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Minority Students and STEM Careers: Will Mentoring Help?

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Abstract

Science is critical to the progress of humanity through its unveiling of the intricate processes that co-mingle in different aspects of life. Particularly, the next generation of citizens will carry a burden of scientific uncertainties that will require the breaking of new frontiers, discovery and invention for the very survival of humanity. Discrimination based on economic, social and racial status in the imparting of scientific knowledge, burdens society and slows the progression of scientific knowledge. Despite these challenges and the preeminence of the US in scientific research, US high school students continue to lag behind students from many other nations including those from newly emerging economies, particularly in international tests of scientific knowledge [1,2].

Keywords: STEM; Minority students; Mentoring

Science Education in America

The understanding of science beyond the textbook is not normally an aspect that is impressed upon young minds. This might be one of the strongest reasons why, at an early age, students lose interest. Instead, they develop the notions that science is difficult and that the payoffs are intangible [3]. Science is not just reading a textbook, following the syllabus and getting high grades on an exam. Science is a process of measurement, observation, and reasoning that could answer society's most pressing questions. If this idea is instilled into the students at an early stage, then sufficient talent may be attracted to careers in science. On the other hand, if barriers are erected to talented individuals, the discoveries and progress will be insufficient to meet our needs. It is the responsibility of the teachers, educators and parents to show that science is exciting and "COOL" so that students at an early age can get involved.

While immediate action is needed, a review published by the American Educational Research Association suggests that there is a long road ahead before the US achieves proper standards of science education and reaches competitive levels of student performance [4]. There have been previous efforts to reverse the generally poor performance in the sciences observed in the broader population. Taking Science to School, a National Academy of Sciences (NAS) report, recommended reconsidering current standards to focus more on rudimentary ideas, and creating programs of study to build on the knowledge and comprehension of students [5]. A National Academy of Sciences study, America's Lab Report, also recommended the complete redesign of laboratory experiences to increase the significance of integrated teaching and clear comprehension [6]. Moreover, two other studies, Teaching Science in Five Countries and The American Association of Advancement of Science's Project 2061 suggested that American students have fewer chances to link conceptual ideas [7] and are also unable to make logical connections within the context of the subject matter [8].

Minority Students in Sciences

It is expected that increased numbers of science and engineering jobs will be generated nationally, driving the demand for highly trained individuals with strong foundations in the sciences [9]. Surveys, however, indicate that reduced numbers of basic and clinical scientists are being trained in the US [10]. The data for recruitment of minority groups African American, Native American, and Hispanic students-into the biomedical sciences are especially disappointing. From the 2004 survey, 91% of scientists in the US are either White or Asian, compared to only 6% of Hispanics and African Americans [9] and this latter number appear to be declining [11] while the percentage of minorities in the population, particularly of Hispanics, is rising. Though the situation continues to worsen, objective assessments of current and new approaches are scant. Although progress has been made to advance participation of traditionally underrepresented minorities in STEM graduate education, a lack of parity remains in comparison to White, Asian, and international students [12].

While a range of factors could account for this dismal situation, the most obvious is the segregation of Hispanics, African and Native Americans into low performing school systems located in pockets of urban, suburban or rural poverty [13]. As of 2005, minority students attending a high poverty secondary school were less likely to graduate high school, attend a four-year college and to graduate from that college compared to White or Asian students [14]. Although a narrowing of the gap for African Americans was reported, no such salutary outcomes were noted for Hispanics. Given current economic conditions, it seems unlikely that this trend has improved [15]. Poverty, discrimination, family stress [16], lack of support networks, low expectations, negative peer pressure, reduced high school resources and lack of enrichment during the secondary school years, have all been cited [13]. The low rate of minority graduates entering into science careers may arise from the lack of qualified faculty, science and technology programs and pre-college preparation programs [17]. Because these students often lack high quality instruction (instructors teaching out of their field of expertise), and science enrichment programs, the students are not as competitive or prepared for Science, Technology, engineering and Mathematics (STEM) based programs, causing them to fall further behind as college students [18]. Pre-college student enrichment programs would appear to be a necessary component in providing minority students the academic resources they need to be more competitive for science and engineering programs in college.

Few studies, however, provide quantitative evidence for successfully promoting an interest in science, particularly among minorities. Marcelin surveyed high school participants in the Junior Fellows Program of the New York Academy of Medicine, between 1996-2000 [19]. These students (86% minorities) attended lectures, took hospital tours, met with health professionals in small groups and, wrote literature based research papers. 56% of the respondents said that the program increased their interest in a health or science career. Similarly, Michalek and Johnson evaluated the effect of summer research programs on interest in a science career. Participants in 1995-2003 included 35% underrepresented students. In all, 85% of these high school students reported that they would like to pursue a career in a scientific field upon completion of the program [20]. Thurmond and Cregler tracked underrepresented minority students who participated in an enrichment program at the Medical College of Georgia between 1984 and 1991. The authors emphasized the importance of summer programs and mentoring, but noted that many of these students lost interest when they encountered difficult science courses. This problem was also identified in studies of undergraduate programs [21]. Dirks and Cunningham found that students in their Biology Fellows Program at the University of Washington benefited from a program in which they were taught science process skills such as data analysis, graphing data, and scientific writing [22]. Villarejo et al. [23] noted that an undergraduate curriculum that includes supplemental instruction in mathematics and chemistry was a large factor in determining academic success.

STEM Careers and Minority Students

In the U.S., too few students are choosing a STEM career and there is concern that those who do, may not meet the country's future employment needs [9,24]. Interest in STEM careers appears to be particularly low for African American and Hispanic students [9,11]. There are many possible reasons for this lack of participation of students from minority school districts: lack of interest, lack of information about the opportunity, or financial and practical roadblocks. There is evidence to suggest that girls benefit from mentoring more than do boys [25,26] although the gender-specific benefit of a mentored research experience is unknown. Parental understanding, acceptance and consent are essential components of mentoring [25].

The important issues of retention of minority college students, their college graduation and long-term career outcomes [27] should also be evaluated. Any positive impact of participation in a short term science enrichment program will probably wane and have minimal influence on career choice decisions [21]. Clearly, there is a need to maintain and increase interest in STEM careers beyond what can be achieved in the classroom. This problem is exacerbated for students enrolled in low-performing schools. The results of retrospective analyses [23,26-30] suggest that participation in a mentored research program may significantly increase the likelihood for choosing a STEM career. To the best of our knowledge, this idea has not been tested with a prospective, randomized study.

Measuring the quality of the faculty-student mentoring relationships is important to understand whether program participants are well matched and our mentors are performing well. Recognizing the importance of family in fostering academic growth in students [31] is also critical in mentoring programs. The published study of the Meyerhoff Scholars Program [28] provides some information regarding mentoring. This study examined African-American students who were offered scholarships to a special scholars program at the University of Maryland. The authors compared students who accepted this scholarship with students who declined the scholarship. Thus, both groups of students were qualified to receive the scholarship. The study reported the standard deviation of GPA scores among these high achieving students (10%). They also reported the percentage of students who majored in an SEM discipline (Science, Engineering, and Mathematics). 87% of the students who accepted the Meyerhoff scholarship went on to graduate with a degree in SEM (this includes several students who had not yet graduated, but were on track to get the SEM degree). In contrast, only 49% of those who declined the Meyerhoff scholarship went on to graduate with a SEM degree.

Mentored Research Experience

Mentoring is an ancient, perhaps primal, approach to education and socialization. Mentoring can be defined as a relationship between an older (mentor) and a younger person (mentee) in which the senior person's knowledge and guidance are intensively transmitted to the mentee over a period of time [32]. The acquisition of knowledge and development of skills encompassing social and culture norms are central to the mentoring process [33]. This is often accompanied by development of an emotional bond consisting of mutual respect, and identification of the mentee with the mentor. During the 20th century, mentoring was used in the US to address the problems of juvenile delinquency [31]. Over the past 20 years, the US has experienced an upsurge in support for mentoring programs that target the at-risk youth population. Government sponsored and school based programs have garnered huge financial support with more than 4000 agencies and programs offering youth mentoring [34].

Most often, so-called natural mentoring occurs between adolescents and nonparental adults, with the process being mostly informal, unstructured and sometimes infrequent. Despite an unstructured or natural character, at-risk youth having these relationships have improved educational and financial status and fewer health problems [34]. Far fewer mentoring experiences involve relationships that are structured and formalized. Big Brothers/Big Sisters is the most well-known mentoring organization for at-risk youth. Participation in this program has been shown to improve scholastic competence, parental and peer relationships, and reduce the risk of drug abuse and future criminal behavior [35]. Although the mentoring relationship can produce positive outcomes, meta-analysis of such programs has shown that their long-term benefits to the mentee can be quite small. On the other hand, improved mentoring programs that involve appropriately matched, highly committed participants who attain deep connections can be very effective, especially if they are focused on specific goals, such as sports or academic programs.

In areas of academic improvement and career development, various successful programs have been instituted. One such program - "Career Beginnings', which focused on minority 11th and 12th grade students in six different cities, found that participants were more likely to attend college after completing the program. The Sponsor-a-scholar program (Philadelphia, PA) found that low achieving students significantly improved their GPA's and were more likely to attend college after the program [36]. On the other hand, students with a high level of academic achievement did not show further improvement. Another program, Myerhoff Scholars (Baltimore, MD) targeted high achieving African American students entering the University of Maryland. This successful program enhanced the academic performance of University of Maryland's African American students and increased the proportion tracking into STEM [30]. Initially, it was reported that those who eventually obtained science PhD's often cited undergraduate research experience as an important factor in their career choice [28]. A later assessment suggested that this was not statistically significant. The latter study noted that there was no determination of the quality of the high school research experience in the Meyerhoff Scholars program.

The impact of two science enrichment programs on the science attitudes of 330 gifted high school students was evaluated using a multi-method, multi-perspective approach that provided a more comprehensive evaluation of program impact on science attitudes than did previous assessments of science programs [25]. Although pre–post comparisons did not indicate positive impact on science attitudes, other measures provided strong evidence of program effectiveness. The study concluded that students involved in science enrichment programs demonstrated increased interest and confidence in science following these programs. These types of enrichment programs were most beneficial to girls and children with supportive faculty, mentors and family [25].

The psychosocial model of mentoring emphasizes the influence of "mutuality, trust and empathy" as enhancing social, cognitive, emotional, and identity development [31]. Acting synergistically with a supportive family environment, mentoring is believed to reinforce positive behaviors including academic achievement and improved well-being. Although other less costly methods of mentoring have been devised, such as group, team and peer, the deeper aspects of mutuality, trust and empathy are unlikely to be replicated in those approaches.

In a retrospective study of high achieving minority undergraduate students in the Biology Undergraduate Scholars Program at UC Davis, it was found that a similar research experience was transformative and positively influenced the later career paths of minority students [23]. A review of the Thayer Program (Boston, MA) reported that high school students who had the opportunity for a mentored research experience had a higher probability of entering and maintaining a career in the sciences [29], although no analysis of minority student performance or career choice was reported. Overall, these studies are in accord with the contention that a mentored research experience can be a positive contributor, indeed a determining factor, in the decision to pursue a career in research. The results are consistent with the assertion that "when students are provided the opportunity to engage in state-of-the-art biomedical research, with appropriate facilities, support and mentorship, their appetite will be whetted to enter a career in biomedical research" [37].

It is generally agreed that the traditional mentoring relationship can be extremely valuable to the young mentee. In the worst case, however it could be damaging to the aspirations and even the self-image of the protégé (as in the case of an abusive or indifferent mentor) or, compared to group didactic learning activities, it may simply be a waste of significant invested effort (the ineffective mentor and/or disengaged mentee). In the case of mentored research, the ill-prepared student could suffer from the experience, and may develop a negative attitude towards the scientific process which is always challenging and can often be tedious [38]. Those of us who have mentored graduate students have become accustomed to this model, and have seen its successes (and failures), but we are unlikely to recognize any other approach to inculcating and developing young scientists, which begs the question: Is a mentored research experience the best investment to attract minority students to the sciences? Given the substantial energy invested by the mentor and mentee, and the significant financial support required in a formalized setting, society should expect that these relationships be productive for at-risk youth, compared to less costly learning experiences [39]. Few studies, however, have evaluated the effectiveness of this mentoring approach for underprivileged/under-represented students, particularly when coupled to a scientific research experience, and none have used a prospective randomized approach to track the results from high school through college summer.

It has been established that supplemental instruction is also associated with enhanced academic performance by minority students. For example, the Biology Undergraduate Scholars Program has shown that those students having engaged in supplemental instruction, outperformed non-participants, as well as students with better SAT scores, in chemistry and calculus [40]. It could be argued that this is a superior use of the student's time, energy and scarce resources compared to a mentored research program.

Mentored Research

Many adolescents are still highly receptive to mentoring type relationships [31] when they start high school. Consistent with attachment theory, positive antecedent parental bonds or prior natural mentoring relationships with non-parental adults, have been shown to promote effective future mentoring relationships between the child and non-parental adults; therefore, those who may benefit most from mentoring are likely to already have supportive parenting or have well established relationships with non-parental adults. Although the frequency of natural mentors may be similar for boys and girls [31], it is unclear how gender differences may be related to the benefits of a mentored research experience.

It is important to note that mentoring relationships should be long-lasting-those of too brief duration can actually do more harm than good [36] and at best have little positive benefit. To summarize, as talented students from minority school districts fail to pursue a career in STEM, it is highly imperative to take appropriate measures to inculcate the culture and excitement of scientific endeavors, their principles and rewards in these adolescents. Mentoring and teaching should learner-centered. Introductory interactive lectures followed by question guided discussion cover basic concepts designed to stimulate and excite the students. While the advanced nature of the topics often exceeds the capacities and backgrounds of some students, these difficulties are not necessarily a setback but rather, are desirable. Challenging students to struggle with concepts may actually promote learning. Consider, for example, the concept of "translation". A basic science lecture on protein function will include the "translation" step. To reinforce this difficult concept, the lecture should be followed by a workshop discussing "translation" of experimental findings from the basic sciences into practical clinical applications. The fuller comprehension of science requires such an integration of various knowledge bases. The introductory lecture followed by a relevant laboratory or applicable experience motivates students to organize, connect, and realize new information. This allows us to bring back the idea of improving science education through conceptual linkage and growing logical connections between subject context and real world examples.

In the typical high school science curriculum the students are burdened/forced to acquire knowledge by the teachers in the absence of critical discussion and are often confined to the narrow subject matter and goal at hand. However, many bright students of high school age have the attitude that they also want to be on the giving end rather than always on the receiving end of the knowledge transaction, but this is actively suppressed by today's focus on rote learning. The idea that "the student should challenge the teacher" should be incorporated into teaching. This concept will encourage students to be more than passive learners, to think critically and challenge authority.

Conclusion

By the completion of any mentoring program some of the aims need to be accomplished. Impart awareness of the sciences to students. Impress high school students with the notion that "SCIENCE IS COOL" by bringing the students and the medical school faculty together. Provide select students from minority school districts with the opportunity to work with a university faculty member in a one-to-one long-term scientific research mentoring program. Assess the effectiveness of our program to attract more talented students from minority schools into scientific careers. Provide new insights into the failure of our society to attract these bright and talented students into scientific careers. Compare the effectiveness of short-term vs. long term engagement in science and research with regard to students choosing science as a major and their academic success in college. We expect that outcomes from educational studies will contribute to guidelines and future directives to increase the number of students, particularly from underserved minority schools choosing a STEM career.

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