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Secondary Education Systemic Issues: Addressing Possible Contributors to a Leak in the Science Education Pipeline and Potential Solutions

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To maintain the legacy of cutting edge scientific innovation in the United States our country must address the many pressing issues facing science education today. One of the most important issues relating to science education is the under-representation of African Americans and Hispanics in the science, technology, and engineering workforce. Foreshadowing such under-representation in the workforce are the disproportionately low rates of African American and Hispanic students attaining college degrees in science and related fields. Evidence suggests disparate systemic factors in secondary science education are contributing to disproportionately low numbers of African American and Hispanic students in the science education pipeline. The present paper embarks on a critical analysis of the issue by elucidating some of the systemic factors within secondary education that contribute to the leak in the science education pipeline. In addition, this review offers a synthesis and explication of some of the policies and programs being implemented to address disparate systemic factors in secondary schools. Finally, recommendations are offered regarding potential mechanisms by which disparities may be alleviated.

KEY WORDS: science education; teacher quality; coursework; funding; minority students.

The societal and global implications of racial and ethnic disparities prevalent in the science education pipeline are clearly evident. For instance, in 1999, African Americans and Latinos made up only 6.8% (each group at 3.4%) of the number of individuals with a bachelor's degree or higher who were working in a science or engineering occupation (National Science Foundation, 2004), while comprising almost 25% of the U.S. population (U.S. Census Bureau, 2001). Additionally, there is even greater under-representation in certain areas of the science workforce. For instance, African Americans comprise less than 2% of the individuals employed in occupations in the life sciences (i.e., chemistry, biology, and other related sciences) and Hispanics make up only 2.6% of those employed in physical science occupations (National Science Foundation, 2004). In addition, the statistics that speaks most sharply to the extent of under-representation are the percentages of African Americans and Hispanics (2.3 and 2.7%, respectively) out of all individuals who have completed a doctoral degree and are employed within science and engineering fields, (National Science Foundation, 2004).

Such under-representation in the workforce is resulting, in part, from a leak in the science education pipeline. Specifically, the issue refers to the disproportionate rates of African American and Hispanic students pursuing and attaining college degrees in the sciences and related fields. The severity of the leak is not necessarily indicated by the proportion of under-represented minority students intending to major in science and related fields, but rather the proportion of minority students who complete their degree requirements. More specifically, African American and Hispanic students, in 1998, made up 22% of all first-year undergraduate students at institutions of higher education and comprised 19% of the first-year students intending to major in science or engineering

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(National Science Board, 2000). While only 50% of students, in general, who intend to major in science or engineering actually graduate with a degree in these fields of study, the percentage is even lower for under-represented minority students. In fact, in 2001, African American and Hispanic students made up 13.6% of all students graduating with concentrations in any of the sciences (including social sciences and psychology), mathematics, or engineering (National Science Foundation, 2004), while representing approximately 31% of the U.S. population 18–24 years old (U.S. Census Bureau, 2003). The latter percentage indicates we are far from a level of parity in the opportunity to pursue science fields. Moreover, in 2001, African Americans comprised only 2.9% and Hispanics 3.6% of the doctoral degree recipients in the biological, computer, and physical science fields (National Science Foundation, 2004). Even taking into consideration the social sciences and engineering, the percentages (4.3 and 4.2%, respectively) are highly disproportionate to their representation in the population.

Projections for the demographic shift by the year 2030 indicate African Americans and Hispanics will make up a combined 34% of the U.S. population (U.S. Census Bureau, 2004). A necessary component for fulfilling the demand for science and engineering expertise that will be needed in this century is to promote equitable opportunities for all students to pursue science curricula in higher education. Adequate preparation and training in high school is essential for students to fulfill core requirements needed for college. Perhaps more importantly, high school science education provides an opportunity to establish students' interests and preparation for pursuing more advanced, and often more specific, areas of study in college.

Disparities among racial and ethnic groups in secondary education systemic factors, such as teacher quality, course taking, school funding, and expenditures on instructional resources, are considered key contributors to the leak in the science education pipeline. Given evidence of such disparities among students' secondary education experiences, it is argued that certain groups, specifically, African American and Hispanic students, are less likely to receive adequate exposure to and preparation for rigorous science college curriculum. Addressing the systemic disparities in secondary education is a key step in moving toward equity in opportunities and, in doing so, tapping into previously untapped potential.

DISPARITIES IN SYSTEMIC FACTORS

Teacher Quality

Teacher quality is thought to be one of the most prominent factors impacting student achievement (Greenwald *et al.*, 1996). Greater attention in the past decade has been placed on addressing teacher quality in secondary science education. This is, in part, due to the results from the Third International Math and Science Study indicating U.S. twelfth graders on average scored lower on the general science assessment than students from most other participating countries (National Center for Education Statistics, 1999). At the present, subject matter competency is considered a key indicator of high-quality science teachers (National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Commission on Teaching and America's Future, 1996; National Science Board, 2004).

Various indicators of subject matter competency are being utilized by states and districts, specifically undergraduate coursework in the primary subject taught and subject certification exams. There is moderate empirical support for the relationship between teachers' undergraduate coursework and students' achievement in science classes (Goldhaber and Brewer, 1996; National Center for Education Statistics, 2001). Some of the research has found a rather puzzling negative relationship with teacher coursework in the sciences and student achievement (Monk, 1994; Monk and King, 1994). Further research is needed to clearly discern the impact of teachers' undergraduate science coursework on student learning in science secondary courses. In addition, there is a paucity of literature examining the effect of teacher coursework in the sciences and subject certification on lower income and minority students' science achievement. Nonetheless, it is very common for such teacher qualifications to be used as indicators of teacher quality.

Greater attention to the achievement gap among racial and ethnic groups has spurred researchers, policymakers, and administrators to address the question of who has access to qualified teachers. The Schools and Staffing Survey (SASS) out of the National Center for Education Statistics is the most comprehensive dataset available to address this question. Researchers using data from the Schools and Staffing Survey most often designate *out-of-field teachers* to mean teachers with less than an undergraduate minor in the subject they are primarily assigned to teach. Based on data from the 1993–1994 Schools and Staffing Survey, Ingersoll (2002) found minority enrollment in schools significantly predicted the percentage of courses taught by out-of-field teachers. Moreover, results from the analysis of the 1999–2000 Schools and Staffing Survey indicate out-of-field teaching, in general, is more prevalent within schools serving predominantly minority students than predominantly White schools (Jerald, 2002).

In regard to science courses, specifically, Ingersoll (2002) found greater percentages of out-of-field teachers in predominantly minority schools than in schools with low-minority enrollment. Based on data from the 1999–2000 Students and Staffing Survey, The National Science Board (2004) points out that students in predominantly minority schools are more likely to be taught science by out-of-field teachers; however, the results were not statistically significant. It is possible we are making progress toward alleviating the gap in who gets the teachers most highly trained in the subject matter they teach, yet further examination of the prevalence of out-of-field teaching in science courses by school type is necessary to corroborate these results. This is especially true given the different methods used to analyze prevalence of out-of-field teaching. Ingersoll (1996) addresses in more depth the distinction between analyzing the percentage of students being taught by out-of-field teachers and the percentage of teachers teaching out of field within schools or districts.

Another indicator of teacher quality, teacher experience, has been linked to students' achievement (Greenwald *et al.*, 1996; Rivkin *et al.*, 2001). Throughout the K-12 educational system, African American and Hispanic students are more likely to encounter young, inexperienced teachers (Rivkin *et al.*, 2001). Lankford, Wyckoff, and Papa (2000) found urban schools in New York, which have high percentages of minority students, more often than suburban schools hired teachers with no prior teaching experience. This may speak to the difficulty many inner-city schools have recruiting an adequate pool of candidates for the selection of new hires (Roza and Hill, 2004).

In addition, the revolving door within the teaching field (i.e., teacher attrition) is more prevalent in lower income and predominantly minority schools (Freeman *et al.*, 2002; Hanushek *et al.*, 2004). For instance, Freeman, Scafidi, and Sjoquist (2002) found schools in Georgia with high African American student enrollment experience much greater teacher attrition than predominantly White schools. They also found such attrition is on the rise. Those students regularly exposed to the inconsistency that results from teacher turnover are at a disadvantage. In addition, the burden of constantly replacing teachers is both work and fiscal intensive. Ingersoll (2002) points out schools often missassign current teachers as a means of dealing with teacher attrition in the most cost effective way possible, which takes us back to the issue of out-of-field teaching. Evidence suggests the pattern of teacher attrition in predominantly minority schools can be linked to the challenges perceived by teachers, potentially due to working with greater proportions of students living in poverty and achieving at lower levels than their appropriate grade lavel (Prince, 2002). In addition, cultural differences between the predominantly White teaching force and minority students may play a role in the perceived challenges teachers face. Addressing the issues of hiring and retaining high-quality teachers to take on more challenging positions is a major component to alleviating disparities in who receives highly qualified teachers.

Advanced Science Coursework

Another prevalent systemic factor disadvantaging minority students is the gap in who takes advanced science coursework. High school coursework in the sciences is a gateway into college science concentrations, as well as a necessary component of students' success in the workforce and day to day functioning within today's highly technological society (Clark, 1999). A push for all students to engage in higher level academic courses initially came out of the National Commission on Excellence in Education's report in 1983, *A Nation at Risk.* The Commission recommended states raise high school graduation standards and incorporate a core curriculum that included, among other things, 3 years of science.

The benefits of higher level courses include having greater knowledge and skills to apply to the workplace and daily tasks, and, very importantly, having the opportunity for further study in science and related fields. Science coursework is considered to be essential, yet not necessarily sufficient, if students are to be adequately prepared for science coursework in college. Another imperative for success in college level science is students' thorough grasp of basic core concepts in the area of science they pursue. The research supports conventional theories that more coursework is related to greater competency. For instance, taking higher level science courses (e.g., biology, chemistry, or physics) is related to higher average scores on the 12th-grade science NAEP assessment (Perkins *et al.*, 2004). Futhermore, students who were engaged in a science course at the time of the 12th-grade NAEP assessment scored higher (O'Sullivan *et al.*, 2003). The same result was true for students who had taken an AP science course as compared to students who had not.

The proportion of students taking higher level science courses, such as chemistry or physics, has increased since 1983 (Council of Chief State School Officers, 2003), yet gaps still exist among racial and ethnic groups. For instance, based on data from a study conducted in 1996 in collaboration with NAEP, O'Sullivan and Grigg (2001) found African American and Hispanic students were less likely to have taken more than five semesters of science. In addition, results from a sample of students who had taken, or were enrolled in, a science AP course, indicate African American and Hispanic students are less likely to have engaged in at seven or more semesters (3.5+ years) of science coursework compared to White students. In terms of specific courses taken, the Council of Chief State School Officers' (2003) analysis of data from the 1998 High School Transcript Study found 53% of African American students and 44% of Hispanic students took chemistry in high school in comparison to 63% of White students.

In addition, disparity among racial and ethnic groups participating in AP science courses is a prevalent issue. African American and Hispanic students are far less likely than White or Asian students to take AP science. Out of all students who took AP science examinations in 2002, the national average was 4 and 6%, respectively, for African American and Hispanic students (College Board, 2002a). Granted not all students who enroll in AP courses take the exam, yet it is likely there is only a slight underestimation for students taking AP courses. The issue at hand is the under-representation of African American and Hispanic students participating in AP science. In 2002, African American and Hispanic students represented 34% of the public school population (National Center for Education Statistics, 2003a). This disparity is not easily teased apart. The issue of access to advanced courses is a greater problem for minority students (Oakes, 1990). There are additional cogent factors disadvantaging minority students in the engagement and achievement in higher level science coursework. For instance, tracking systems disproportionately place minority students in lower tracks (Wheelock, 1992), thereby perpetuating a gap in the participation in higher level science among racial and ethnic groups. Another argument claims the way in which science is traditionally taught lacks culturally relevant methods for engaging minority students effectively in science (Ault and Norman, 2001). Without adequate engagement, a lack of interest or motivation may prevent minority students from continuing on into courses like AP biology or AP chemistry, and certainly from pursuing science in college. In addition, teacher expectations and encouragement certainly influence students' interest and desire to pursue certain courses, such as AP, and their level of dedication to such courses. Ferguson (2002) found, in suburban schools, teacher encouragement was a prominent motivator, in general, for minority students, especially African American students. However, minority students more frequently than their White peers endure lower levels of expectations and less affirmation from teachers (Norman *et al.*, 2001).

The discrepancy in science course taking, especially AP science courses, speaks to the disadvantage certain groups face. The rigor of college science curriculum is best tackled with solid preparation. In order to achieve adequate representation of African Americans and Hispanics in college science degree attainment and alleviate the workforce disparities in these fields, science course taking patterns in secondary schools must be addressed.

Funding and Resources

The debate as to whether school expenditures are related to student achievement still exists; however, recent research provides solid evidence in support of the conventional assertion that funding is indeed related to achievement. A meta-analysis conducted by Greenwald, Hedges, and Laine (1996) reanalyzed prior research and employed more appropriate statistical techniques to find the relationship between resources and student outcomes was statistically significant. Given the magnitude of the effects were rather large, the authors concluded that "moderate increases in spending may be associated with significant increases in achievement" (p. 362). In addition, research shows greater school expenditures reflected in higher cost school inputs, such as class size and hiring teachers with higher test scores and more education, are significantly related to student outcomes (Ferguson and Ladd, 1996). Moreover, Grissmer *et al*., (1997) found reductions in class size, a resource indicator, to be significantly related to lower income and minority students' performance on NAEP, while the same impact was not found for more advantaged White students. The latter finding suggests additional funding is better served through strategic appropriations to more disadvantaged students. In further support, research found gains in achievement are significantly affected by school expenditures for students from lower-socioeconomic backgrounds (Grissmer *et al*., 2000).

Increasing the allotment of funding to more disadvantaged students is not an easy feat. In fact, resource disparities continue to pervade our K-12 educational system. Carey (2004) points out, in the majority of states, inequitable state and local revenues are evident among districts with varying poverty levels, as well as between predominantly minority and predominantly White districts. Such funding disparities occur, in large part, due to the funding structure of the educational system and funding formulas. In particular, the educational funding systems' heavy reliance on local tax revenues contributes substantially to inequitable funding (Rebell, 1998). Minority students disproportionately live in districts with lower-property values, thus placing them at a disadvantage within the educational system. In addition, states' funding formulas take into account senior level staff which benefits schools that have been successful in retaining teachers and disadvantages schools fraught with high proportions of inexperienced teachers. More specifically, weighting procedures are incorporated to adjust for higher salaries assigned to teachers with more experience and education. The funding inequities are further manifested within districts. In part, this is due to a failure to ensure experienced teachers are equally dispersed within a district. It is common for teachers to work for a few years in high poverty or predominantly minority schools, after which they migrate to schools within the district that have lower rates of poverty and minority students (Krei, 1998). Within districts, initial allotment of funding for teachers' and administrators' salaries is most often based on the district average, yet school expenditures are based on real salaries of teachers within schools. Money allotted for teacher salaries is often shifted to those schools with more high-salaried teachers. For example, Roza and Hill (2004) found inequitable per-pupil spending across schools within four large districts for this very reason. Higher poverty and predominantly minority districts and schools, which struggle to hire and retain experienced and advanced-degree teachers, are placed at a severe disadvantage within states' and districts' funding procedures. In addition, funding inequity goes beyond the disparate dollar amounts allotted to schools. It is further reflected in the barrier certain districts and schools face which inhibits the ability to adequately address specific student needs (Ucelli *et al*., 2002). More specifically, the specific needs of certain students are not adequately taken into account by state or district funding formulas. Given the additional expense necessary for attending to the needs of English language learners, lower-income and lower-achieving students, equity in dollar amounts certainly does not mean equitable resources and opportunities in districts and schools with greater numbers of high need students.

Funding allotments must cover a conglomerate of expenditures, and in schools with a large proportion of high needs students, purchasing or updating instructional equipment, especially lab equipment or technology, is likely to be sacrificed. Evidence suggests inequities in school funding negatively impact the instructional opportunities afforded to lower income and minority students (Ferguson, 1991; Kozol, 1991). Further evidence finds certain groups of students are more apt to be affected by the disparity in classroom resources to advance learning, specifically technology and laboratory equipment. For instance, African American and Hispanic eighth graders engage in hands-on activities with science equipment, such as thermometers, electricity, or chemicals less frequently than White or Asian students (National Center for Education Statistics, 2003b). In addition, while computer use in schools has increased tremendously in the past 10 years, there remains a gap in access, with lower income and minority students on average less likely to use computers and the internet in school (Anderson and Ronnkvist, 1999). Such inequities in opportunities to learn science and technology are likely a reflection of inadequate and disparate funding. In addition, the resources necessary for purchasing and sustaining technology equipment are enormous, in general. Through an examination of the barriers school districts experienced in the successful implementation and maintenance of technology programs, Joyner (1998) found that competing financial needs taking priority was one of the major obstacles.

It is of great importance to ensure all students have equitable opportunities to participate in hands-on science activities and utilize technology. These experiences foster active learning and interest, as well as contributing to a better grasp of scientific phenomenon and the basics of technology. In particular, research shows a relationship between exposure to hands-on science activities in the classroom and students' achievement in science (National Center for Education Statistics, 2001). In addition, more frequent use of computers, specifically to collect and analyze data, in high school is associated with significantly higher scores on science assessments (O'Sullivan *et al.*, 2003). If students can leave high school having acquired basic technology skills and attaining proficiency in science courses, they will be better prepared for the job market and for college. In addition, students who've used more advanced technology and gained experience with laboratory science are at a tremendous advantage in pursuing science, engineering, and technology concentrations in college. Unfortunately, under-represented minority students are not as likely to have such opportunities as other students. Consideration must be given to systemic funding inequities and the adequacy of funding to address the specific needs of students within districts and schools, which includes attention to ensuring all students receive equitable instructional opportunities.

EXAMPLES OF POLICIES AND PROGRAMS

Teacher Quality

Current federal policies (i.e., No Child Left Behind) require by the year 2005–2006 that all teachers in core subjects are highly qualified. The federal government has provided states with guidelines for defining highly qualified. It is advantageous for the federal government to employ high standards for teachers; however, it is not clear how states, districts, and schools will undergo such a transformation to have all students, regardless of race, being taught by highly qualified teachers. In particular, the prevalent issue is how to successfully recruit and retain qualified teachers where they are needed most. Most states and districts are aware of the situation, but have not, as of yet, attempted to address the issue. Higher salaries are touted as the most effective strategy to entice and keep high-quality teachers at schools most difficult to staff (Hanushek *et al.*, 2004). Hesitation to adopt such tactics may very well be due to limited evidence of outcomes, as well as resistance to changing the current salary structure. Initial evidence in support of the efficacy of salary incentives in recruitment comes from a report by Prince (2002) on an initiative in New York City which offered 15% pay increases to highly qualified teachers interested in transferring to certain low-performing schools. The report indicates 600 applications from teachers were filed in response, of which half were accepted.

Greater considerations have been given to financial incentives which aim to supplement the traditional single-salary pay scale. Again, however, states and districts have been slow to implement targeted recruitment and retention efforts involving substantial fiscal incentives for highly qualified teachers to teach in more challenging schools. Two exceptions are New York and California (Prince, 2002). Both states' initiatives are in nascent stages, therefore long term results cannot be discerned. In New York, a key component of the Teachers of Tomorrow program is the annual bonuses of up to $10,000 for qualified teachers willing to teach where they are needed most. Overall, in 2000 and 2001, New York expended $25 million to fund Teachers for Tomorrow. California allocated over $300 million for their teacher recruitment and retention efforts. Highlights of California's program also include annual bonus up to $10,000, as well as loan forgiveness up to $11,000. In addition, California offered grants to school districts which were used for signing bonuses, to supplement teacher compensation, and to improve working conditions. In one school district, such efforts resulted in being able to fill all teacher openings with certified teachers between 1999 and 2001 (Prince, 2002).

Another example of strategic efforts to address recruitment and retention of highly qualified teachers to predominantly minority and high-poverty schools is the Benwood Initiative in Chattanooga, Tennessee (Public Education Foundation, 2004). While the initiative is focused on primary education, the underlying structure of the program can serve as a model for secondary schools. Specifically, the program incorporates housing incentives, free tuition for teachers wanting to pursue a master's degree in urban education, and bonuses based on students' performance gains. In addition, to raise the quality of the teachers currently employed, a substantial amount of resources were put into subject-specific training. This initiative has made significant strides at recruiting and retaining highly qualified teachers in nine urban schools and producing substantial student achievement gains (Public Education Foundation, 2004). Policy makers, administrators, and educators must give greater consideration to fiscal mechanisms, used for both offering financial incentives and the improvement of working conditions, for the successful recruitment and retention of highly qualified teachers in all core classes within predominantly minority and high-poverty schools.

Advanced Science Coursework

Today more than ever, there is a need for higher level cognitive skills in the workplace. There is also an increasing demand for individuals pursuing the science, engineering, and technology workforce. These two key factors are touted as reasons behind the push for more students to engage in high-level science courses within secondary education (Barth, 2003). The poor performance of students from the United States disclosed through international comparisons on science achievement has also spawned the drive to increase students' science course taking, in addition to addressing the rigor and content of science courses (National Center for Education Statistics, 1999). State-wide efforts toward establishing or mandating all students participate in a rigorous academic high school curriculum have gained momentum. For instance, in 2004, Texas implemented a college-prep course sequence as the expectation for all students, unless they and their parents consciously choose to opt out (Barth, 2003). In addition, Indiana is quite far along in giving consideration to requiring a college-prep curriculum for graduation which would include, among other things, science coursework through chemistry (Hupp, 2004). It is extremely important that outcomes are closely examined to discern the impact such policies have on alleviating gaps in course taking and any unintended negative consequences, such as higher drop-out rates.

The National Science Foundation has been a major contributor to the concerted attention addressing the under-representation of certain groups in science and related fields. In particular, programs through the National Science Foundation have been created to address the gap in advanced science course taking among racial and ethnic groups. One example of such a program is the Comprehensive Partnership for Mathematics and Science Achievement: CPMSA (Kim and Crasco, 2003). The CPMSA program has established partnerships with urban schools within 27 mid-sized cities with a goal to improve and advance students' educational experience in math and science. More specifically, the initiative's primary aim was to increase under-represented minority students' enrollment in advanced mathematics and science coursework, in addition to improving students' achievement, advancing teacher preparation, and promoting interest in mathematics and science fields. The partnerships have been formed to assist in creating systemic changes through strategic plans. Districts used a combination of methods specific to their unique situations. Some of the specific actions employed to address the primary goal include: eliminating tracking systems, establishing either curriculum recommendations or requirements including higher level science courses (e.g., chemistry and physics), academic support (e.g., tutoring), science enrichment programs with businesses or foundations that fostered laboratory and research experiences, and outreach to parents to convey the importance of students' participation in higher level coursework. In addition, the initiative incorporated substantial investment in professional development to enhance teachers' content and pedagogical preparation. Certain partnerships have experienced more success than others. Kim and Crasco (2003) conducted case studies on five partnerships which elucidates in more depth specific outcomes. Results from two of the full cohorts (1993 and 1996) demonstrated progress in alleviating the advanced science participation gap between under-represented minority students and White students (Figs. 1 and 2).

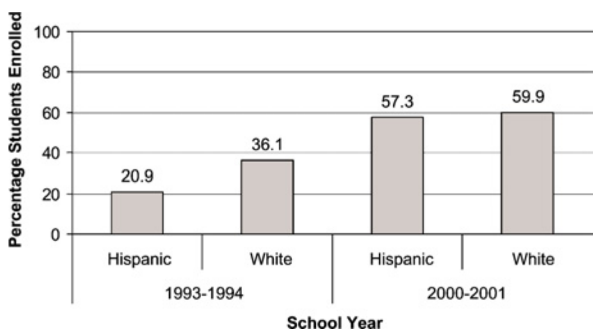

Fig. 1. Percentage of students from the 1993 CPMSA cohort (Brownsville) by race/ethnicity enrolled in higher level science courses, specifically, biology, chemistry, and physics (Kim and Crasco, 2003).

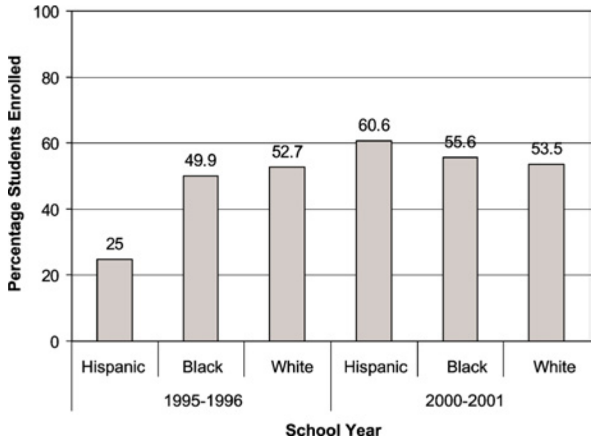

Fig. 2. Percentage of students from the 1996 CPMSA cohort (East Side Union, Jackson, Newburgh, Paramount, Prince George's County, and Roanoke River Valley) by race/ethnicity enrolled in higher level science courses, specifically, biology, chemistry, and physics (Kim and Crasco, 2003).

In 1993, the National Science Foundation also launched the Urban Systemic Initiative: USI (Kim, Crasco, Smith, Johnson, Karantonis, and Leavitt 2001), a program quite similar to CPMSA. Through the USI program, partnerships have been established in 22 urban public school districts in large cities. The goal of the program was to assist with large scale systemic reform efforts to increase urban students' enrollment and success in higher level mathematics and science courses. Similar tactics utilized in the CPMSA program were employed through USI to increase under-represented minority students' enrollment in college prep science coursework. Kim and Crasco (2001) found similar results to those found in the CPMSA program. More specifically, increases in science course participation and achievement for under-represented minority students outpaced gains made by other students, thereby reducing the achievement and course-taking gaps. In addition, Kim and Crasco (2001) noted the overall emphasis on systemic changes speaks to the likelihood progress will be sustainable.

States, districts, and schools have put in place initiatives aiming to increase participation in AP courses; however failure to embody strategic efforts targeting minority students will not necessarily result in equitable outcomes, as evidenced in the state of Massachusetts. More specifically, Massachusetts, between 1996 and 2002, set aside a significant amount of funding to advance high-level course taking Massachusetts State Department of Education (2002). In particular, they established a fee reduction program for low-income students taking AP examinations and competitive grants for the expansion of AP programs to more schools. It is quite possible that by 2002 more schools were offering AP courses, and that is indeed the claim they made based on results from a survey that had a 50% response rate. However, in 2002, 5% of students from public schools taking an AP examination and 4% of science AP test takers in Massachusetts were African American or Hispanic (College Board, 2002a), while representing almost 20% of public school students in Massachusetts (National Center for Education Statistics, 2003a). In order to address the disparities in AP enrollment effectively, efforts to promote access and participation should strategically target minority students and, especially, predominantly minority schools.

An example of such effort is apparent in College Board's promotion of equitable access to AP courses. In particular, they have utilized national colloquiums and on-line resource guides to disseminate information and promote discussion around issues of equity in access. Moreover, College Board offers competitive funding opportunities that assist with the start up costs for expanding access to AP courses and training for teachers in disadvantaged and predominantly minority schools. They have also taken the liberty of highlighting instances of success in schools and districts employing strategic efforts to increase under-represented minority students' participation in AP courses (College Board, 2002b). One example is Mount View High School, a suburban school within the Mount View-Los Altos Union high school district. Mount View High removed constraints for participation in AP courses, established outreach programs in Spanish to educate parents about the importance of engaging in rigorous curriculum, and had AP teachers participate in diversity training programs. The school witnessed a tremendous increase in Hispanic students' participation in AP courses, although not reaching full parity. For instance, in 2000–2001, Hispanic students represented 7% of students taking AP courses while comprising 13% of the schools' student body. Another example of successful efforts is seen in Guilford County Schools, in Greensboro, North Carolina. In this case, schools within the district actively recruit students for AP courses. This includes students who show any signs of potential for engaging in the rigors of such courses. In 2002, African American students made up one-third of the district and 17% of AP examinees. In the state of North Carolina, African American students make up 31% of public schools and 9% of AP examinees. Although North Carolina still has a long way to reach equitable participation, Guilford County Schools are noteworthy for making great strides. Even greater success is evident at Henry T. Gunderson High School in the San Jose Unified School District. Specifically, 42% of AP examinees and 43% of the school are Hispanic students. The key to the schools' efforts was placing high expectations on all students, getting rid of GPA requirements for participation in AP courses, and holding teacher-led study sessions in the evenings and on weekends.

In addition, Florida stands out for its successful state-wide efforts to increase participation in advanced level courses. The Florida Partnership, as it's called, emphasizes increasing access to AP in secondary schools through the expansion of AP programs (College Board, 2002b). The initiative utilizes family outreach in various languages to spur parental involvement by conveying the importance of rigorous academic curriculum. Moreover, the program has incorporated the college preparation process in middle school. The goal is to have students arriving in high school ready to embark on college prep coursework. The results suggest Florida's efforts are working. In fact, the number of African American and Hispanic students participating in AP courses has more than doubled since 1999. While such gains are lauded, more strategic efforts are necessary to increase the participation of African American and Hispanic students in science AP courses. In 2002, there were lower rates for African American and Hispanic students who took science AP exams in Florida (College Board, 2002a), than the percentages for all AP exams combined. With a national agenda for promoting advanced academic coursework, in general, for all students, policy makers, administrators, and educators must not lose sight of more specific issues, such as the under-representation of minority students in advanced science coursework.

Funding and Resources

Some states have begun to address the funding gap between high- and low-poverty districts, as well as between predominantly minority and predominantly White districts (Carey, 2004); however most states or districts have not adequately addressed the funding inequities resulting from both the distribution of high-salaried teachers and the failure to supply adequate funding necessary for higher needs students (e.g., English language learners, low-income and low-achieving students). Again, funding equity does not only mean equal dollars, but also the allotment of resources necessary for equitable outcomes. Ucelli *et al.* (2002) highlight three districts that have moved to student-based budgeting as a means of working toward resource equity. Each district defined such budgeting efforts differently based on their unique situations, yet several underlying principles were adopted. These included budgetary decisions (1) that allow schools greater power in budget decision-making and flexibility in spending and (2) that take into account students' specific needs within schools (e.g., employing weighting procedures for lower-income and English language learners). Through dialogue with representatives from each district, Ucelli *et al.* (2002) found all three districts had achieved their goals of moving toward more equitable funding across schools. More specifically, through student-based budgeting, most schools' were allocated funds that came close to matching what the average district allocations would have been with weighting procedures to account for student-specific needs. Whereas, traditional staff-based formulas within these districts (prior to the enactment of student-based budgeting) resulted in more than 50% of schools receiving funding that deviated substantially from the ideal weighted allocations. Several key challenges with implementing student-based budgeting were noted. In particular, the political ramifications of the "robin hood" effect (i.e., reduced funding to certain schools to level the playing field), the challenge of holding schools accountable for budgetary decisions, and administering adequate training for an effective shift of fiscal responsibilities. Suggestions to address these challenges include establishing greater constituency support for budget reform efforts by emphasizing the importance of such reform to accomplishing larger system goals, gradually phasing in student-based budgeting while ensuring the necessary components are in place for successful implementation, and using formative evaluations as a mechanism for improvement throughout the process. Equitable educational opportunities regardless of race/ethnicity or class are dependent on widespread implementation of funding strategies that fully incorporate students' specific needs.

In addition to overall educational funding structures, efforts have been made to address more specific funding issues. Increasing equitable access to instructional resources, such as laboratory-type equipment and technology, within schools has most often been achieved with the assistance of external funding. For instance, programs such as the Comprehensive Partnership for Mathematics and Science Achievement (CPMSA) and the Urban Systemic Initiative (USI) incorporated an agenda for improving access to hands-on science instruction. Fiscal support for the initiatives came through a variety of sources, including the National Science Foundation, the U.S. Department of Education, corporations, and community sponsors. In addition, funding from states and districts, as well as from Title I, were utilized for these programs, although not necessarily to fund instructional resources directly. There are currently a host of external funding sources that would allow schools to implement more hands-on science instruction, as well as increasing access to technology. One of the major factors that prevent schools from taking advantage of these resources is the staff necessary to complete applications and paper work, not to mention the process of locating funding sources. A case study of five districts' implementation of technology programs reported one of the major barriers for successful implementation and maintenance of the technology programs was the lack of adequate staff to manage the fund-raising efforts (Joyner, 1998). Until systemic funding inequities are alleviated, providing equitable learning opportunities in science and technology for all students will remain a major challenge.

RECOMMENDATIONS

Successful recruitment and retention of teachers competent in their primary assignment area within predominantly minority schools is purported to be contingent upon fiscal measures. Specifically, offering considerable financial incentives and assuring reasonable working conditions are likely to be the most effective methods for increasing the applicant pool of highly qualified teachers and reducing teacher migration and attrition. First and foremost, it is imperative that funding mechanisms are secured to guarantee sustainability. In addition, extensive evaluation of such initiatives is essential for both formative purposes and to ascertain the effectiveness of such efforts. Further consideration must also be given to several unanswered questions. First, will the structure of the current salary system support differentiated pay within more challenging districts and schools? Second, how substantial must fiscal incentives be to recruit and retain highly qualified teachers to certain schools? Lastly, how can schools adequately improve working conditions?

In addition to valuing teachers' skills and expertise through compensation, providing teachers with appropriate training is likely to increase retention. More specifically, professional development and training within education programs should be utilized not only for advancing pedagogical skills in a content area, but also to better prepare teachers for working effectively with students in high poverty and predominantly minority schools. The Benwood Initiative's use of tuition reimbursement for teachers wanting to pursue a master's degree in urban education is a great example of how schools can promote a long-term commitment to educating under-represented minority students.

In regard to coursework, states' implementation of a required core curriculum, including at least 3 years of science, is advantageous for both students and states. For students, it provides greater opportunities for success in college. Research shows students' high school curriculum is the single greatest predictor of college degree attainment (Adelman, 1999). States will benefit as more students complete college and as high school graduates entering the workforce have higher levels of skills and knowledge. In regard to the present issue of the under-representation of African Americans and Hispanics in the science field, the implementation of core curriculum for all students will alleviate participation disparities in advanced level science courses. Increasing participation in science coursework throughout high school offers African American and Hispanic students greater opportunities to pursue and succeed in college science concentrations. The caveat, however, is that requirement to take a course does not guarantee students will gain a sufficient level of competency in that subject. In part, learning the material is influenced by the quality of the teacher, as well as the instructional and supplemental resources available. In addition, expecting more students to participate in higher level academic courses requires that additional academic support systems are put in place.

Ensuring adequate resources for teachers to address the needs of lower income, English language learners, and lower achieving students is an important component in addressing the larger systemic funding inequities. The federal government and some states have taken substantial measures to support the educational needs of lower-income students (Carey, 2004). It is recommended that all states and districts restructure funding formulas to provide greater fiscal allotments per-student for not only lower-income students, but also English language learners and lower-achieving students. In addition, reducing the educational systems' reliance on local tax revenues and having states supplement districts disadvantaged by lower-property values is another key component to addressing funding inequities. Such efforts may allow schools to ensure all students have equal opportunities to learn and excel. This is especially important for improving access to instructional resources, such as hands-on science learning and technology.

CONCLUSION

In the interest of advancing science and technology fields in the United States we must address the issues facing science education today. The underrepresentation of African Americans and Hispanics in science and technology occupations indicates a leak is occurring in the science education pipeline. Disparate rates of college and advanced degree attainment in the sciences and related fields have been identified as the leak. A search for the contributing factors to this diagnosis resulted in evidence suggesting disparities in secondary education systemic factors. More specifically, African American and Hispanics students are more likely to be taught science by out-of-field teachers, have inexperienced teachers, participate in less rigorous science coursework, and be exposed to funding inequities which disadvantage their opportunities to learn science and technology. It is imperative that research guides the development and implementation of programs and policies to address disparate systemic factors. The programs and policies identified in the present review are based on evidence elucidating *why* racial and ethnic disparities in the educational system are occurring. Most reform efforts addressing these issues are in the nascent stages and warrant further evaluation to discern their long-term effectiveness for change.

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