively. To produce the best mathematicians, scientists, and engineers, we must encourage all segments of society to achieve to the limits of their abilities in these fields. Since these abilities are randomly distributed among the population, exclusionary policies are bound to miss "diamonds in the rough." The country cannot continue with these failed policies if it is to prosper in the 21st century.

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American Attitudes About Mathematics

To make today's complex semiconductor chips, a company must use statistical quality control. To use statistical quality control, every production worker must master it. To do so requires learning some simple operations research, but to learn what must be taught, workers must know algebra. Americans are not used to a world where ordinary production workers have to have mathematical skills (Thurow, p. 160).

The Success Myth

The most dangerous, yet most pervasive, myth associated with education in mathematics at every level is that **"Success in mathematics depends more on innate ability than on hard work"** (National Research Council, 1991, p. 10). The Success Myth operates at every educational level. Even a preschooler can be labeled "good in mathematics!" Such a child is encouraged all along the way to learn, and is taught, as much mathematics as possible while others may be discouraged from learning more than a minimal amount. The irony is that many of these obviously talented children develop little or no interest in the fields in which teachers identified them as "good." For example, a practice among some advanced high school students is to use the AP courses, such as Calculus AB and BC, as a way to bypass mathematics requirements in college.

Even though a student may have done well at previous stages, the winnowing process continues. Students with good high school mathematics backgrounds often arrive at college planning to major in a quantitative field, only to be discouraged by the "filtering out" process that occurs in many beginning calculus courses. Then, good undergraduate mathematics majors are weeded out of graduate programs, changing to other areas of study or dropping out of school altogether.

Two recent articles identify the reasons attributed by undergraduate students for switching out of quantitative majors. "A large proportion of switchers leave their SME (science, mathematics, and engineering) major due to problems that arise from structural and cultural sources rather than from problems of personal inadequacy" (Seymour, 1992a, p. 234). The problems most often cited were "poor teaching, faculty unapproachability, fast curriculum pace, work overload, insufficient faculty help through periods of academic difficulty, inadequate high school preparation, financial and other problems created by the unexpected/growing length of SME majors" (Seymour, 1992b, p. 285). "Most women found it difficult to learn from faculty who took no personal interest in them. Although little blatant sexism was reported, nearly all of the women students complained of daily irritation caused by sexist remarks from male peers, and of subtle faculty messages" that they didn't belong or measure up (Seymour, 1992b, p. 289).

The Success Myth not only affects students but faculty as well. New faculty are hired after completing highly regarded doctoral programs, only to be denied tenure because of opinions about the quality of their research and their abilities to make a significant contribution to their field of expertise, then to go elsewhere and complete groundbreaking research that is universally recognized. This myth even affects mathematical researchers who come to feel that a breakthrough must be the result of talent rather than long periods of hard, concentrated work.

Intelligence Theory

What insight can commonly held views of intelligence give us into the Success Myth? The modern study of intelligence began with Alfred Binet, Director of the Psychology Laboratory at the Sorbonne. According to Gould (1981),

> Not only did Binet decline to label IQ as inborn intelligence; he also refused to regard it as a general device for ranking all pupils according to mental worth. He devised his scale only for the limited purpose of his commission by the ministry of education: as a practical guide for identifying children whose poor performance indicated a need for special education—those whom we would today call learning disabled or mildly retarded. (p. 152)

As Gould notes, the history of intelligence testing in America began with the version of the Binet scale introduced by Lewis M. Terman, a professor at Stanford University in 1916, "the Stanford-Binet, the standard for virtually all 'IQ' tests that followed" (p. 175).

The concept of innate ability has its origin in the ideas of intelligence espoused by American Charles Spearman (his *g* or general intelligence) and Englishman Cyril Burt (innate, general, cognitive ability). They were major proponents of the theory that intelligence is measurable by a single number (Spearman) and largely hereditary (Burt). Arthur Jensen is a modern proponent of these discredited hereditarian theories (Gould, 1981, pp. 317-320). Richard Herrnstein and Charles Murray (1994) have attempted to resurrect these ideas again in their book, *The Bell Curve: Intelligence and Class Structure in American Life*—another example of old wine in new wineskins.

An alternative theory of multiple intelligences was introduced by Howard Gardner (1983) in a major work. There he gives a definition of an intelligence or "intellectual competence," identifies eight criteria for an intelligence, and suggests seven different intelligences that people manifest, one being logical-mathematical. The book is based on Gardner's empirical work with normal and gifted children, as well as studies on brain-injured adults. He defines an intelligence as "the ability to solve problems or fashion products which are valued in one or more cultural settings" (p. x).

Unfortunately, Gardner also perpetuates the Success Myth. He refers to the writings of the mathematician Arthur Adler and says "the major work of most mathematicians is over by the age of twenty-five or thirty. If little has been accomplished by that time, little is likely to be accomplished in the future. . . . This situation contrasts with that found in many humanistic areas of scholarship, where major works typically appear during the fifth, the sixth, or even the seventh decades of life" (p. 154).

Gardner's awe of mathematics blinds him. "While the products fashioned by individuals gifted in language and music are readily available to a wide public, the situation with mathematics is at the opposite extreme. Except for a *few initiates* [italics added], most of us can only admire from afar the ideas and works of mathematicians" (p. 136). He is no less awestruck of the physical scientist. In his view, a personal lack of success with mathematics may account for much of his own attitude and that of the general public.

The thesis of this paper is that the problem is the reverse. Negative attitudes interfere with most persons in America learning significant mathematics. This reinforces the Success Myth. It is interesting to note that many foreign countries have high expectations of all students in mathematics, and their students consistently outperform U.S. students on international tests.

The Fallacy of the Success Myth

Since many subjects including mathematics and science are taught without reference to historical context, few students know any details about the human beings who created significant portions of the subject they are learning and whose lives show the importance of hard work for success. Unfortunately, many believe that all prominent contributors to the progress of mathematics and science were geniuses whose talent was apparent virtually from birth. But, what evidence is there that hard work is more important to success in mathematics and science than innate ability? Let me give four counterexamples from mathematics and then three from physics.

David H. Blackwell is one of only two living African American members of the National Academy of Sciences, the only African American mathematician, and the first of only three African Americans ever to be elected to membership. Although a good mathematics student, his initial career goal was to become an elementary teacher; later, he revised that to becoming a high school teacher (Albers & Alexanderson, 1985). His high school geometry teacher was a major influence. He eventually earned a Ph.D. in mathematics and was a professor of mathematics at Howard University for 12 years and a professor of statistics at the University of California at Berkeley from 1954 until his retirement in 1990.

Lenore Blum left her native New York with her family at age nine and continued her education in Caracas, Venezuela. Although mathematics was her favorite subject, her instruction wa poor and so she became self-taught in high school and graduated at the age of 16. When she expressed an interest in continuing her study of mathematics in college, her mathematics teacher advised against it stating that "Everything important was discovered 2000 years ago. You don't want to go into a dead field" (Perl, 1993, p.82). Despite this discouragement, she majored in mathematics and applied to MIT for graduate study. During the application process, an admissions officer told her MIT was no place for women and gave her an alternative list of schools. Nevertheless, she applied ar d was admitted to MIT, received a doctorate in mathematics, and did post-doctoral work at Berkeley. She went on to promote women in mathematics in the 1970s and establish a productive research career in mathematics and computer science throughout the 1980s continuing to the present. She gives us insight into the perseverance necessary in mathematical research. "Some days I might sit at my desk for hours and scribble only a few lines. But each day, my understanding increased, and I began to see things fall into place" (p. 91). Her impressive research credentials give evidence that persistence and hard work in mathematics pays off.

Andrew Wiles of Princeton University announced on June 23, 1993 during a series of lectures at Cambridge, England that he had solved a 356-year-old mathematics conjecture known as Fermat's Last Theorem. In an interview given to Kolata (1993), he talks about how he spent the last seven years secretly trying to find a solution in a "barren attic office" in his home without a computer or telephone. He first had heard about the problem when he was 10 and had been fascinated about it ever since, crediting it with attracting him to the study of mathematics. Kolata regrettably calls Wiles a "math whiz" (p. C1), thus reinforcing the stereotype of the Success Myth. This subtly contradicts the fact that "he dedicated his life . . . to prov(ing) Fermat's last theorem" (p. C11).

Evelyn Boyd Granville grew up in a tiny apartment in a building in which her father was a caretaker in an African American neighborhood a few blocks from the most elegant parts of Washington, DC. Graduating valedictorian from her high school class, she hoped to become a teacher. She attended Smith College, initially without financial aid, majoring in mathematics and physics, and her career goals broadened. She eventually received a doctorate in mathematics from Yale University, being one of the first two female African Americans to receive this esteemed degree. In spite of her distinguished educational background, she found she had to overcome prejudice both because she was African American and a woman. Her spirit of adventure and determination has prompted her to undertake varied careers in different locations throughout the United States, including college professor, IBM computer specialist with the Vanguard missile program, and mathematical analyst at Space Technology Labs.

The lives of physicists Albert Einstein, Marie Curie, and Stephen Hawking illustrate many of these same ideas, such as overcoming obstacles and the necessity of hard work.

Albert Einstein (1879-1955) was the pre-eminent mathematical physicist of the 20th century. He received the 1921 Nobel Prize for Physics for his contributions to mathematical physics, especially the theory of special relativity, and his explanation of the photoelectric effect. Yet, his academic beginnings were inauspicious; he learned to speak late and was still not fluent at nine years of age. According to Clark (1984), ". . . when

Hermann Einstein asked his son's headmaster what profession his son should adopt, the answer was simply: 'It doesn't matter; he'll never make a success of anything'" (p. 27).

In a major biography of the two-time Nobel Laureate in Physics and Chemistry, Pflaum (1989) states that Marie Sklodowska Curie (1867-1934) entered the Sorbonne in 1891. She earned the Master's degree, *licence ès sciences physiques* (summa cum laude)—the first woman to receive such a degree at the Sorbonne; the *licence ès sciences mathématiques* (magna cum laude); and the degree, "Doctor of Physical Sciences - summa cum laude"—the first woman to earn a Doctorate in France. When starting her course of study, she found she "lacked the mathematics necessary for a basic understanding of the physical sciences on a university level . . . her French was also inadequate" (p. 27). She and her husband Pierre Curie began their research on radioactivity (a term she coined) in 1897 with uranium and later thorium, and discovered polonium and radium—in an unheated, damp, glass-paneled artist's workshop, much like a greenhouse. "They were to learn the hard way, by the most drudging sort of toil, that radium was less than 1/1,000,000 of a part, and that it would require about fifty tons of water and five to six tons of chemicals to treat one ton of pitchblende and obtain five to six grains of radium—about three hundred to four hundred milligrams" (p. 74), less than 0.02 ounces.

Since 1979, Stephen W. Hawking has held the position of Lucasian Professor of Mathematics at Cambridge University, the chair once held by Sir Isaac Newton, Charles Babbage, and P. A. M. Dirac (White & Gribbin, 1992). He made little effort as an undergraduate and had mediocre results on his final exams in 1962. An oral exam convinced Oxford to give him the first-class honors he needed to pursue graduate study at Cambridge. In 1963, he was diagnosed with amyotrophic lateral sclerosis (ALS) (Lou Gehrig's disease) which eventually left him unable to walk or write, and barely able to speak. He received his Ph.D. in 1966 and that same year shared Cambridge University's most prestigious award in mathematics and physics, the Adams Prize, with the British mathematician, Roger Penrose. One of the world's foremost cosmologists, he "lectures" by speaking with the aid of a computer to a graduate student who writes his computations on the blackboard.

The Problem With American Mathematics Education

If the route to success is inventing new products, the education of the smartest 25 percent of the labor f rce is critical. Someone in that top group will most likely invent the new products of tomorrow. If the route to success is being the cheapest and best producer of products, new or old, the education of the bottom 50 percent of the population moves to center stage. This part of the population must staff those new processes. If the bottom 50 percent cannot learn what must be learned, new high-tech processes cannot be employed (Thurow, p. 52).

International Comparisons

What do international comparisons show about America's best and brightest? The Second International Mathematics Study, reported on by McKnight, Travers, and Dossey (1987), was conducted in 1981-82. Twelve thousand American public and private school students from 250 schools took part. The first group of students was chosen in all countries in the grade when they would be 13 at the middle of the school year, i.e., 8th grade in the U.S. The second group consisted of "those students in their last year of secondary school who were still engaged in the serious study of mathematics" (McKnight et al., p. 17)—our 12th grade.

American mathematics students ranked 14th out of 20 at grade 8 and 12th out of 15 at grade 12. The students in grade 12 did even worse than those in grade 8. Japan scored at or just below the top at both grades. In addition, for the 8th grade test, the Japanese students were in the 7th grade. The 8th grade test covered arithmetic, algebra, geometry, statistics, and measurement. The 12th graders were tested on number systems, sets and relations, algebra, geometry, elementary functions and calculus, and probability and statistics. American 8th graders were about average in arithmetic, algebra, and statistics, but near the bottom in geometry and measurement. U.S. 12th graders scored below the international average in all topics.

It is important to recognize that all the older students were enrolled in advanced mathematics classes, were college preparatory mathematics students, and were "the cream of the crop." It is **not** the case that average American 12th graders were compared to elite groups in other countries—this is a common misconception.

The most startling comparison involves the top 1% and 5% of the 12th grade students on the tests in functions and calculus. The top 1% of Japanese students outscored students from all other countries on these tests. "The most able American students . . . were among the lowest in calculus" (McKnight et al., p. 26). Average Japanese students scored higher than the top 5% of American students." Moreover . . . the top 1% of U.S. students exceeded Canada (British Columbia) by only a few points. But calculus is not even included in the curriculum of British Columbia!" (p. 27).

As one might expect a variety of reasons are given for these striking international comparisons. Attitudes differed between the Japanese and American teachers regarding mathematics education. American mathematics teachers said the subject was easy to teach; Japanese teachers thought it was hard to teach. Our teachers offered student-related reasons for lack of achievement, while the Japanese tended to view it as due to their own professional limitations. Teaching loads were heavier in the U.S. than many other countries. Mathematics teacher meetings in Japan dealt more with teaching content and strategies and much less with managerial, administrative, and school policy matters, the primary topic for U.S. 12th grade teachers.

What does explain U.S. underachievement? Four reasons are low expectations, a repetitive and poorly organized curriculum, ineffective use of class time, and low teacher status. The first reason is discussed in detail.

Low Expectations

A study of American, Taiwanese, and Japanese elementary children by Stevenson, Lee, and Stigler (1986) investigated attitudes about success in school. Mothers were asked to rate the importance of four factors: effort, ability, task difficulty, and luck. All the mothers indicated that effort was the most important factor, but the Asian mothers gave it higher rankings. Asian mothers rated ability much lower than effort. American mothers rated ability almost as highly as effort.

Similar findings emerged in a follow-up study (Stevenson, Chen, & Lee, 1993) from responses which eleventh graders and their teachers gave to a question about the relative importance of "a good teacher, innate intelligence, home environment, and studying hard." More than 60% of Chinese and Japanese students said studying hard was the most important compared to less than 30% of Americans who responded similarly. Among teachers, 93% of Japanese teachers indicated studying hard was important, compared to less than 30% of American teachers. "In contrast, the first choice of 41% of American teachers, but of only 7% of the Japanese teachers was innate intelligence" (p. 57).

American students and their mothers believed less than the Chinese and Japanese that "'Everyone is my class has about the same natural ability in math'" (p. 57). Clearly, more Americans believe in the importance of innate ability.

Performance of Minorities

According to the 1990 U.S. Census, African Americans formed 12.1% of the total population, Hispanics constituted 9.0% of all Americans, and American Indians totaled 0.8% of the U.S. population (i.e., altogether these minorities comprised about 21.9% of the total American population). Statistical theory indicates that, when large amounts of data are collected at random about participation in a given societal activity, similar percentages of all population groups should occur. For example, whether looking at 8th grade mathematics students, college freshmen majoring in mathematics, or mathematicians in industry or university settings, one would expect 9% of the individuals to be Hispanic. "All things being equal," one would likewise expect that minority student norms would be statistically indistinguishable from those of majority students. Unfortunately, the reality differs considerably.

Barriers to Minority Achievement in Mathematics

A recent study by Oakes, Ormseth, Bell, and Camp (1990) for the RAND Corporation has identified barriers to mathematics opportunities in high school. Minority access to high-track mathematics classes diminished as minority enrollment increased, i.e., as the proportion of minority students increased, the relative proportion of college preparatory or advanced course sections decreased. In a racially-mixed school, minority students were more likely than their White peers to be tracked into low-level classes. There tends to be less access for minorities to "gatekeeping" courses such as algebra, geometry, and high school calculus (pp. 35-42).

The importance of this last finding cannot be overemphasized. Research by Pelavin and Kane (1990) has shown that high school geometry is a primary gatekeeper to college enrollment. Specifically, all ethnic groups attend college at about an 80% rate when they have completed a year of geometry; the rate increases when they also plan to go to college. The study found that no other course was a better predictor of college attendance. The College Board Project Equity 2000 is based in part on this research and is focused on ensuring that **all** youngsters take algebra by at least grade 9 and geometry by at least grade 10. For this and many other reasons, it is important to ensure that minority youngsters have available and take as many years of mathematics as possible in their high schools, including geometry, Algebra II, and beyond. Data from NAEP show a similar pattern, that students who have taken more mathematics courses do better on the assessment in grades 8 and 12.

Moreover, low-income and minority students have less access to the best qualified mathematics teachers (Oakes et al., 1990, pp. 57-62). As the percentage of White students increases, the percentage of certified mathematics teachers increases as does the percentage of those with Bachelor's or Master's degrees. A striking finding was that low-ability students in more advantaged schools (high socioeconomic status, predominantly White, suburban) had a higher percentage of qualified teachers on each of these measures than students in high-ability classes in less advantaged schools (low socioeconomic status, minority, inner-city). A recent report by the Educational Testing Service (1991) corroborates Oakes' findings.

Tracking

The negative effects of tracking in mathematics in contrast to other fields, hinted at by the College Board study of Pelavin and Kane (1990), are strongly supported by the data in the study (National Center for Education Statistics [NCES], 1992) on characteristics of students scoring below proficiency in basic mathematics, basic reading, and dropping out of school. The NCES study looks at the demographic variables of gender, ethnicity, and socioeconomic status (SES) as well as other characteristics and adjusts the data for these characteristics. Minority 8th-graders, after adjusting for gender and SES, were **not** statistically more likely to drop out by grade 10 than White students.

The remaining data in this NCES study is adjusted for gender, ethnicity, and SES. Students attending remedial English were also not statistically more likely to drop out. However, students attending remedial mathematics classes were almost 2.5 times more likely to drop out than students attending regular mathematics classes, while those eighth graders attending algebra classes (i.e., advanced mathematics classes) were 60% less likely to drop out than those attending remedial classes.

In a paper (Slavin & Braddock, 1993) disseminated at an Equity 2000 conference in May 1993, forceful arguments against tracking were given. Two other papers in the Research-Based Decision Making Series (Kulik, 1992; Rogers, 1991) also discuss issues related to tracking. Another significant work on tracking is by Rose (1992). Braddock used data from the National Longitudinal Study. He "followed eighth-grade students who attended schools in which ability grouping was or was not used, and examined many outcomes for these students in the tenth grade. He statistically controlled for prior grades and test scores and other factors; and compared high, average, and low achievers separately in the tracked schools to their counterparts in the untracked schools" (Slavin & Braddock, 1993, p. 3).

Slavin and Braddock argue that low-track students suffer in comparison to low achievers in untracked schools in a number of ways. They have less opportunity to learn; they perform more poorly on achievement tests in reading, mathematics, science, and social studies; their classes are more segregated by race and socioeconomic class; they have less self-esteem and more feelings of inferiority; they are more likely to be delinquent and to drop out. On the other hand in terms of achievement test scores, ". . . there was no consistent corresponding benefit of ability grouping for high or average achievers" (p. 3).

It is important to understand what kinds of grouping are acceptable. Slavin and Braddock write:

> Flexible within-class grouping to provide additional assistance to students who need help has been found to be effective in upper-elementary mathematics, for example. There is also evidence to support use of the Joplin Plan, in which students are placed in mixed-ability classes for most of the day, but are regrouped according to reading performance across grade lines. Acceleration programs for extremely able students have been supported by research, and advanced placement and other advanced course work for high school students can be beneficial. However, they need to be accompanied by efforts to see that minority students and other underrepresented groups also have access to them. A comprehensive, reasonable, and practical strategy for restructuring schools might well include some forms of grouping. What must end, however, is the kind of ability grouping that sorts students into categories that have long-lasting consequences; that is the between-class grouping strategies often called tracking. (pp. 6-7)

Minority Underrepresentation in Advanced-Level Mathematics

The first Ph.D. degree in mathematics awarded to an African American man was given in 1925 to Elbert Frank Cox at Cornell University—one of only 28 Ph.D.s awarded that year. The first Ph.D.s in mathematics to African American women were awarded in 1949 to Marjorie Lee Browne at the University of Michigan and Evelyn Boyd Granville at Yale University. The magnitude of this latter accomplishment is revealed by the fact that only 9 Ph.D.s in mathematics were awarded to women of all races in 1950. The first Hispanic American Ph.D. was Joaquin B. Diaz who received his degree in 1945 from Brown University. Anecdotal information suggests that the first Native American was Thomas Storer who graduated from the University of Southern California in 1964.

To put these dates in perspective, the first White male to receive a Ph.D. was J. H. Worrall in 1862 from Yale University; the first White female was Winifred Edgerton Merrill in 1886 from Columbia University. Interestingly, the first African American to receive a Ph.D. in any field was Alexander Bouchet in 1876 from Yale University in the field of Mathematical Physics.

Last year, there were 2 African American men, 1 African American woman; 5 Hispanic American men, 2 Hispanic American women; and 1 American Indian man who earned 11 Doctorates out of the 469 awarded to U.S. citizens in the mathematical sciences according to the Annual AMS-MAA Survey of New Doctorates (Fulton, 1994). Since 1973 (the first year that statistics included ethnic background), African Americans have earned 1.45%, Hispanics have earned 0.89%, and American Indians have earned 0.33% of the mathematical sciences Doctorates awarded in the United States.

Why are minority students less successful in reaching the end of the pipeline? While the data show differences between genders when it comes to pursuing mathematics, science, or engineering in college (the percentage of males, 31%, choosing these majors is twice that of females, 16%), ethnic differences are minor. Specifically, about 25% of college graduates from the high school class of 1980 majored in these fields whether they were White, African American, or Hispanic. Thus, the problem of underrepresentation stems from the low college attendance and graduation rates experienced by minorities (NCES, 1990). The 1993 National Collegiate Athletic Association Division I graduation rates were 32% for African Americans, 41% for Hispanics, 30% for Native Americans versus 56% for Whites (Carter & Wilson, 1994).

In examining the undergraduate and graduate education of minority mathematics majors, it is important to note the impact of historically Black colleges and universities (HBCU) and historically Hispanic institutions (HSI). The historically Black colleges and universities enrolled only 18% of all African American undergraduates in the fall of 1991, which actually represented an increase during the decade (Boulard, 1993). Yet, in the fall of 1989, they produced 48% of the African Americans earning Bachelor's degrees in mathematics (Hill, 1992a, p. 48-49). Even more striking is the statistic that 31% of Ph.D.s awarded to African Americans in mathematics were earned by HBCU graduates during the years 1985-1990 (Hill, 1992b, p. 12). Between 1986 and 1989, 17 of the top 20 Baccalaureate institutions for African Americans earning Ph.D.s in all fields were HBCUs. For that same period, 10 of the top 20 Baccalaureate institutions for Hispanics were HSIs (Office of Scientific and Engineering Personnel, 1990). This contradicts the assumption often made that minority institutions are not academically competitive. Thus, the question to be addressed by majority institutions is why they cannot accomplish similar results with minority students.

What Can Be Done

While the superior performance of European or Japanese high-school graduates is lost by the time they graduate from college, and while American graduate schools have no equal elsewhere in the world, there is still a problem in higher education. It produces too few scientists and engineers relative to the total college population—only 15-17 percent in the United States, as compared to about 40 percent in Germany or Japan. But this problem cannot be solved at the college level until high school science and math education has been improved. Most Americans have effectively already closed the door on a science career by the time they graduate from high school (Thurow, p. 276).

Curriculum and Assessment Standards

It is clear that we need an educational system that encourages each child to develop his/her true potential. In the area of school mathematics, the National Council of Teachers of Mathematics (NCTM) (1989) has promulgated new curriculum and evaluation standards (NCTM *Standards*). The 100,000-member NCTM consists of mathematics educators at both the precollege and college level. It seeks to "foster excellence in school mathematics curricula and instructional programs, including assessment and evaluation . . ." (NCTM, 1992, p. 1).

It is worth noting that the NCTM *Standards* are the model for new science standards in the areas of curriculum, evaluation, and assessment being developed under the aegis of the National Research Council for publication in draft form in 1994. Another prominent example of the growing influence of the NCTM *Standards* is the decision by the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) (1993) that by 1995 all participating agencies (a total of 16) "will provide support and incentives to encourage all States and school districts to adopt the . . . NCTM mathematics standards" (Committee on Education and Human Resources, FCCSET, p. 13).

The NCTM *Standards* seem designed expressly to address the curriculum deficiencies highlighted in the Second International Study. A common thread throughout the *Standards* is the concern that all students learn significant mathematics, hence a core curriculum. High expectations are to be maintained for all. No longer will the curriculum consist of years of arithmetic, followed by algebra and geometry for only the select few. Many of the curriculum strands persist over several levels, but the approach involves fewer topics at greater depth and increasing sophistication. These changes will inspire students to more challenging levels of mathematics and instill a belief in the value of hard work.

The SUMMA Program

The NCTM *Curriculum and Evaluation Standards* and the prototype assessments represent the efforts of mathematics educators to change school (K-12) mathematics. Members of the Mathematical Association of America (MAA), college and university faculty, precollege and college students, high school teachers, and mathematicians outside of academia, focus their efforts on undergraduate mathematics education. This association has undertaken a program to address the problem of minority underrepresentation in mathematics-based fields called Strengthening Underrepresented Minority Mathematics Achievement (SUMMA).

SUMMA is a national effort focused on increasing minority participation in mathematics at every level, from elementary through graduate school and beyond. The goals of SUMMA are to improve the mathematics education of minorities and to increase the representation of minorities in the fields of mathematics, science, and engineering. The SUMMA Program has eight project components designed to address the underrepresentation of minorities at each stage of the pipeline in ways appropriate to a professional organization.

The components are:

- Mathematics-Based Projects for Minority Students
- A SUMMA Consortium of Intervention Projects
- Attracting Minorities Into Teaching Mathematics
- Mainstreaming Projects for College Students
- A National Collaborative for Mathematics Departments at Minority Institutions
- A Minority Graduate Student Mentoring Project
- An Archival Record of Minority Ph.D.s in Mathematics or Mathematics Education and a Directory of Minority Mathematicians
- A Collaborative With the Bureau of Indian Affairs (BIA) to Create a New Vision of Mathematics in BIA Schools.

To facilitate implementation, SUMMA collaborates directly with a variety of mathematics-related organizations, such as the American Indian Science and Engineering Society, the American Mathematical Association of Two-Year Colleges, the Alliance to Involve Minorities in Mathematics of the Mathematical Sciences Education Board, the Benjamin Banneker Association, the National Association of Mathematicians, and the Society for the Advancement of Chicanos and Native Americans in Science.

Conclusion

The need for changes in attitudes and practices in mathematics education is made clear by the poor American performance in international comparisons. It is being said more and more often that making mathematics work for minorities is the only way to make it work for other students as well. Only by utilizing the mathematical ability of all of our citizens can we hope to address the problems of the 21st Century.

Guidelines for Teachers

Guideline 1: Mathematics is no different from any other human endeavor. Hard work is the key to longlasting accomplishment.

Discussion: This is not to minimize the obvious talent possessed by certain persons in given areas such as literature, painting, sculpture, music, dance, science, and even mathematics. Nonetheless, a high level of attainment in mathematics is accessible to all students.

We will never encourage large numbers of our citizens to be scientifically literate unless we demystify mathematics and science. They will need to make informed decisions about expenditures for science and technology and related issues and will need educational preparation in these fields for the careers of tomorrow. If mathematics-based studies are the purview of only a few Americans, we will never compete with countries that educate large numbers of their students in these same fields.

Guideline 2: Familiarize yourself with the NCTM *Standards* so your students can take advantage cf the tremendous changes taking place in the K-12 mathematics curriculum.

Discussion: Since the lecture method is not effective with many students, you can use a variety of methods such as cooperative learning, projects, and hands-on learning. You can use more open-ended problems, classroom-based assessments, and portfolios. You can take advantage of opportunities for in-service workshops for calculator and computer use. You can become teacher-leaders in the mathematics reform movement.

Guideline 3: Access multicultural materials detailing the mathematical accomplishments of non-Western societies.

Discussion: Major publishers such as Dale Seymour and Carolina Biological have materials discussing Edna Boyd Granville, Benjamin Banneker, and Omar Khayyam, for example, as well as African, Mexican, and American Indian mathematicians. Minority students cannot be expected to be interested in subjects to which they are told their ethnic group has made no past or present contribution. Two very useful sources are by Ascher (1991) and Zaslavsky (1979). There is even a field of ethnomathematics, which "covers all the practices of a mathematical nature, such as sorting, classifying, counting, and measuring, which are performed in different cultural settings, through the practices acquired, developed, and transmitted through generations" (D'Ambrosio, 1992, p. 1183). Improved historical understanding of the growth of mathematics in other cultures shows the universality inherent in the pursuit of mathematical knowledge.

Guideline 4: Encourage mathematical talent among minority middle and high school students through mentorships and advanced intervention programs.

Discussion: Most students can point to only a handful of teachers who made a memorable difference in their lives. Efforts to mentor students and involve them in mathematics enrichment activities during the academic year and summer provide powerful incentives to all students to persevere.

You can organize a program encouraging minority or other professionals to mentor one (or more) students to ensure that the mentees pursue appropriate courses in preparation for quantitative majors in college. Local professional organizations, churches, and businesses as well as fraternities and sororities are possible places to recruit the professionals. The professionals can also participate in Mathematics Awareness Days, Career Days, the judging of Science Fairs, and the like.

You or someone in your school might also be interested in establishing an after-school and/or summer intervention program based at your school or some neighborhood facility, such as a Mathematics Club or intramural Mathematics Competition. The emphasis should be on enrichment, not remediation. The SUMMA Program has available a directory of mathematics-based intervention projects at colleges or universities within your state.

Guideline 5: The number one concern of all science, mathematics, and engineering students (whether still pursuing a degree or having changed to a nonquantitative major) was the "poor teaching and unapproachability" of their faculty (Seymour, 1992a, p. 234).

Discussion: "The worst teaching ratings often went to mathematics faculty, where small departments were portrayed as struggling to 'process' very large numbers of introductory-course students across the whole range of engineering and science majors" (Seymour, 1992b, p. 286). The importance and difficulty of mathematics changing from a critical filter to a pump is masked by the simplicity of the metaphors. Without improvement in the teaching of collegiate mathematics, there can be no significant change in the small numbers of students completing quantitative majors, however great the country's need for technically trained personnel.

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