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INCREASING ACHIEVEMENT AND HIGHER-EDUCATION REPRESENTATION OF UNDER-REPRESENTED GROUPS IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS FIELDS: A REVIEW OF CURRENT K-12 INTERVENTION PROGRAMS

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Abstract

The under-representation of women and ethnic minorities in Science, Technology, Engineering, and Mathematics (STEM) education and professions has resulted in a loss of human capital for the US scientific workforce and spurred the development of myriad STEM educational intervention programs. Increased allocation of resources to such programs begs for a critical, prescriptive, evidence-based review that will enable researchers to develop optimal interventions and administrators to maximize investments. We begin by providing a theoretical backdrop for K-12 STEM programs by reviewing current data on under-representation and developmental research describing individual-level social factors undergirding these data. Next, we review prototypical designs of these programs, highlighting specific programs in the literature as examples of program structures and components currently in use. We then evaluate these interventions in terms of overall effectiveness, as a function of how well they address age-, ethnicity-, or gender-specific factors, suggesting improvements in program design based on these critiques. Finally, program evaluation methods are briefly reviewed and discussed in terms of how their empirical soundness can either enable or limit our ability to delineate effective program components. “Now more than ever, the nation’s changing demographics demand that we include all of our citizens in science and engineering education and careers. For the U.S. to benefit from the diverse talents of all its citizens, we must grow the pipeline of qualified, underrepresented minority engineers and scientists to fill positions in industry and academia.”—Irving P. McPhail..

Keywords

under-representation in science and math; women in STEM; minorities in STEM; K-12 STEM programs; recruitment

1. INTRODUCTION

Increasing the representation of women and ethnic minorities in Science, Technology, Engineering, and Mathematics (STEM) education and careers has been a goal of education researchers for nearly half a century. The proportions of females and ethnic minorities in STEM fields have increased dramatically in recent decades, but the data continue to indicate substantial room and need for improvement for both groups, as their representation at the

end of the science career pipeline falls far short of their presence within the education stages of the various disciplinary pipelines (see, e.g., Ceci and Williams, 2007, 2010, 2011; 2011; Ceci, Williams, & Barnett, 2009).

2. WOMEN IN STEM FIELDS

Consider first the situation for women and girls. Recent trends in female STEM representation are encouraging, indicating tangible effects of efforts to increase female representation in these fields. For example, the percentage of female assistant professors in many STEM fields tracks closely with the proportion of recent PhDs in these fields (Nelson and Brammer, 2010). However, other indicators are worrisome. For instance, even though early in the STEM pipeline, girls are taking a greater number of challenging math and science courses in high school and receiving higher grades in these courses than boys are; girls still lag behind boys in the number of Advanced Placement exams taken in subjects such as chemistry and physics (Ceci and Williams, 2010). Similarly, women now have, on average, higher science and math grade point averages (GPAs) in college than do men, and the proportion of STEM bachelor's degrees awarded to women continued to increase between 1998 and 2007. However, these gains were primarily in fields that were already heavily female, such as biological sciences and psychology [National Science Foundation (NSF) Science and Engineering Indicators, 2009]. Furthermore, after engineering, physical science, and computer science disciplines witnessed encouraging gains in the female proportion of bachelor's degree recipients during the first half of the past decade (1998–2003), these gains greatly slowed between 2003 and 2007, and in some fields such as mathematics, electrical and mechanical engineering, physics, and computer science, the percentage of female bachelor's degree recipients has fallen in recent years (NSF, 2009; Whitecraft and Williams, 2011).

Trends for women in STEM fields have been even more mixed at the postbaccalaureate level. Although there was a net increase in the proportion of STEM master's degrees awarded to women between 1998 and 2007, these increases only matched (i.e., did not exceed) the female-percentage increases in all fields, both STEM and non-STEM. There was also a net *decrease* in the percentage of computer science master's degrees awarded to females, a field that continues to experience particular difficulty recruiting women (NSF, 2009; Whitecraft and Williams, 2011). At the same time, there were relatively large increases in the proportion of females receiving doctoral degrees in STEM fields, overall—as well as increases in doctoral degrees in fields such as mathematics, physical sciences, computer science, and engineering (NSF, 2009), fields that have historically been most resistant to increases in female representation. It is unclear, however, whether these increases simply reflect substantial increases in the proportion of females receiving doctorates in all fields, both STEM and non-STEM, inasmuch as the latter experienced increases between 4.5% and 8.7% in social science PhDs; see Nelson and Brammer, 2010).

The data are even more discouraging once women reach the workforce. In 2008, women made up approximately 46% of the total US workforce, but only 41% of the biological and life sciences, 26% of the mathematical and computer sciences, and 11% of the engineering workforces. Although these figures represent considerable increases since the 1960s, when women were only 2% of the STEM workforce, current data still indicate the need for improvement in representation (NSF, 2009). And, despite earning 40% of STEM doctoral degrees in 2008, women comprise only 27% of tenured and tenure-track faculty in academia, disproportionate in the non-math-intensive social sciences (Ceci and Williams, 2011).

So while women have closed some aspects of the gender gap in early science and math achievement, and have increased their representation substantially in the past few decades, they still continue to drop out of the pipeline through graduate school and beyond (NSF, 2009). Fortunately, a generational shift appears to be on the horizon; the most recent cohort of female scientists and engineers (age 29 and younger) comprises one-fifth of all female scientists and engineers, whereas males from this cohort make up less than 14% of all male STEM professionals. Maintaining recent gains in female representation, and making greater efforts in fields such as computer science, physical sciences, and engineering, are thus more important than ever if we hope to take full advantage of the momentum provided by this generational shift.

3. ETHNIC MINORITIES IN STEM FIELDS

For ethnic minorities, recent progress in representation has also been mixed, at once indicating dramatic increases in representation, but low STEM participation overall. As of 2008, minority groups continued trends in closing racial math and science gaps for grades 4–8, and the percentage of African American first-year undergraduate students intending to enter an STEM discipline was comparable to that of whites—and this percentage among Hispanics (38%) was greater than for whites (32.9%), representing an estimable achievement (NSF, 2009).

When one looks longitudinally across the pipeline, from bachelor's to master's to doctorate degrees received by ethnic minorities, an interesting pattern emerges. The percentage of degree recipients who were ethnic minorities increased from 1997 to 2006 for all three degrees, but more so for master's degrees (+10.4%) than bachelor's (+6.8%) and doctorates (+2.3%); and by 2006 the percentage of master's recipients who were minorities (32.8%) was greater than the proportion of minority bachelor's recipients (30.3%). Thus, we might say that the “leaky pipeline” analogy (Barlow and Villarejo, 2004), in which representation decreases with each increase in degree level, now only applies to the transition between master's and doctorate programs; the “leak” between bachelor's and master's programs appears to have been “patched,” and between doctorate degrees and the level of professional scientists and engineers, the representations of African American and Hispanics increased slightly.

Yet ethnic minorities continue to show discouraging STEM discipline dropout rates in the late college years (NSF Science and Engineering Indicators, 2009), lending further support to claims that the undergraduate years are the most critical for maintaining ethnic minorities in the STEM pipeline (Maton *et al.*, 2000). Between 1997 and 2006, the percentage of all STEM bachelor's degrees awarded to African Americans increased by 1.1%, and Hispanics by 1.6%. The majority of each of these increases occurred between 1997 and 2003, with little progress since 2003 (NSF Science and Engineering Indicators, 2009). Despite obtaining between 6.6% and 28.7% of bachelor's degrees, and between 6.7% and 19.2% of doctoral degrees in various STEM fields in 2005, minorities accounted for only 2.2% to 12.9% of STEM faculty in the top fifty colleges and universities. These figures are much lower in the most mathematically intensive fields, such as computer science, in which minorities received 20.6% of bachelor's and 6.5% of doctoral degrees, yet comprised a mere 2.5% of faculty at these institutions, and only 3.1% at the assistant professor level, meaning that we are not simply witnessing a cohort effect.

4. ADDRESSING UNDER-REPRESENTATION WITH PROGRAM INTERVENTIONS

Although the root of under-representation is still debated (Ceci and Williams, 2011), most agree that early socialization and achievement experiences of women, girls, and ethnic minorities can have a substantial impact, positive or negative, on students' decisions to pursue and persist in careers in science and math throughout the STEM pipeline. Without intervention, these STEM experiences can be lacking or, worse, negative for females and minorities. Without intervention, elementary school students from under-represented groups may be underexposed to STEM (Fadigan and Hammrich, 2004; Kort, 1996; Marshall and Buckingham, 1995; Richardson *et al.*, 2003), disinterested in science and math by their teens (Atwater *et al.*, 1999; Bartsch *et al.*, 1998; Benore-Parsons *et al.*, 1995; Rea-Poteat and Martin, 1991), underestimate their science and math abilities before leaving high school (Haussler and Hoffman, 2002; Riesz *et al.*, 1994; Steele and Aronson, 1995), and begin college with misconceptions about STEM careers, what it takes to pursue one, and what sorts of people choose these careers (Atwater *et al.*, 1999; Eccles, 2007; Mawasha *et al.*, 2001).

Luckily, educators have recognized the potential benefits of providing early, positive STEM socialization. One of the more popular approaches to increasing STEM representations in recent years has been targeted intervention programs that provide such experiences to females and ethnic minorities. A literature search of such interventions revealed a wide array of programs stating a broader goal of increasing female and ethnic minority representations in STEM disciplines and, as our later review of these programs will make clear, this body of literature is growing exponentially. Of the dozens of programs revealed by our search of peer-reviewed scientific journals (a search focusing on K-12 programs), only two (Mason and Kahle, 1988; Ellis and Smith, 1984) were implemented prior to the 1990s. Additionally, the authors' informal experience in high schools and on college campuses suggests that there are a far greater number of initiatives and programs underway that have not been formally discussed in the scientific literature.

These interventions thus represent a growing aspect of the effort to increase STEM representation, and one into which a great deal of time and resources has been and will continue to be invested. However, little is known about the impact of these ever-evolving programs. Given these investments, a general review and critique of programs, and their evaluations, is past due. Despite thorough descriptions and reviews of some individual programs (e.g., Jayaratne *et al.*, 2003; McShea and Yarnevich, 1999), and one impressive, if highly abstracted, meta-analysis of forty NSF-funded programs for females (Darke *et al.*, 2002), we found little that would be of immediate help to researchers wishing to understand the current strengths and weaknesses of programs from a theoretical, developmental standpoint. Nor did we find any syntheses bridging theory and application for educators or administrators seeking a starting point for constructing a theoretically driven, developmentally appropriate STEM-specific intervention program for females and/or ethnic minorities in grades K-12. Our goal here is to provide such a synthesis.

More specifically, we first describe the range of K-12 STEM educational programs currently in use to give readers a better sense of the substantial variation between programs and the many ways under-representation is being addressed with interventions. To be clear, our focus is on programs directly targeting students, rather than programs focused on teacher training. Although teacher training programs are just as important as student-focused interventions, thoroughly reviewing their unique theoretical bases and similarly sizable body of literature would come at the cost of the type of program prescription specificity that we were aiming for.

Second, we offer a critical review of the corpus of K-12 STEM programs described in the peer-reviewed literature. We base this judgment of adequacy on inclusion of components that address age- and population-specific developmental issues and, when empirical evaluations are available, on empirical evidence indicating that these components are actually effective in practice. Third, we enrich our development-centric critical review by looking across programs and reducing the corpus of reviewed programs to a program-component typology that sorts programs in the literature according to the component categories they contain (e.g., mentoring, inquiry-based experiences, social enrichment, etc.), as well as the methodological components comprising their evaluations (e.g., randomly assigned controls, pre- and post-testing, longitudinal data, etc.).

Taking this typology into account, along with available evaluation results, we describe the support for the effectiveness of each program. The typology and associated summaries allow for easy comparisons between programs, and between the levels of proven effectiveness corresponding to different combinations of components. Future researchers can use our analysis as a point of comparison between what theory has suggested are the specific social factors and causal relationships affecting representation, and whether these causal relationships are supported when these social factors are addressed in an empirical context. Future STEM program designers can use this organizational scheme to tailor a program to the unique developmental needs of a given target population and resources available, based on an analysis of component combination effectiveness reported by past programs. We conclude by offering suggestions to those interested in designing and improving these programs, based on our critiques of the literature. We hope these suggestions will help future researchers, science policy specialists, and educational administrators streamline the design and implementation process.

Gandara and Bial (2001) provide a useful review of components of effective K-12 intervention programs for groups under-represented in postsecondary education. They also include a well-conceived summary/checklist of major categories of program components, as well as subcomponents within these categories. We have based our STEM-specific program summary upon their model, with amendments to reflect the STEM-specific nature of the programs we focused on. Schultz and Mueller (2006) updated this work with recent developments and additional K-12 intervention programs, and added a summary/checklist specific to program evaluation components that we adapted for use in the context of K-12 STEM programs. Whereas these seminal reviews concerned K-12 intervention programs targeting groups that are under-represented in postsecondary education, our review concerns *STEM-specific* K-12 intervention programs in the literature. One might assume that an STEM-specific review would be subsumed by the broader reviews of Gandara and Bial and Schultz and Mueller, but there are three reasons why an STEM-specific K-12 program review is warranted.

First, only one of the STEM-specific programs we found in the literature was included in either review (Lam *et al.*, 2000). This was partly because some of these STEM programs were published after those reviews, but mainly because these initial reviews concerned K-12 intervention programs for groups under-represented in postsecondary education in general. However, the numerous STEM-related programs targeting females—who are under-represented in math-intensive STEM fields, but not postsecondary education in general—were thus not included in these reviews. Second, the STEM pipeline has been studied in detail for these groups to a degree that more general K-12 program critiques cannot match, in terms of assessing how well programs address specific attitudinal and achievement-based milestones and changes that are unique to STEM development. For instance, critiquing a program like the one described by McShea and Yarnevich (1999) from a general point of view would fail to consider the importance of providing minority students with personal,

hands-on scientific inquiry experiences to counter their underexposure to firsthand STEM experiences (Maton *et al.*, 2000)—and as a result would overlook the fact that this program lacked such an essential STEM-specific program component.

The last point concerns reviewing and categorizing program *evaluations*. The evaluation overview provided by Schultz and Mueller is predicated upon the assumption (shared by the US Department of Education) that the composition and quality of evaluations should be judged against a “gold standard” of randomized, controlled experiments with long-term, quantitative outcome measures. However, as Lawrenz and Huffman (2006) point out in an NSF report on the current state and theory of program evaluations, working under this assumption blinds us to the more specific “how” and “why” of explaining program successes and missteps. These are insights that can be more easily revealed with idiographic, qualitative measures documenting the learning processes and experiences of affected students, teachers, and administrators, either individually or in terms of group attitudes. Downplaying qualitative evaluations underestimates the importance of understanding the processes through which programs instill students with an *intrinsic* interest in science and math. It is precisely this intrinsic interest that would keep students in the STEM pipeline once they reach postsecondary school. Thus, we have tailored our evaluation typology to include evaluation methods encompassing both quantitative and qualitative approaches.

Methodologically, we began with general internet searches for K-12 intervention programs with the stated goal of increasing female and/or ethnic minority representation in STEM fields, in order to get a general idea of the number and scope of existing programs. The vast majority of the many programs we found were described in a general way in newsletters, local publications, and websites devoted to these programs with a primary purpose of recruiting eligible participants. These sources rarely contained enough specifics about program components and evaluations to be of use to the current review. We thus limited subsequent search efforts to the peer-reviewed empirical literature, using the Educational Research Information Center (ERIC) database, PsychINFO, JSTOR, Engineering Village, MathSciNet, and Google Scholar. The features of the thirty-four programs found in the peer-reviewed literature were then noted, including the target population (age, female and/or minority status), general structure (e.g., summer camp, after-school), approximate duration, and the academic, social, cultural, and personal components comprising the program. The specifics of these program component categories are discussed in detail below.

5. K-12 STEM INTERVENTION PROGRAMS: WHAT DO THEY LOOK LIKE?

In practice and in the literature, programs range from after-school clubs (e.g., Mawasha *et al.*, 2001; Richardson *et al.*, 2003; Thompson, 2002) and summer camps (e.g., Kort, 1996; McShea and Yarnevich, 1999; Lam *et al.*, 2000; O’Brien *et al.*, 1999; Rea-Poteat and Martin, 1991) to residential plans (e.g., Atwater *et al.*, 1999; Jayaratne *et al.*, 2003). Approaches vary from providing positive experiences in science and math (e.g., Bartsch *et al.*, 1998; Kort, 1996; Marshall and Buckingham, 1995; Richardson *et al.*, 2003; Kahle and Damjanovic, 1994) and exposing students to STEM role models and career possibilities (Benore-Parsons *et al.*, 1995; Campbell *et al.*, 1998; Jayaratne *et al.*, 2003; O’Brien *et al.*, 1999; Rea-Poteat and Martin, 1991), to assisting students in early STEM “gateway” courses (Atwater *et al.*, 1999; McShea and Yarnevich, 1999). Level of selectivity among programs varies from meeting basic eligibility criteria, such as age or sex (Baker *et al.*, 1999), to more intensive selection procedures and criteria, such as having a high GPA and submitting multiple letters of recommendation (Miller *et al.*, 2007). Stated program goals range from general goals such as increasing interest in science (e.g., Bartsch *et al.*, 1998; Kahle and Damjanovic, 1994; Marshall and Buckingham, 1995; Thompson, 2002) to those that are

highly targeted such as producing STEM professionals from under-represented groups (Hanks *et al.*, 2007).

Although K-12 STEM programs have wide-ranging structures, approaches, and goals, much of this variation is motivated by the age of the target population, because factors underlying under-representation differ far more by age than by gender or ethnicity of the target population. It is no coincidence that a longitudinal analogy, the STEM pipeline, is so frequently invoked when discussing under-representation. According to developmentalists and program designers, the major demarcations in the factors influencing the STEM pipeline are between junior high school and high school, and between high school and college (Alexander *et al.*, 1997; Allen, 1999; Barlow and Villarejo, 2004; Fisler *et al.*, 2000; Hathaway *et al.*, 2001; Maton *et al.*, 2000; Moreno *et al.*, 1999; Murphy *et al.*, 1998). This is an age when perceptions of sexism about the place of females in science show pronounced impact. Brown and Leaper (2010) show that among Latinas and European-American females, the transition from middle school to high school reveals that perceptions of sexist comments regarding the role of women in science become increasingly likely to lower females' perceptions of their scientific competence—even when actual scientific and mathematical ability is controlled. As such, our review of K-12 programs is split into two age groups: elementary and junior high school versus high school.

5.1 Elementary and Junior High School (Grade K-8) Programs

Programs targeting elementary and junior high school students tend to focus on instilling and maintaining interest, self-confidence, and experience with science and math (Bartsch *et al.*, 1998; Benore-Parsons *et al.*, 1995; Haussler and Hoffman, 2002; Rea-Poteat and Martin, 1991; Riesz *et al.*, 1994), while keeping in mind the long-term goal of increasing STEM representation in higher education and careers. As students progress through these early school years, they form identities related to future career interests (Baker *et al.*, 1999; Bartsch *et al.*, 1998; Benore-Parsons *et al.*, 1995; Kahle and Damjanovic, 1994; Kort, 1996; Marshall and Buckingham, 1995; Rea-Poteat and Martin, 1991; Richardson *et al.*, 2003). Later, during high school years, students make important math and science gateway course choices that have a substantial impact on their interest in pursuing STEM majors at the postsecondary level, and on how well prepared they are for these majors (Atwater *et al.*, 1999; McShea and Yarnevich, 1999).

Again, researchers and theorists have argued that we are losing women and ethnic minorities as they lose interest and self-confidence in science and math subjects, for reasons having more to do with misconceptions and stereotypes than with science or math ability (Eccles, 2007). One frequently cited example of negative STEM socialization is the concept of stereotype threat, in which exposure to negative stereotypes pertaining to a particular group's competence in a given subject area can negatively affect one's performance in that area. Research shows, for instance, that performance on math tests can be manipulated simply by reminding students of groups they belong to which have stereotypes, however erroneous, related to mathematical ability associated with them (Correll, 2004; Shih *et al.*, 1999; Steele and Aronson, 1995). These stereotypes and misconceptions are unwittingly conveyed to students via parents, teachers, and the media (Becker, 1981; Berenbaum and Resnick, 2007; Frome and Eccles, 1998). Fortunately, the effects of stereotype threat on performance can be reversed by simply exposing the at-risk population to positive STEM-relevant role models, or by carefully scripting messages conveyed to students in the classroom (Dweck, 2007; McIntyre *et al.*, 1995), such as a "values affirmation" statement at the beginning of a fifteen-week physics course that elevated women's modal grade from C to B and narrowed sex differences in learning and performance (Myake *et al.*, 2010). Separate from misconceptions about ability, yet equally important, is the fact that high school students often possess misconceptions and erroneous stereotypes about career

possibilities in STEM disciplines (Eccles, 2007). As Ceci *et al.*, (2009) opined, “It is one thing to be disinterested in a career for valid reasons; it is quite a different matter to be disinterested in it for the wrong reasons.”

Consider one prototypical example of a program designed to provide early, positive STEM experiences and knowledge to pre-high-school students, the Find Your Wings program (Marshall and Buckingham, 1995). This program focuses on (a) informing girls of the importance of early math and science preparation, (b) changing girls’ attitudes toward math and science, (c) improving girls’ math and experimental skills, and (d) exposing girls to the possibility of high-tech careers, all under the umbrella context of aviation and aerospace, which were chosen due to the high degree of influence of these industries on the community in which the program took place. Choosing STEM themes related to local industries was a common thread among programs in the literature, presumably because staying local is a cost-effective way to tie STEM lessons to a relatable context. This six-week intervention has two major components: an in-school portion and weekend field trips. The in-school segment consists of an hour-long, once-per-week session led by female pilots, engineers, and mathematicians. A new question related to the science and math of aeronautics is posed at each session, followed by discussion of ways to solve it using teamwork and creative problem-solving. The conclusion of each session includes hands-on activities in which models are constructed to demonstrate the potential solutions to the question at hand. Weekend sessions consist of field trips to local aviation research labs, Air Force bases, and airports, where students get firsthand exposure to real-world science, and meet female role models employed in STEM occupations at each site.

Richardson *et al.*, (2003) take a similar approach to pre-high-school intervention, aiming to influence fourth and fifth grade girls’ interests, achievement, and career awareness in science and math topics with a two-year intervention, also comprising in-school and out-of-school portions. This program, Sisters in Science, aims to directly influence students’ interest in science and math through lessons and field trips, while indirectly influencing students through gender-sensitive, integrated science education methods, and by exposing students’ families to science. The in-school portion meets for two hours per week, and focuses on real-world science and math related to the environment. It is led by science teachers trained to use gender-sensitive teaching methods. The after-school program meets once per week for an hour and a half, in addition to a Saturday “academy” that runs twice a month for four hours, and a summer program consisting of two weeks of field trips. These programs are led by graduate elementary-education students and volunteers from STEM fields, who serve as role models and mentors. The Saturday academy portion is designed to be more hands-on, focusing on technology, such as computer building and webpage design, and the science and math behind sports such as fencing and tennis. The summer field trips allow students to explore city rivers, map local waterways, and create model rivers, bringing them in contact with environmental science that is not only in the “real world,” but in students’ own backyards.

The family education component of Sisters in Science occurs quarterly, and includes family science nights, trips to a local aquarium, and a science showcase. Along with the gender-sensitive teacher training, this portion is posed as a way of countering the negative STEM socialization that girls may encounter in broader developmental contexts, namely the teacher–student and parent–child environments. This multifaceted approach, where the family environment is included, is somewhat unique compared to most programs for this age group, such as student-only interventions of the Find Your Wings program. Sisters in Science is also unique in its simplicity; while other programs also target students’ broader social contexts (e.g., Atwater *et al.*, 1999), these programs usually do so with more complex and expensive means.

5.2 High School (Grade 9–12) Programs

While programs posed during the early primary-school years have a more general focus on increasing interest in science and math, high-school-age programs narrow their focus to increasing achievement in college-track or gateway science and math courses, maintaining interest in science and math instilled at younger ages, and bridging the gap between these interests and the skills and knowledge necessary to turn an interest into an undergraduate major—and, hopefully, an STEM career. Campbell *et al.*'s (1998) Gateway to Higher Education program, an intervention targeting high-school-age ethnic minorities, is typical of high school programs. It is school-based, and includes an extended school day, with a double period of either math or science in addition to after-school tutoring; an extended school year, with a month-long summer program; participant-only math and science classes with a twenty-five-student size limit; requirements that participants take the SAT I, the SAT II Biology and Chemistry tests, and AP courses; college visits, a college fair, and seminars on financial aid and admissions for students and their parents; and exposure to professional scientists during field trips and internships. The college visits, college fair, and seminars on financial aid and admissions included in this program are of particular importance to ethnic minorities, as they often face the unique problem of being first-generation college students with parents who lack important knowledge and experience about the application process and college life in general.

The Upward Bound program for ethnic minorities at The University of Akron (Lam *et al.*, 2000) also targets high school math and science gateway course achievement and matriculation in STEM undergraduate majors. This program includes a six-week summer residential program during which students take classes in English composition, math, physics, biology, and a foreign language, and spend time with faculty and staff in engineering laboratories; a school-year program including career workshops at local companies and research facilities, and weekly tutorials from mentors and tutors; and a freshman year transition program that takes place after high school graduation, which includes lectures and academic workshops in college algebra, precalculus, and calculus. As with the Gateway to Higher Education program, the focus here is narrowed from instilling interests to developing these interests, and providing skills necessary to realize these interests at the college level and beyond. Again, the inclusion of college preparatory components, such as the freshman year transition component of this program, is of particular importance to programs for high-school-age ethnic minorities, because these individuals may be first-generation college applicants, and are thus at a disadvantage in terms of tacit knowledge related to the college application and preparation processes.

The Taking Your Place program (Rea-Poteat and Martin, 1991) is a prototypical summer residential program for precollege students—a two-week summer camp for ninth and tenth grade girls, organized around three main education strategies: demonstration, instruction, and counseling. The demonstration strategy is carried out through field trips to local technology-related industries, the goal being to highlight real-world science and occupations in science and technology. The instruction-based strategy consists of classroom learning and hands-on application of learned concepts, such as assembling AM/FM radio kits. The counseling component includes individual and group career counseling, and lectures and panel discussions (run by women in STEM careers) about nontraditional careers for women, the history of women and work, sex role stereotyping in occupations, career decision-making, life and work values, and assertive behavior. Of all the programs in the literature, only one explicitly targets both girls and ethnic minorities, as well as low-income and rural students: the Science and Mathematics Summer Institute (SAMSI) at the University of Georgia (Atwater *et al.*, 1999). This program is quite innovative in this respect, tapping into commonalities among the factors affecting precollege students from various under-represented groups and posing one intervention for all groups. SAMSI consists of a three-

week stay on the University of Georgia campus, during which students are immersed in various STEM experiences, such as field trips to learn about real-world applications of science and meet science and engineering role models. They also attend classes in biology, math, physical science, technical and creative communications, and computer science. Cooperative and supportive teamwork-oriented science is stressed to participants of SAMSI, as a way of encouraging positive STEM peer social skills. Again, the focus of this high-school-age program is on honing previously instilled STEM interests, and providing both the skills necessary to persist in them and the role models to show where this persistence can lead.

6. CHARACTERISTICS OF EFFECTIVE PROGRAMS AND SUGGESTIONS FOR FUTURE DESIGN

As a whole, the reviewed K-12 STEM-specific programmatic efforts appear to be something of a “shotgun” or “throw it at the wall and see what sticks” approach, a mixed bag of workshops, summer programs, curriculum changes, field trips, mentors, and family science nights. Once broken down conceptually, however, these programs all adhere to at least some, if not all, of the criteria cited by Gandara and Bial (2001) and Schultz and Mueller (2006) as criteria of effective K-12 programs: (1) including individuals who monitor and guide students, as a group and individually, over an extended period of time, sometimes even after the formal program has ended; (2) offering high-quality instruction, more specifically through access to the most challenging courses (also known as “untracking”), supplementary coursework (e.g., tutoring, remedial classes), or a broader revamping of the curriculum; (3) involving longer-term investments in participating students, to guide students through the college application process and bridge the gap between secondary and postsecondary phases of the STEM pipeline; (4) sensitivity to the cultural back-grounds of students; (5) providing peer-to-peer interactions in which participants offer each other academic, as well as social/emotional, support; and (6) providing financial assistance either in the form of scholarships or paying for “academic leveling” opportunities, such as college visits or SAT preparatory classes (Gandara and Bial, 2001). The caveat is that among reviewed programs, the effectiveness of these criteria was often dependent on target population characteristics, such as age and minority status. These deconstructed components have been categorized and summarized (see Tables 1–3), based on Gandara and Bial’s summaries, but adapted for STEM-specific programs.

In Table 1 we also provide for each reviewed program an overall rating of effectiveness. In judging effectiveness, we took into account both the soundness of the evaluation methods (discussed in detail below) and the reported outcome effects, to give an overall rating using a three-tiered rating system: Promising, Suggestive, and Limited. “Promising” refers to programs with evidence from sound empirical evaluation indicating that the program affects targeted outcomes positively. “Suggestive” refers to programs with evidence implying that the program affects targeted outcomes positively, but empirical issues in the evaluation hinder definitive statements of effectiveness, or evidence from empirically sound evaluations indicates program effectiveness is ambiguous and requires further study. “Limited” refers to programs in which significant methodological issues in evaluation prohibit definitive conclusions on effectiveness, or programs in which evidence from an empirically sound evaluation indicates the program is ineffective.

The purpose of these ratings is to give readers an idea of differences in program quality in the broadest sense. We acknowledge that using this crude rating system on a sample whose size is empirically modest has inherent limitations, such as confounding effectiveness decreases that are due to exclusion of certain program components with effectiveness decreases due to a lack of soundness in program evaluation. Future efforts will, we hope,

critique and improve upon this initial attempt at quantifying program characteristics and outcomes. The advantage of providing these ratings is that it allows us to begin testing whether or not various components tend to be related to increases in program effectiveness, and whether such relationships depend on target audience (e.g., age, female and/or minority status). This is the type of information that will bring us closer to what Perna and Swail (2001) call for, a way of identifying which “packages” of components are most effective. So, while statistical analyses were not a primary focus of this review, we did perform bivariate correlational analyses to test for associations between program component inclusion (e.g., number of counseling components included in a given program) and program effectiveness, coding our three-tiered effectiveness rating system ordinally (1 = Limited; 2 = Suggestive; and 3 = Promising).

First, it has been suggested that effective programs include individuals who monitor and guide students, as a group as well as individually, over an extended period of time, sometimes even after the formal program has ended (Gandara and Bial, 2001). These individuals can take the form of program directors, faculty members, industry professionals, or guidance counselors. This raises the question of whether there is a difference, outcome-wise, between “mentors” (in this context, a specialist or professional in an STEM field) and “counselors” (nonprofessionals). From our analysis of reviewed program components and ratings of program effectiveness (Limited, Suggestive, or Promising, explained in detail below), effectiveness of mentors versus counselors depended on target population age: Among programs for high school students, both types of guidance were positively related to program effectiveness [$r(19) = 0.454, p = 0.048$, and $r(19) = 0.477, p = 0.039$, for mentorship and counseling, respectively]; among programs for elementary and middle school students, however, there was almost no relationship between program effectiveness and number of mentorship components, $r(15) = -0.205, p = 0.46$, and a significantly *negative* relationship between number of counseling components and program effectiveness, $r(15) = -0.734, p = 0.002$. While this may have been an artifact of the small sample size, an alternative possibility is that too much career-related guidance may turn off young students who are not yet sure if they are interested in science. In any event, the importance of guidance for older students, whether in the form of mentorship by professionals or advice from teachers or other nonprofessional counselors, is clear.

Second, effective K-12 programs are said to be characterized by access to the most challenging courses (also known as “untracking”), supplementary coursework (e.g., tutoring, remedial classes), or a broader revamping of the curriculum (Gandara and Bial, 2001). In the STEM program literature we reviewed, this applied mainly to programs for high school students (e.g., McShea and Yarnevich, 1999; Atwater *et al.*, 1999). Programs for younger students were much less focused on classroom-based learning in favor of exposing students to personal, enjoyable science-related experiences (e.g., Reid and Roberts, 2006; Paris *et al.*, 1998), again because, in the STEM developmental timeline, the issue younger students must overcome is a lack of exposure to science and math in their everyday lives (Bartsch *et al.*, 1998; Benore-Parsons *et al.*, 1995; Haussler and Hoffman, 2002; Rea-Poteat and Martin, 1991; Riesz *et al.*, 1994). Indeed, as with mentorship and counseling, a positive, if nonsignificant, relationship was found between program effectiveness and number of academic programs in high-school-directed programs, $r(19) = 0.270, p = 0.263$, but a negative (but nonsignificant) relationship arose in programs targeting sub-high-school-age students, $r(15) = -0.270, p = 0.33$.

Third, Gandara and Bial state that effective programs tend to involve longer-term investments in participating students. This contrasts with the sorts of day- or weekend-long workshops that Clewell *et al.* (1991) said typified female-targeted programs, as compared to programs aimed at ethnic minorities. In reviewing the literature it was clear that there is now

much less distinction between programs for females and minorities in terms of length of investment, compared to when Clewell *et al.* noted the discrepancy. On the whole, this appeared to be the point of greatest variation between different programs we reviewed. Quantifying exact lengths of investment is difficult with the information available, but in comparing programs of limited, suggestive, and promising levels of effectiveness, beyond the brief day- or week-long workshop-type programs (all of which were rated as “limited” in effectiveness), variance in program length seemed unrelated to program effectiveness.

Fourth, effective programs tend to be sensitive to the cultural backgrounds of students. This was a common trait among our reviewed programs, with much of the between-program variation existing in the degree to which this was achieved explicitly. Explicit cultural sensitivity took the form of, for instance, embedding geoscience lessons within issues affecting Alaskan tribal lands and customs in a program for Alaskan Native Americans (Hanks *et al.*, 2007). More frequently, the cultural sensitivity was implicit, such as recruiting instructors, mentors, and role models of the same sex and/or ethnicity as program participants (e.g., Bartsch *et al.*, 1998; Rea-Poteat and Martin, 1991; Kort, 1996). Some programs included discussions and workshops specifically on factors, STEM-wise and in general, unique to the target group’s gender or ethnicity (e.g., Hanks *et al.*, 2007; Winkleby *et al.*, 2009; Riggs *et al.*, 2007). But among all reviewed programs the most promising programs were just as likely as the least effective programs to include such sessions.

Fifth, effective programs, according to Gandara and Bial, provide peer-to-peer interactions in which participants offer each other academic, as well as social/emotional, support (Gandara and Bial, 2001). In the STEM programs reviewed here, this was often achieved through group projects and social events within same-sex (e.g., Benore-Parsons *et al.*, 1995) or same-ethnicity (e.g., McKendall *et al.*, 2000) contexts, though many programs lacked such a component. Interestingly, the most limited-effectiveness programs often included many social enrichment components; and while there was an overall positive correlation between number of social components and program effectiveness, it was not significant, $r(34) = 0.222$, $p = 0.39$.

Last, according to Gandara and Bial, effective programs provide financial assistance either in the form of scholarships or paying for academic leveling opportunities, such as college visits or SAT preparatory classes. This was a point of great interprogram variation, partly because these are primarily concerns for high school program participants, and many of the STEM programs we reviewed were for females and younger students. But, even among high school minority STEM programs, this was the least likely of the six criteria of effective programs to be fulfilled, and thus it is hard to relate scholarships to program effectiveness among these K-12 programs with the available information. The lack of scholarship components is likely due to limited resources, as many programs recognized the college information gap experienced by some of these students and provided college information sessions and/or counseling in lieu of direct financial assistance (e.g., Rodriguez *et al.*, 2004; Miller *et al.*, 2007).

In addition to the more general criteria of effective programs outlined by Gandara and Bial, we offer the following STEM-specific suggestions for effective programs. Programs posed in the elementary and junior high school years should focus resources on influencing students’ interests and attitudes related to science and math, as these earlier years are when attitudes and interests begin to form (Baker *et al.*, 1999; Marshall and Buckingham, 1995; McIntyre *et al.*, 1995). Because early gender and race differences in interest in science have been attributed to the fact that boys and whites come in contact with science outside school more often than do girls and ethnic minorities (Fadigan and Hammrich, 2004), programs should expose under-represented youth to science and math concepts using contexts that are

familiar to them, are hands-on, and take place in a context related to their local community, in order to bridge the gap between their everyday lives and the science and math that take place in the classroom. Very few programs in our review of the literature, regardless of the target population, excluded hands-on, inquiry-based activities, and most of the programs that did were limited in effectiveness (e.g., McShea and Yarnevich, 1999).

Identities and attitudes toward STEM are more fully formed by the high school years. Thus, high school programs should begin to place more focus on increasing students' STEM knowledge base and test scores in gateway courses that serve as precursors to undergraduate STEM courses (Atwater *et al.*, 1999; McShea and Yarnevich, 1999; Richardson *et al.*, 2003). As the Gateway to Higher Education, SAMSI, and Upward Bound programs exemplify, however, programs posed at this age group should not neglect components that will both maintain and narrow students' interest in science and math topics (e.g., experiences at research facilities). Focusing solely on achievement in this age group, without maintaining interest through research experiences, might turn capable students off to the idea of pursuing science as an undergraduate and beyond.

Some special considerations affect programs targeting ethnic minorities in high school. More specifically, there should be a particular emphasis on career mentorship and nuts-and-bolts career counseling; as these students are often first generation college applicants, they are at an information disadvantage when it comes to precollege course choices, the college application process, and how these parlay into career paths (Maton *et al.*, 2000). For instance, the positive relationship between program effectiveness and the amount of mentorship and counseling was much more dramatic for high school minority programs, $r(15) = 0.666$, $p = 0.007$, than all programs combined, $r(34) = 0.212$, $p = 0.23$.

Regarding other population-specific considerations, if the target population is girls, all-female environments appear preferable to coeducational environments, because girls tend to do better with STEM concepts when social pressures to conform to their gender are absent (Allen, 1999). Note, however, that Haussler and Hoffman (2002) found that girls exhibited the best cognitive and affective outcomes *not* in single-sex classrooms, but in classrooms that alternated between single-sex and coeducational.

On a more general note, field trips to local STEM-related industries represent a particularly creative option for providing hands-on experiences and/or interactions with STEM role models. Firsthand experience with science need not necessitate a residential stay at a university; student interest can be increased with experiences that are no more expensive, intensive, or complicated than a trip to local waterways (e.g., Richardson *et al.* 2003) or a local airport (e.g., Marshall and Buckingham, 1995). This cost-effective approach creatively uses local industries and destinations to give students firsthand experience with STEM professionals doing exciting science right in their hometowns. Industries are often willing to assist in such efforts, which result in their names being associated with worthy causes in their local communities.

Last, given the research consensus that family and home environments can have a substantial impact on STEM-related development in students, it was somewhat surprising that only seven reviewed programs included a parent-related component. Without more programs with a parent component, it is difficult to relate parent involvement in STEM programs to program effectiveness objectively, but parent involvement appears to be important. Of the parent components in the reviewed programs, half were informal family-oriented science demonstration nights, and half were more formal information sessions—the former for parents of younger students, the latter for parents of high school students. While it is logical to emphasize show-and-tell for parents of younger students, and college

preparation information for parents of older students, future program designers may want to consider demonstrative events for older students' parents and information sessions for younger students' parents, as well. Parents of older students engaged in actual scientific research with mentors, as many students in the reviewed programs are, would likely be impressed by the professional nature of their child's science activities. Meanwhile, with college preparation beginning as early as middle school, parents of younger children might be interested in learning about preparing their child for an STEM career.

7. PROGRAM EVALUATIONS

Despite limited resources, it is nevertheless essential that program interventions be evaluated for effectiveness. Yet the most striking feature of our literature review was the dearth of useful, empirically valid evaluations of program interventions. While we agree with Lawrenz and Huffman (2006) that more qualitative, idiographic evaluations have their place and importance in this work, there is a difference between systematic qualitative methods, and the offering of anecdotes as evidence of program effectiveness (e.g., Kort, 1996; Benore-Parsons *et al.*, 1995). To give the reader an overview of the nature of evaluations among reviewed programs, we provide a version of Schultz and Mueller's program evaluation summary, adapted for our purposes, which summarizes the evaluation efforts of the programs we reviewed (Table 4).

For the majority of programs that attempted quantitative, empirical evaluations, serious methodological issues were evident. Most common among these was a lack of a proper control group; twenty-five of the programs reviewed lacked a control group altogether, while others used poorly matched comparison groups (e.g., Campbell *et al.*, 1998). The next most common issue was a failure to administer a baseline, preprogram assessment or survey, and instead reporting program successes, attitudinal and/or academic, based only on postprogram measures and surveys (e.g., Bartsch *et al.*, 1998; Mawasha *et al.*, 2001; Rea-Poteat and Martin, 1991). Without a pre-post comparison, even qualitative evaluations fail to provide the learning-process insights that Lawrenz and Huffman (2006) argued make them valid tools for evaluating programs.

In light of these shortcomings in program evaluations reviewed, we agree with Gandara and Bial (2001) that the most immediate improvements in program evaluation concern increased use of control groups and collection of baseline data. They also stress the need for longitudinal data on STEM course-taking behaviors, and science and math achievement throughout and beyond the K-12 years, the need for monitoring and reporting of attrition rates, both program- and STEM pipeline-wise, and reporting and discussing cost-benefit analyses of each program component. From our review, we concur with these assessments as well; only twelve programs had longitudinal data of any sort, ten had attrition data, and none of the program descriptions or evaluations discussed cost.

With regard to control groups, we recognize that having a control group is a difficult-to-attain expectation for program administrators who may not have the resources or opportunity to perform this sort of in-depth program evaluation. For one, adequate control groups are particularly hard to obtain for these evaluations, again due to the selection bias inherent in evaluating a selective program. Randomly selecting which students will benefit from limited program resources, while casting merits and enthusiasm aside, is not the most appealing option. In the case of young women, for whom STEM interest is fragile to begin with, leaving opportunities to foster these interests up to random assignment is potentially questionable. The evaluation performed by Jayaratne *et al.* (2003) is particularly commendable in this respect, especially among "summer camp" programs, due to the fact that the authors took the risk of randomly selecting participants from the pool of all

applicants, neutralizing the selection bias that may have arisen had they chosen participants based on their applications.

As a result, their important longitudinal findings of improvement among white and Asian-American girls' attitudes and behaviors known to be indicative of future course-taking patterns—such as science self-concept, interest in science, and number of high school science courses taken—cannot be as easily challenged on methodological grounds. Unfortunately, neither can their finding that female ethnic-minority participants showed an even steeper decline over time on these measures than their ethnic-minority-control counterparts. However, knowing that these unfortunate results were gleaned from a methodologically sound design means that the program can be adjusted, rather than wasting resources on what amounted to counterproductive efforts on behalf of the most under-represented subset of the target population—female minorities. Similarly useful is Brown and Leaper's (2010) finding that Latinas experienced steeper declines in perceptions of their scientific competence than their female European-American counterparts from middle school to high school.

8. CONCLUSION: HOW TO ACHIEVE GAINS IN REPRESENTATION WITH EDUCATIONAL INTERVENTIONS

Again we pose the question: *How can we achieve and maintain increases in STEM representations of women and ethnic minorities?* More specifically, how can we change the approach of programs and program evaluations to more effectively reach this goal? To help meet the goal of optimizing program construction and research on these programs, we offer program summaries/typologies of reviewed STEM programs (Tables 1–3). We hope these summaries/typologies will help make program design and implementation a more streamlined process in which theory has already been actualized and reduced to basic program components, which can be compared alongside program effectiveness. It is up to researchers and program designers to take these component pieces, tailor them to their particular goals and resources, and place them in whatever context will best resonate with their particular target population and research questions.

In the immediate future, the most important improvements that can be made are, again, in the evaluation of programs. It is difficult to improve program effectiveness if we have no baseline of effectiveness from which to gauge progress. While it is encouraging to read anecdotes detailing excitement and positive feedback of participants in certain programs (e.g., Rea-Poteat *et al.*, 1991), if this excitement and feedback masks program ineffectiveness, then in the long run it provides only a false sense of progress. Considering the number of poorly evaluated programs, substantial resources may be unwittingly wasted on ineffective programs. Without carefully designed program evaluations, we do not know whether a program is effective, how and where a program has failed or succeeded, or how to use this knowledge to our advantage in creating future programs. Although the majority of programs reviewed have a solid theoretical basis, the lack of extensive evaluations to test in practice the theories underlying these programs limits our ability to describe with confidence specifically which program components work, and which should be improved or eliminated.

Despite the shortcomings of programs and evaluations reviewed here, there is also much of value addressing the problem of under-representation at various early points in the STEM pipeline. Based on experiences with programs in the literature, future researchers, program designers, and policymakers have a general blueprint to work from, as well as numerous options for specific program elements to meet the needs of their program or research agenda, based on target population, funding availability, and specific goals.

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Overview of reviewed STEM programs

TABLE 1

Program	Program name	Duration	Years instituted	Funding source(s)	Annual enrollment	Target audience	Subject(s)	Effectiveness
Thompson, 2002	Research Apprenticeships for Minority High School Students	3 hours/day during school year	1977–present	Corporate, private donations	10,000	High school minorities	Environmental science, engineering, technology	Promising
Kort, 1996	Math, Science, and Computer Camp for Girls	Full day, 2 weeks	1994–present	University of Rochester	24	3rd–6th grade females	Math, computer science	Suggestive
Marshall and Buckingham, 1995	Find Your Wings	1 hour/day, 1 day/week, for 6 weeks	1993–1995	NSF	994	4th–6th grade females	Aerospace and aviation-related math and science	Suggestive
Richardson <i>et al.</i> , 2003	Sisters in Science	2 years; 2 hours/week during school year; 4 hours every other Saturday; full day for 2 weeks during summer	1997–2000	NSF	2,037	4th–5th grade females	Physical sciences, computer science, math	Suggestive
Kahle and Damjanovic, 1994	N/A	1 lesson/day for 1 week	1993	NSF	669	4th–5th grade minority students	Science, math	Suggestive
Yanowitz and Vanderpool, 2004	N/A	1-day workshop	2003	U. Arkansas	77	5th–6th grade females	Animal behavior, biochemistry, biology, botany, entomology, microbiology, wildlife biology	Limited
Benore-Parsons <i>et al.</i> , 1995	N/A	Full day for 1 week	1991	Michigan Metro Girl Scouts	20	6th–7th grade females	Physical, biological sciences	Limited
O'Brien <i>et al.</i> , 1999	Career Horizons	6 hours/day for one week	1997–1998	U.S. Dept. of Education	~28	6th grade at-risk students	Science, math	Limited
Baker <i>et al.</i> , 1999	Girls Summer Lab	3 days/week for 10 weeks, plus 4 all-day field trips	1998	U.S. Dept. of Energy	37	6th–7th grade female minorities	Science	Limited
Haussler and Hoffman, 2002	N/A	1 school year	2001	N/A	456	7th grade females	Physics	Promising
Bartsch <i>et al.</i> , 1998	FLEDGE-ing Camp for Girls	8 hours/day for 4 weeks	1996–1997	NSF	45	7th–8th grade females	Environmental science, technology	Limited
Rea-Poteat and Martin, 1991	Taking Your Place: Exploring Technology and Tomorrow	8 hours/day for 10 days	1986–present	U.S. Dept. of Education	25–30	9th–10th grade females	Technology, computer science	Limited
Jayaratine <i>et al.</i> , 2003	Summerscience for Girls	2 weeks	2001	NSF	45	9th grade females	Science	Limited
Atwater <i>et al.</i> , 1999	Science and Mathematics Summer Institute (SAMSI)	3 weeks, full day	1993–1995	Howard Hughes Medical Institute	~30	9th–10th grade females and minorities	Biomedical research	Limited
Campbell <i>et al.</i> , 1998	Gateway to Higher Education	Extended school day, month-long summer program	Early 1990s–present	Aaron Diamond Foundation	200	Inner-city High school minorities	Science, engineering	Suggestive
McShea and Yarnevich, 1999	National Society of Hispanic Masters of Business Administration's Summer Enrichment Program	Summer program	1992–1994	National Society of Hispanic Masters of Business Administration	27	Hispanic high school students	Math	Limited

Program	Program name	Duration	Years instituted	Funding source(s)	Annual enrollment	Target audience	Subject(s)	Effectiveness
Lam <i>et al.</i> 2000	Upward Bound/Academic Achievement/Increasing Diversity in Engineering Academics	School-year and 6-week residential summer program	1994–1998	U.S. Dept. of Education, College of Engineering at University of Akron	~35	Minority and low-income high school students	Physical science, math, engineering, computer science	Promising
Mawasha <i>et al.</i> , 2001	Girls Entering Technology, Science, Math, and Research Training (GET SMART)	2-day workshop	1998–present	Ohio Dept. of Education	20	High school females	Physical sciences, math, computer science	Limited
Kerr and Robinson Kurpius, 2004	Talented At-Risk Girls: Encouragement and Training for Sophomores project (TARGETS)	1-day workshop	1994–2001	NSF	~70	10th grade females	Science	Suggestive
Barnett <i>et al.</i> , 2006	Urban Ecology Field-based Studies Program (UEFSP)	Year-long in-school curriculum	2001–2003	NSF	130	High school minorities	Urban Ecology	Suggestive
Parker and Gerber, 2000	Georgia’s Quality Core Curriculum	2 hours/day, 2 times/week, for 5 weeks during the summer	1998	Valdosta State University	11	5th–6th grade minorities	Physical sciences	Promising
Hanks <i>et al.</i> 2007	Rural Alaska Honors Institute	6-week residential summer program	1983–present	NSF	30	High school rural Native Alaskans	Geology	Promising
Murray <i>et al.</i> , 2009	Health Education and Discovering Science While Unlocking Potential (HEADS UP)	3 year in-class curriculum intervention	2004–2005	NIH	1100	6th–8th grade minorities	Health science	Suggestive
Paris <i>et al.</i> (1998)	Hands-On Biology	Three 45-min lab sessions/week, in-school, for 6 weeks	1996	Howard Hughes Medical Institute	184	3rd–5th grade low-income and minority students	Biology	Suggestive
Rodriguez <i>et al.</i> (2004)	San Diego State University Science Enrichment Program	Full day summer residential, for 6 weeks	1998–2001	National Cancer Institute	~50	10th grade minorities	Science and technology	Suggestive
Winkleby <i>et al.</i> (2009)	Stanford Medical Youth Science Program	5-week summer residential program	1988–present	Stanford University, U.S. Dept. of Education, Howard Hughes Medical Institute	24	10th–11th grade minorities	Health sciences	Promising
Reid and Roberts (2006)	Gaining Options: Girls Investigate Real Life (GO-GIRL)	1 day/week, for 10 weeks	2002–present	NSF	74	7th grade low-income, minority females	Math	Limited
Miller <i>et al.</i> (2007)	Summer Experience for Inspiring Interest in Geoscience	Full day, 2 weeks	2002–2005	NSF	~25	11th grade Latinos	Geoscience	Suggestive
Ellis (1993)	Pre-College Institute	1 day/week, for 6 weeks	1989	Lehman College	51	High school minorities	Biology, math, computer science	Suggestive
Wechsler <i>et al.</i> (2005)	Geoscience Diversity Enhancement Program	Full day, 8 weeks	2002–2004	NSF	~40	High school minorities	Geoscience	Limited
Riggs <i>et al.</i> (2007)	Indigenous Earth Sciences Project (IESP)	2-week summer residential	1998–present	NSF	20	High School Native Americans	Geoscience	Promising

Program	Program name	Duration	Years instituted	Funding source(s)	Annual enrollment	Target audience	Subject(s)	Effectiveness
Ferreira (2002)	N/A	Bi-weekly	1999–2000	Exxon Mobil Educational Foundation, Society of Women Engineers	18	7th–8th grade female minorities	Physical sciences, engineering	Limited
McKendall <i>et al.</i> (2000)	Health Sciences and Technology Academy	Summer residential program, then activities throughout 9th, 10th grade	1998–1999	West Virginia University	~50	9th–10th grade Female minorities	Health sciences	Promising
Ellis and Smith (1987)	Summer Mathematics and Science Institute	5-week summer program	1983	Ford Foundation	26	10th–11th grade minorities	Science, math, computer science	Suggestive

Key. “Promising” = Evidence from sound empirical evaluation indicates the program affects target outcomes positively; “Suggestive” = Evidence suggests the program affects target outcomes positively, but empirical issues in the evaluation hinder definitive statements of effectiveness or evidence from an empirically sound evaluation indicates program effectiveness is ambiguous and requires further study; “Limited” = Serious methodological issues in evaluation prohibit definitive conclusions on effectiveness or evidence from an empirically sound evaluation indicates the program is ineffective.

TABLE 2

Summary of academic enrichment program components

Program	Summer program	Tutoring	College-level courses	High school/after-school academic preparation program	SAT/test preparation	Hands-on/inquiry-based research	Technology training
Thompson, 2002			x	x		x	
Kort, 1996	x					x	x
Marshall and Buckingham, 1995						x	x
Richardson <i>et al.</i> , 2003	x			x		x	
Kahle and Damjanovic, 1994						x	
Yanowitz and Vanderpool, 2004							
Benore-Parsons <i>et al.</i> , 1995						x	
O'Brien <i>et al.</i> , 1999					x	x	
Baker <i>et al.</i> , 1999	x					x	
Haussler and Hoffman, 2002						x	
Bartsch <i>et al.</i> , 1998	x					x	
Rea-Poteat and Martin, 1991	x					x	x
Jayarathne <i>et al.</i> , 2003	x					x	x
Atwater <i>et al.</i> , 1999	x			x		x	x
Campbell <i>et al.</i> , 1998	x	x	x	x	x		
McShea and Yarnevich, 1999	x	x		x	x		x
Lam <i>et al.</i> , 2000	x	x	x		x	x	x
Mavasha <i>et al.</i> , 2001						x	x
Kerr and Robinson Kurpius, 2004						x	
Barnett <i>et al.</i> , 2006				x		x	x
Parker and Gerber, 2000	x					x	
Hanks <i>et al.</i> , 2007	x	x	x			x	x
Murray <i>et al.</i> (2009)				x		x	

Program	Summer program	Tutoring	College-level courses	High school/after-school academic preparation program	SAT/test preparation	Hands-on/inquiry-based research	Technology training
Paris <i>et al.</i> (1998)						x	x
Rodriguez <i>et al.</i> (2004)	x		x			x	x
Winkleby <i>et al.</i> (2009)	x		x		x	x	x
Reid and Roberts (2006)	x			x		x	x
Miller <i>et al.</i> (2007)	x		x			x	x
Ellis (1993)		x		x		x	x
Wechsler <i>et al.</i> (2005)	x					x	x
Riggs <i>et al.</i> (2007)	x					x	x
Ferreira (2002)				x		x	x
McKendall <i>et al.</i> (2000)	x					x	
Ellis and Smith (1987)	x					x	x

Key. "Summer Program" refers to programs that have a summer day camp-style component; "Tutoring" refers to program components involving one-on-one remedial or non-remedial academic guidance; "College-level Courses" refers to components either involving Advanced Placement course enrollment as a requisite, or math and science courses taken for college credit at a participating college or university; "High school/After school Academic Preparation Program" refers to instruction that supplements usual math and science coursework, either remedially or to fill any knowledge gaps between high school and first-year college math and science courses. "SAT/test preparation" refers to components aimed at increasing students' performance on standardized tests used for college admissions; "Hands-on/inquiry-based research" refers to components involving students learning science and math concepts through direct experimentation and observation; "Technology training" refers to components in which students learn technologies that are either ancillary to the science and math concepts they are exploring (e.g., computer-aided design for engineering projects), or facilitate scientific communication (e.g., word processing, webpage design).

TABLE 3

Summary of social/cultural/personal enrichment program components

Program	Arts and cultural activities	Field trips	Guest speakers	Peer component	Under-representation education	Programs for parents	Counseling (CF=college/financial; CO=career/occupational; CA=college application; P=personal)	Mentoring (U=university faculty/staff; I=industry professionals; V=Volunteers)
Thompson, 2002							CF, CO, CA	U
Kort, 1996		x	x					U, I
Marshall and Buckingham, 1995		x	x	X				U, I, V
Richardson <i>et al.</i> , 2003		x	x	X	x	x	CO	U, I, V
Kahle and Damnjanovic, 1994				X				
Yanowitz and Vanderpool, 2004			x				CO	
Benore-Parsons <i>et al.</i> , 1995	x				x		CO	U, I
O'Brien <i>et al.</i> , 1999			x	X	x		CF, CO, P	
Baker <i>et al.</i> , 1999	x	x	x	X	x		CO	I
Hausssler and Hoffman, 2002				X				
Bartsch <i>et al.</i> , 1998		x	x	X	x		CO	I
Rea-Poteat and Martin, 1991		x	x	X	x		CO, P	I
Jayarathne <i>et al.</i> , 2003		x	x	X	x		CO	U, I
Atwater <i>et al.</i> , 1999		x	x	X			CO	U
Campbell <i>et al.</i> , 1998		x	x		x	x	CF, CO, CA, P	U
McShea and Yarnevich, 1999				X	x			
Lam <i>et al.</i> , 2000		x	x	X	x	x	CF, CO, P	U, I
Mawasha <i>et al.</i> , 2001		x	x	X	x		CF, CO, CA	I
Kerr and Robinson Kurpius, 2004			x				CF, CO	U, I

Program	Arts and cultural activities	Field trips	Guest speakers	Peer component	Under-representation education	Programs for parents	Counseling (CF=college/financial; CO=career/occupational; CA=college application; P=personal)	Mentoring (U=university faculty/staff; I=industry professionals; V=Volunteers)
Barnett <i>et al.</i> , 2006		x						
Parker and Gerber, 2000								
Hanks <i>et al.</i> 2007	x	x	x	X	x		CF, CO, P	U, I, V
Murray <i>et al.</i> (2009)								
Paris <i>et al.</i> (1998)		x				x		U
Rodriguez <i>et al.</i> (2004)							CF, CA	U
Winkleby <i>et al.</i> (2009)			x		x		CF, CO, CA, P	U, I
Reid and Roberts (2006)		x	x	X		x	CO, P	U, I
Miller <i>et al.</i> (2007)		x	x	X	x		CF, CO, CA	U
Ellis (1993)					x	x	CF, CO, CA, P	U
Wechsler <i>et al.</i> (2005)		x	x				CO	U
Riggs <i>et al.</i> (2007)	x	x	x		x	x	CO	U, V
Ferreira (2002)		x	x	x			CO, P	U, I
McKendall <i>et al.</i> (2000)				X			CF, CO, CA	U
Ellis and Smith (1987)				X			CF, CO, P	U, V

Key: CF=college/financial counseling; CO=career/occupational counseling; P=personal counseling; CA=college application counseling; U=university faculty/staff mentors; I=industry professional mentors; V= volunteer mentors from the community

TABLE 4

Summary of program evaluation components

Program	Randomly assigned controls	Matched controls	No controls	Longitudinal	Pre and post	Quant.-achievement	Quant.-subject matter	Quant.-attitudes	Quant.-attrition	Qual.	No eval.
Thompson, 2002			x					x	x	x	
Kort, 1996											x
Marshall and Buckingham, 1995			x		x		x	x		x	
Richardson <i>et al.</i> , 2003			x		x	x	x	x		x	
Kahle and Damjanovic, 1994			x		x			x			
Yanowitz and Vanderpool, 2004			x		x			x		x	
Benore-Parsons <i>et al.</i> , 1995											x
O'Brien <i>et al.</i> , 1999			x		x			x			
Baker <i>et al.</i> , 1999			x		x			x			
Haussler and Hoffman, 2002				x	x	x	x	x			
Bartsch <i>et al.</i> , 1998	x		x							x	
Rea-Poteat and Martin, 1991			x					x			
Jayaratine <i>et al.</i> , 2003		x		x	x			x			
Atwater <i>et al.</i> , 1999			x	x	x			x	x		
Campbell <i>et al.</i> , 1998		x		x		x	x		x		
McShea and Yarnevich, 1999		x		x		x	x		x		
Lam <i>et al.</i> , 2000			x	x	x	x			x		
Mawasha <i>et al.</i> , 2001			x							x	
Kerr and Robinson Kurpius, 2004			x	x	x			x			
Barnett <i>et al.</i> , 2006		x			x			x		x	
Parker and Gerber, 2000			x		x		x	x		x	
Hanks <i>et al.</i> 2007		x		x	x	x		x	x	x	
Murray <i>et al.</i> (2009)		x			x		x	x		x	
Paris <i>et al.</i> (1998)			x		x		x	x		x	
Rodriguez <i>et al.</i> (2004)			x		x		x			x	
Winkleby <i>et al.</i> (2009)			x	x	x	x		x	x	x	
Reid and Roberts (2006)			x		x		x	x			

Program	Randomly assigned controls	Matched controls	No controls	Longitudinal	Pre and post	Quant.-achievement	Quant.-subject matter	Quant.-attitudes	Quant.-attrition	Qual.	No eval.
Miller <i>et al.</i> (2007)			x	x	x	x	x	x	x	x	
Ellis (1993)			x		x		x	x			
Wechsler <i>et al.</i> (2005)			x		x			x			
Riggs <i>et al.</i> (2007)			x		x			x			
Ferreira (2002)			x		x			x		x	
McKendall <i>et al.</i> (2000)			x	x		x			x		
Ellis and Smith (1987)			x	x		x			x		