Defining a Research Agenda for STEM Corps: Working White Paper

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Contents

1. Study Background 1
1.1 Current paper 3

2. Methods: Literature Searches, Screening, and Reviews 5
2.1 Search and review procedures 5
2.1.1 Reference search 5
2.1.2 Screening process 5
2.1.3 Review process 6

3. Summary of Papers and Programs 7
3.1 Program goals 7
3.1.1 Changing students' attitudes and beliefs 8
3.1.2 Raising students' knowledge and achievement 9
3.1.3 Providing opportunities for specific subgroups of K-12 students 9
3.2 Program Content, Types and Settings 10
3.2.1 Content areas addressed 10
3.2.2 Program Settings 10
3.2.3 Program Target Ages/Grades 11
3.3 STEM Experts' Involvement 11
3.3.1 STEM experts' professional backgrounds 13

4. Summary of Research Conducted 14
4.1 Outcome domains 14
4.2 Framework for understanding study results 14

5. Discussion and Recommendations for Future Research 17
5.1 Discussion 17
5.2 Recommendations for Future Research 17
5.2.1 Articulate the focus and scope of the practice 18
5.2.2 Develop a theory of action and logic model 19
5.2.3 Empirically investigate the theory of action and logic model 19
5.2.4 Strengthen the evidence base through purposefully tiered research designs 20
5.3 Recommendations for papers on STEM experts 21
5.3.1 Explicit program components and role of STEM experts 21
5.4 Role for program funders 22
5.5 Summary 23

6. References 24

Appendix 1: Summary of Articles in Synthesis 29

Appendix 2: Program and Evaluation Characteristics 32

1. Study Background

The vast majority of American students are neither prepared nor sufficiently engaged to become science, technology, engineering, and mathematics (STEM)-literate citizens or innovative STEM professionals (National Research Council, 2007; Carnegie Corporation and the Institute for Advanced Study, 2009; National Science Board [NSB], 2010; President's Council of Advisors on Science and Technology [PCAST], 2010). Evidence from the 2012 Program for International Student Assessment (PISA) international assessment places the U.S. in the bottom third in science (20th of 34 OEPD nations), and bottom fourth in mathematics achievement (27th of 34) (PISA, 2012).[1] Scores from the National Assessment of Educational Progress (NAEP) indicate that less than one-third of U.S. eighth graders show proficiency in mathematics and science, with African-American, Hispanic, and Native American students consistently underperforming compared to their white peers (National Center for Education Statistics [NCES], 2013), and less than 9 percent of U.S. 15-year olds were top performers (level 5 or 6) as measured by PISA (PISA, 2013). These results clearly indicate that American students are ill-prepared for advanced scientific training or the more rigorous STEM courses necessary to pursue post-secondary education and/or careers in the STEM fields.

Moreover, the challenge of developing STEM-literate citizens and building the STEM professional pipeline is multifaceted, and represents more than a lack of academic preparation or achievement. Evidence about students' interest in science—which predicts students' pursuit of science-related careers—is a critical part of the puzzle, as too many high school students report that they dismiss STEM career possibilities because they neither know people who work in STEM areas nor understand what such people do (Tai et al., 2006; Lemelson, 2010). The interest gap is particularly severe among girls and minorities for whom research indicates are far less likely to pursue post-secondary coursework or graduate with STEM degrees than their white and/or male counterparts (Higher Education Research Institute Research Brief, 2010). Increasing students' interest in STEM is an essential step in increasing their subsequent pursuit of STEM education and careers as well as the general competency expected of U.S. citizens in the 21st century workforce (NSB, 2010, 2014).

In today's technological and global society, the STEM disciplines are viewed as fundamental to the nation's economic growth and prosperity. Employment opportunities in STEM fields have increased at a faster rate than in non-STEM fields (Government Accounting Office [GAO], 2006). Additionally, even professions in agricultural and law fields, once perceived as not requiring require STEM skills, are increasingly requiring scientific and technological proficiency (PCAST, 2010). As American students continue to underperform in math and science compared to their international peers, concerns have arisen about America's economic and technological competitiveness. Research also indicates that a large share of U.S. science degrees are awarded to people born abroad (Borjas, 2005), and America's dependence on foreign-born and foreign-trained scientists is on the rise (Xie & Achen, 2009). Such trends have sparked political interest in uncovering means to prepare and engage students in STEM fields more effectively. In 2013, a report from the White House Office of Science and Technology Policy called for "a concerted and inclusive effort to ensure that the STEM workforce is

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[1] Evidence from the most recent TIMMS assessments suggest somewhat better results for 4th and 8th grade students; American 4th graders' scores were in the top third, and 8th graders' scores in the top half for both math and science, respectively (see http://nces.ed.gov/timss/results11.asp).

equipped with the skills and training needed to excel in these fields" in order to sustain the capable and flexible workforce necessary to compete in the global marketplace (National Science and Technology Council, 2013).

How can we, as a nation, better engage our students—and our citizenry—in the pursuit of knowledge and learning about STEM subjects? There are numerous large-scale efforts underway, which include: projects to improve the quality of the teaching force (e.g., 100Kin10, Robert Noyce Scholarship Program[2]); efforts to increase the relevance of instructional materials (e.g., the Common Core State Standards); presidential initiatives (Educate to Innovate, FIRST, First in the World, America Competes, Youth Career Connect); and a wide array of statewide and community-based efforts (e.g., Massachusetts High Tech Council, the Community-based Science Projects sponsored by the National Science Teachers Association).

Policy interest has extended to the role of professionals in STEM education of students. For example, in April 2013, President Obama announced that the Corporation for National and Community Service (CNCS) would launch a STEM AmeriCorps initiative, to build student interest in science and engineering, by mobilizing AmeriCorps national service members in nonprofit organizations to work with STEM professionals and inspire young people to excel in STEM education (CNCS, 2013), and recently CNCS announced an expansion of this effort (CNCS, 2014). In 2013, another ambitious national effort was launched; US2020 is a national partnership organization focused on preparing our students for STEM-related careers by matching girls, underrepresented minorities, and low-income children with STEM mentors.[3] By providing students with a broader range of exposure to STEM content that is more relevant to their lives, from a more diverse set of adults than their teachers alone (including young adults in STEM-related careers), the hope is to provide greater opportunities to larger numbers of students to learn more about STEM subjects, become more interested in STEM content, and ultimately, to pursue additional STEM education and career possibilities.

As evident by the diverse range of existing initiatives aimed at increasing interest and improving academic performance in STEM, the challenge our nation faces is complex, and a requires a multipronged response at national and local levels. Initiatives that can spur multifaceted change, by promoting student interest and academic achievement, may help develop and sustain a STEM-literate citizenry. Accelerating greater interest, competence and achievement in STEM fields requires thoughtful analysis of existing research to parse out what we already know about effective strategies for such acceleration, and to highlight where additional research may be warranted. In fact, within the past several months alone, the National Academies of Science issued a report about integration of STEM into K-12 education, and convened an invited workshop summarizing best practices in informal science, and the GAO issued a report on connections between STEM education and the workforce.[4]

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2 See http://www.100kin10.org/ and http://nsfnoyce.org/, respectively for information about these two initiatives, each of which is designed to improve the quality (and quantity) of STEM teachers.

3 See http://us2020.org/stem-mentoring/.

4 See http://sites.nationalacademies.org/DBASSE/BOSE/DBASSE_086989, and http://www.nap.edu/catalog.php?record_id=18612 for information on the National Academies efforts, and http://www.gao.gov/assets/670/663079.pdf for the GAO's report.

As we grapple with the challenge of bolstering student interest in and preparation for further secondary and post-secondary STEM education and careers, research on youth development more generally may offer important and applicable lessons about how to most effectively engage students. The youth development literature has found, for example, that hands-on project learning (often called inquiry learning) and peer-to-peer interactions have positive impacts on metacognitive development, academic outcomes, and student motivation (Flick, 1993; Haury & Rillero, 1994). Hands-on learning often enables students to work together in groups and, in turn, develop social skills. Such opportunities for students to talk through course materials with peers have been found to help students learn in different ways and retain information more effectively (Johnson & Johnson, 1986). Additionally, the research in this area indicates that use of hands-on activities in the classroom positively influences students' attitudes about the content they are learning (e.g., Gerstner & Bogner, 2010; Randler & Hulde, 2007).

The research also suggests that opportunities for adolescents to have meaningful engagements and supportive relationships with adults can influence a range of outcomes, including educational performance, mental health, and problem behavior (DuBois & Silverthorn, 2005; Eby et al., 2008; Rhodes & DuBois, 2008). The presence of positive adult role models, particularly in the form of mentor relationships, has been shown to have benefits for adolescents across academic and socio-emotional domains (Coleman, 1988; Jekielek, Moore, Hair, & Scarupa, 2002; Karcher, 2008; Werner & Smith, 1992). A meta-analysis of research about mentoring found that mentoring programs particularly benefit at-risk youth (DuBois, Holloway, Valentine, & Cooper, 2002), and an impact study of the Big Brothers/Big Sisters program found that mentored students showed greater scholastic competence, higher attendance rates and grades than those without mentors (Tierney, Grossman, & Resch, 2000).

The research base about youth development provides useful insights for thinking about how best practices for adolescent engagement could apply to programs designed to spur educational and ultimately career interests in STEM. One common element across many current STEM initiatives is expanding the number and types of adults with whom students interact about STEM careers and learning. More specifically, many programs have sought to incorporate mentoring relationships, whether the mentors serve as role models, coaches, informal or formal educators, or as representatives of individuals who work in diverse STEM content areas, to support engagement with the STEM fields. Given that mentoring relationships have been shown to positively influence academic and developmental outcomes for students, there is hope that STEM-specific mentoring programs have the potential to provide some of the same benefits with supplemental content exposure and support.

For this project, we focus specifically on projects that engage STEM-trained adults to work directly with students and identify areas where future research could advance knowledge in the field. By focusing on programs that connect students and adults specifically on STEM content and careers, we can begin to identify the possible benefits of such programs, both in relation to the mission of promoting interest in STEM fields, as well as supporting adolescents' developmental well-being.

1.1 Current paper

The current project set out to identify and synthesize research findings on programs that involve adults trained in STEM fields who engage with students in educational activities, focusing exclusively on programs that measure outcomes for the participating students. We planned to build on that first step, through using those findings to propose directions for developing a cohesive research agenda that could guide future programmatic and research endeavors about using STEM volunteers. Our expectation was that we would find substantial published research on the topic, because it is popular and widely discussed. However, after extensive searching and reviewing, it became clear that the research base was less developed than we expected.

Our search identified numerous papers describing programs, implementation, and general strategies for volunteerism in K-12 education; surprisingly, the number of studies that reported on student outcomes was much smaller. We found papers whose studies addressed quite diverse programmatic goals, and were correspondingly diverse in the types of STEM experts, nature of their involvement, and centrality of their roles to the overall program goals. Most papers described program evaluations designed to provide information for program developers and operators, through rich descriptions of program implementation and outcomes. Further, the large majority of papers described programs for which STEM experts represented one of many program elements that varied in importance.

The consequence of finding far fewer papers than we expected led us to shift the focus away from synthesizing research results, and using those results to make specific research recommendations. Instead, the current state of research led us toward developing a description of the research landscape more generally, and toward developing recommendations about steps that could be taken to conceptualize and initiate a more systematic research agenda.

Below, we describe the literature search conducted to identify studies on programs in which STEM professionals interact with K-12 students. Next, we summarize the identified literature, the programs addressed, and the research results described in relevant studies. Finally, we discuss the limitations of the literature, and make recommendations for steps to be taken toward establishing a cohesive research base on the involvement of STEM professionals in K-12 education.

2. Methods: Literature Searches, Screening, and Reviews

The chief goal of the literature search was to identify research about educational programs that involved STEM professionals who engaged directly with K-12 students—and that reported on student outcomes. Initially, the search purposefully cast a wide net about the types of adults, students, and STEM engagement studied. The literature review included papers that described projects, programs, and initiatives that targeted students' general STEM interest and engagement, as well as student retention and academic achievement in STEM courses, and students' aspirations and plans for post-secondary careers and education. Below, we summarize the approach used to locate, identify, and obtain relevant research; a more detailed description of the search procedures is presented in Appendix 1.

2.1 Search and review procedures

In this section, we describe the multi-step processes used to identify sources, conduct initial screening, and review papers.

2.1.1 Reference search

Searches were conducted online initially using Google Scholar and the EBSCO database, which covers a wide range of periodical databases, including: Academic Search Complete; Biomedical Reference Collection: Corporate; Business Source Corporate; EconLit; Environment Complete; MEDLINE; SocINDEX; Psychology and Behavioral Sciences Collection. These searches were followed up by manual searches of selected online journals, including relevant titles (Appendix 1).

Initial searches surfaced thousands of articles about adjacent and related topics. Coders systematically screened bibliographic material (e.g., abstracts, keywords, citations, etc.) to group articles into "relevant" and "not relevant for our purposes" categories. Perhaps not surprisingly, considerably fewer articles could be immediately categorized as directly relevant. Ultimately, literature searches generated nearly 500 articles, reports, books, dissertations, and other sources that met the initial screening criteria, and were deemed potentially topically relevant for the literature review.[5]

2.1.2 Screening process

The bibliographic information for sources identified as potentially relevant was entered into a screening database and systematically reviewed by trained coders who used a standardized screening protocol. The criteria for an initial review included:

1. The focus of the paper or article was on a program (or programs) that engages K-12 students in STEM activities, in and/or outside of school (e.g. afterschool programs, camps, and competitions), using adults or older students as mentors or volunteers to increase student engagement, interest, persistence and achievement in STEM education (and ultimately) STEM careers; and
2. The paper described specific programs, practices, activities etc., rather than more general discussions about (a) why student engagement in STEM is important, (b) guidance or

[5] This number includes duplicates of studies identified at different times in the search process.

recommendations for establishing programs to engage K-12 students, or (c) policies related to STEM engagement.

Papers not meeting these two criteria were screened out, resulting in 235 articles.

The study team obtained the full text of each study determined to be eligible for a full review.

2.1.3 Review process

The next procedural step included a more specific review than the initial screening process described above, by applying two additional criteria (presented in italics). Specifically, we focused on those papers that:

1. Provided descriptions of specific programs that engage K-12 students in STEM activities, in/outside of school (e.g. afterschool programs, camps, and competitions);
2. Described programs or interventions that rely on adults or older students as mentors or volunteers to increase student engagement, interest, persistence and achievement in STEM education (and ultimately) STEM careers;[6]
3. *Described programs that used a wide range of adults or mentors who were employed by organizations engaged in STEM-related functions, whether technology, life sciences, analytics, engineering, or other STEM fields, or were engaged in academic pursuit in a STEM-related field (e.g., biology, medicine, IT, etc.) whether as faculty, postdoctoral researchers, graduate students, or undergraduates in a university STEM program.*
4. *Explicitly described empirical research about student outcomes (i.e., reported data on student outcomes, whether academic, attitudinal, behavioral in nature, that had been collected, analyzed, and were described with sufficient detail for reviewers to characterize the nature of data collection activities).*

Articles that met these criteria were reviewed in depth, and information about those articles was entered into a database. Those not meeting our criteria were set aside. Ultimately, 29 articles were deemed eligible for inclusion.

The selected articles were then reviewed by trained coders who recorded and summarized key pieces of information into a database using a structured coding protocol. Information entered into the database about each article could be (and was) further coded, and later synthesized. The coding process was iterative; papers were re-examined in light of new themes and information that emerged from the review and synthesis processes.

Exhibit 2-1. Summary of articles identified, obtained, screened, and reviewed

	Number
Met initial screening criteria	474
Full text obtained (and reviewed)	416
Met initial criteria for review	235
Retained in synthesis database after full review	29

6 Articles were retained regardless of type of adults or mentors, whether they were K-12 students older than the target population, college or graduate students, or community volunteers. Similarly, articles were retained regardless of the nature of activities provided to participants (e.g., in-person or online).

3. Summary of Papers and Programs

The 29 papers included in the final review were published or posted between 1986 and 2013. Most were published in 2000 or later (Appendix 2). The studies were disseminated via peer-reviewed journals, government reports, conference papers, dissertations, and program websites. Some were unpublished reports posted on program or project websites. All of the papers described studies that in some way measured the impact or effectiveness of programs in which STEM professionals or other adults work directly with K-12 students.

The papers reflected diverse audiences, purposes, and levels of detail. Some papers were written for external audiences (e.g., journal articles) and provided details on program characteristics. Other papers were written for internal audiences such as program operators and/or funders, particularly unpublished papers found on program websites. Further, some papers focused primarily on evaluation results, while others described the programs and/or the theories guiding them. The diversity across papers—especially in terms of level of specificity about program elements—made it difficult to group programs into separate and mutually exclusive categories. In fact, rather than providing concrete examples of how different programs incorporated STEM experts into their educational activities, many of the papers provided little detail on STEM experts' assignments and roles, which made it difficult to discern the exact nature of STEM experts' roles.

Recall that our literature search sought papers about studies of any programs designed to improve student outcomes. This focus may have contributed to the diversity of program types as well as the small number of each type represented in the corpus. Perhaps had we focused the search on a specific program type (e.g., summer programs designed to provide K-12 students with exposure to university-based research settings) rather than on finding research results on outcomes, we might have been more likely to find more papers describing these types of programs. Even so, we suspect we would have ended up with a very small set of studies that presented findings on student outcomes—despite the fact that the initial number of potential papers was so much higher. We note this discrepancy because the numbers and types of programs retained in our research summary do not represent what is in the larger population of papers/articles about STEM education that reference using volunteers. The papers retained in our review reflect a series of analytic decisions based on reported student outcomes rather than program types. Below, we summarize characteristics of some programs within our review to provide context for understanding the results. However, the programs described below should not be interpreted as being representative of the larger group of program that try to engage students in STEM subjects using volunteers. With these two caveats in mind, we describe some of the programs included in the review corpus.

3.1 Program goals

Program goals, whether described explicitly or indirectly, were categorized based upon what we could extract or infer from the text of articles. Given that most of the articles (in our review) reported on program evaluations, most papers included descriptions of program goals. Coders used a two-stage process to summarize programs' goals. In the first stage, we examined articles to learn whether authors had explicitly reported program goals. In the second stage, coders deduced program goals from information provided in articles that did not explicitly articulate goals.[7] The articles revealed a range of underlying program theories.

The specific program goals varied extensively, and many programs had multiple goals. The descriptions of most programs, however, included goals related to changing students' attitudes and beliefs, interest in STEM, and motivations to engage in STEM activities, K-12 and college classes, and careers (Exhibit 3-1). Only four of the 29 articles in the review database did not include these types of goals in their program descriptions.

Exhibit 3-1. Program goals

Program goals	Number
Change students' attitudes, beliefs, or plans	25
Raise desire to pursue a STEM college course, graduate school, or career	13
Increase interest, excitement, or engagement in STEM topics	20
Increase confidence and self-efficacy when addressing STEM topics	7
Increase STEM participation in particular groups of students (e.g., girls)	17
Increase STEM content knowledge, skills, or academic achievement	20
Increase rate of participation in STEM K-12 classes	3

Notes:

1. Since we selected programs on the basis of whether students were participating in programs with STEM adults about STEM activities, we categorized programs as having this goal only if it was explicitly reported and the program espoused no other goals.

3.1.1 Changing students' attitudes and beliefs

A majority of the reports described programs' intentions to inspire students' interest in STEM. Such programs seem to be predicated on the belief that students who are interested in STEM and perceive its value will subsequently be motivated to pursue STEM careers (as well as the college and graduate-level coursework that may be necessary to do so). More than two-thirds of the programs were described as having goals related to increasing students' interest, excitement, or engagement in STEM topics. More than half of the programs espoused goals of motivating students to pursue STEM college or graduate degrees and/or careers. One example of a program with this type of goal is the *Discover Engineering Summer Camp.* The camp was designed to educate students, especially girls, about engineering, and demonstrate to them that engineering represents a viable career option via hands-on activities, exposure to higher educational engineering faculty and students, and panel presentations by female engineers (Anderson & Gilbride, 2003).

Almost one quarter of the programs were designed to help students develop greater self-efficacy in STEM topics. These programs followed the theory that some students, especially those from groups typically underrepresented in STEM fields, could harbor implicit assumptions about whether they

[7] This information included logic models, research questions or hypotheses, and research outcomes. If, for example, a given paper's research questions asked whether an intervention led to improvement in students' math achievement, our coders would deduce that improved academic achievement was a program goal. We wanted to be appropriately cautious, however, about over-interpretation, so we limited this kind of deduction to instances where there was explicit enough information about program activities to infer goals. Coders did not, for example, use foci in literature reviews to deduce program goals.

perceive themselves as interested and/or able to enter STEM fields. The *Gaining Options: Girls Investigate Real Life (GO-GIRL)* program for seventh grade girls is one such program; the university-based math enrichment program was designed to place girls in math courses, by using university labs and resources, to help them learn about math-related careers, and work collaboratively as teams led by university student mentors (Trotman Reid & Roberts, 2006).

An approach used by some programs to change students' perceptions of STEM fields as inhospitable was to provide opportunities for students to challenge themselves and succeed in STEM activities. An underlying assumption of such program developers seems to be that the process of successfully meeting challenges in STEM areas would alter students' self-perceptions, so that they would subsequently perceive themselves as capable of succeeding in STEM fields. Other programs sought to provide students with STEM role models with whom they could identify. For example, the *FIRST Robotics Competition (FRC)* provided team-building opportunities for students to construct robots in competitions; the underlying premise was that the experiences would build their confidence and interest, and to establish contact with the university students or professionals who served as mentors to teams (Melchior, Cohen, Cutter, & Leavitt, 2005).

3.1.2 Raising students' knowledge and achievement

More than half of the programs in the review were designed to increase (1) students' academic achievement; (2) development of STEM skills; or (3) development of content knowledge directly. These types of programs aimed to engage students in STEM classes and/or activities that involved STEM professionals as a way of increasing their STEM knowledge in specific fields. For example, Li, Moorman, and Dyjur (2010) investigated whether the use of group remote mentoring via videoconferences and emails in conjunction with inquiry-based classroom learning activities (i.e., *Inquiry-Based Learning with E-mentoring (IBLE)*) would affect rural students' math and science learning. The students worked as groups on issues associated with grizzly bears, and interacted with bear experts using the internet and videoconferencing.

Another example is the FEMME program (Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007); this study described five sites that offered multidimensional programs for female students including classes and lab experiences, field trips, and counseling. FEMME also brought STEM experts in to meet participating students (e.g., female engineers came in to discuss engineering career options).

3.1.3 Providing opportunities for specific subgroups of K-12 students

More than half of the projects focused on engaging specific subgroups of students in STEM activities that involved experts. Female students represent the most commonly targeted population, although some projects also focused specifically on increasing the engagement of minority students as well as students in under-resourced communities, whether rural or urban.

Programs used different approaches to provide opportunities targeted toward specific student subgroups. Some programs arranged activities for students to interact with STEM experts, and be exposed to such adults as role models and mentors. Another approach used by programs focused on involvement of STEM professionals in activities that incorporated more informal and social learning processes, aspects of education thought to support girls' learning styles particularly well (Koch, Georges, Gorges, & Fujii, 2010).

The *Build IT* program brought middle school girls together to explore using information technology (IT) tools (e.g., mobile devices, software, web tools etc.). Participating girls were collectively guided by professionals while using the tools to design and troubleshoot technologies. The program included family nights and field trips, among other activities. Through the program, IT professionals worked with participating girls, and discussed IT issues as well as their own paths to and experiences in IT careers. The activities and interactions with IT professionals were hypothesized to provide experiences that would inspire girls' interest, and would help them develop more confidence in their ability to pursue IT-related careers (Koch, et al., 2010).

The *Starbase-Atlantis* program sought to provide urban at-risk students with hands-on learning experiences in the presence of STEM professionals. Upper elementary students were brought to a Navy Fleet training center for several days to experience hands-on science activities and computer-based simulations and games to learn concepts in math, science, planes and ship maintenance, meteorology, and navigation (Lee-Pearce, Plowman & Touchstone, 1998). The authors of the pilot study about this program theorized that the program activities inspired students' interest and activated their "… desire, initiative, resourcefulness, and persistence" (p. 234).

The programs articulated wide-ranging goals, although the overarching intent (and associated activities) generally addressed efforts to influence students' attitudes about and knowledge of STEM content areas, procedures, and careers. The activities used to achieve program goals also varied widely, and included exposure to role models, engagement in hands-on projects, or place-based learning.

3.2 Program Content, Types and Settings

3.2.1 Content areas addressed

The programs spanned a range of STEM content areas, often combining more than one (Exhibit 3-2). Nine programs explicitly noted that their content foci addressed multiple STEM topics, including science, and six programs included a focus on science. Eight programs noted specifically that they focused on engineering, and five programs included a focus on mathematics.

Exhibit 3-2. Educational STEM content areas addressed

	Number
Science	6
Engineering	5
Technology	4
STEM	2
Mathematics	2
Science + mathematics	3
Science + technology	3
Science + engineering	2
Science + mathematics + engineering	2
Total	**29**

3.2.2 Program Settings

The program settings ranged from schools and museums, to community centers, and institutions of higher learning (IHEs). However, the programs can be grouped into several categories (Exhibit 3-3).

Not surprisingly, the majority of programs were housed primarily in educational settings, including K-12 schools during school hours, university or college campuses, and afterschool programs (Exhibit 3-3). Three programs placed students extensively in such STEM-related settings as hospitals, corporate labs or other work spaces. Two programs used combinations of school-based and other settings and occurred in multiple locations.

Exhibit 3-3. Program settings

	Number
K-12 schools and classrooms	12
IHE campuses	8
IHE campuses and schools	4
Unspecified	1
Various settings across multiple sites	2
Places of STEM employment or research sites	2
Total	**29**

3.2.3 Program Target Ages/Grades

Most of the programs served children in middle and high school (Exhibit 3-4). Fewer (five) programs focused exclusively on students in elementary grades.

Exhibit 3-4. Grades served in programs

	Number
Elementary school (K-5)	5
Elementary + middle school	4
Middle school (6-8)	9
High school (9-12)	9
K-12	2
Total	**29**

3.3 STEM Experts' Involvement

Each program included at least one component in which STEM professionals (or experts, for our purposes) interacted directly with K-12 students in STEM-oriented activities, settings, or classes. Generally, STEM experts played multiple roles (e.g., role model, leader of inquiry-based activities). Yet the papers also described STEM experts with quite distinct roles (e.g., IHE faculty teachers in a summer program, or undergraduate students who served as mentors to individual K-12 students). Given the level of information available across the 29 papers in our review, we could not characterize individual programs as relying upon a single type of STEM expert model (Exhibit 3-5). The *Discover Engineering Summer Camp*, for example, relied upon several different types of STEM experts: it organized camps for female high school students as well as classroom inquiry-based activities in schools. Female science and engineering university faculty taught courses for female students, undergraduate students served as role models, and female engineering professionals participated in panel discussions (Anderson & Gilbride, 2003).

Some individual programs cannot be categorized, yet the roles STEM experts played can be—keeping in mind that individual experts could and did play multiple roles in many programs. Twenty-three programs included components in which students and STEM professionals engaged together in inquiry-based learning, research, and design projects. Two of these programs (described in three articles) organized design competitions in which students worked in teams to design robots for competitions (Karp, Gale, Lowe, Medina, & Beutlich, 2010; Karp & Schneider, 2011; Melchior et al., 2005). All 23 of these programs emphasized inquiry-based or hands-on learning approaches in which students used tools, procedures, or content knowledge from such STEM fields as engineering.

Exhibit 3-5. STEM Experts' Roles

	Number
Lead or support for inquiry-based learning activities	23
Role Model and/or Mentor	13
Presenter of short-term workshops, classes, lectures, group activities, field trips to museums, etc.	8
University faculty teaching courses for K-12 students	8
Leader of STEM team in a competition	3
Support/resource for classroom teaching and learning (excluding hands-on activities)	3
Apprenticeship leader/internship supervisor	2

Notes

1. STEM experts could (and did) play multiple roles within and across programs; as a result, the number of programs within which experts could play specific roles exceeds the number of programs.

In these projects, STEM experts led and/or supported students engaged in various projects to demonstrate how STEM experts in the "real world" problem-solve; they also typically provided content expertise from their respective substantive fields. Students could observe how the experts conducted research (or design) in action. In many of these programs, STEM experts developed relationships with students and became their mentors.

Almost half of the articles described participating STEM experts as role models and/or mentors. For the most part, experts acted as mentors for such specific activities as completing a research or design project, providing advice on college and career pathways and choices, or facilitating groups of students engaged in hands-on activities. In the *FIRST Robotics Competition* described above, for example, STEM experts supported teams of students building robots for competitions. They were described as mentors to the students, though their participation centered on competition-related activities (Melchior et al., 2005).

Eight programs featured faculty from IHEs. K-12 students attended university-based programs, often held in the summer, in which STEM faculty, graduate, and undergraduate students taught classes, worked with students during field trips or project-based activities, or acted as counselors and activity organizers for students. A college campus, for example, was where the *Summer Science Exploration Program* operated (Gibson & Chase, 2002); participating middle school students conducted experiments using laboratory and field procedures and equipment to explore their own (as well as others') research questions. The setting allowed students to learn using state-of-the-art equipment while being taught by both college faculty and middle school teachers.

STEM experts were presenters or guests in short-term events such as classes, panel discussions, or workshops with students in eight programs. In this capacity, they visited classrooms, gave career presentations, took part in panel discussions in summer programs, and participated in field trips to museums and STEM workplaces. These programs presented STEM experts as featured guests rather than as regular participants with whom students develop relationships.

Two articles featured programs that placed students into extended internships or apprenticeship relationships with STEM experts working in their fields. In these programs, students either worked with or shadowed STEM experts as they worked in research sites, hospital labs, or corporate settings focused on STEM activities.

3.3.1 STEM experts' professional backgrounds

The STEM experts working with K-12 students in the reviewed programs reflected diverse professional backgrounds (Exhibit 3-6). Almost half of the programs included STEM experts employed as researchers, employees of STEM-related businesses, health care workers and/or lab technicians. Because the majority of papers provided scant detail about the backgrounds or characteristics of STEM experts, we do not have sufficient information with which to summarize STEM experts' employment, experience, or educational preparation.

Another form of STEM expertise (represented in the reviewed papers) came from IHEs' STEM departments. Undergraduates participated as STEM experts in almost half of the programs, and graduate students participated in a third of programs. STEM faculty participated in 10 programs. About one-third of the programs did not explicitly reference university students or faculty, although it is possible that the programs described in these reports may have included researchers with university affiliations, albeit without explicit acknowledgement.

Exhibit 3-6. STEM Experts' professional roles

	Number
Employed in STEM profession (other than in an IHE)	12
Undergraduate student	13
Graduate student	10
Faculty member in an IHE	7
Diverse across programs	1

Notes

1. The type of STEM experts in one program was not explicitly described.
2. Because programs could have multiples types of STEM experts, the number of roles exceeds the number of programs.

4. Summary of Research Conducted

Recall that our goal was to summarize existing research literature about effective practices (as measured by student outcomes) for using STEM professionals to engage in STEM activities with K-12 students. To this end, we included articles only if they reported student outcomes from studies that provided a comparison between conditions (e.g., the outcomes in a group of students before and after they experienced a program) or between groups of students, some of whom attended the program being evaluated, and some of whom did not. Below, we identify the studies' outcome domains, discuss the study designs used, and outline the types of evidence they can potentially provide.

4.1 Outcome domains

The goals for the programs were quite diverse—and so too were the specific outcome domains described in the 29 papers. Most studies addressed student attitudes, interests in STEM, and students' self-efficacy and confidence in STEM fields (24 articles, Exhibit 4-2). Almost half of the programs addressed student outcomes related to academic achievement or the acquisition of specific STEM skills or knowledge.

Exhibit 4-2. Outcome domains addressed in evaluations

	Number
Attitudes and beliefs	24
Achievement, skills, knowledge	11
Knowledge about a STEM field and practitioners	9
Enrollment and/or persistence in college (and/or post-college) STEM courses	3
Other	4

Notes

1. Programs could (and did) address multiple outcome domains; as a result, the number of outcome domains exceeds the number of programs.

4.2 Study designs

Understanding the studies' results can be informed by two distinct considerations: (1) the diversity of STEM experts' involvement and roles across programs; and (2) the importance of using designs that can support causal claims about the relationships between student outcomes and program components. Each is discussed below.

Each paper in the corpus reported on student outcomes for the program being studied—and did not report on the impacts of STEM experts' involvement specifically. For example, in a program that includes inquiry-based activities, visits from STEM professionals to talk about their careers, and graduate students helping to guide students in STEM learning activities, we cannot disentangle whether and how student outcomes might be attributable to any one (or some combination) of these three activities.

Assessing the impact of STEM experts on student outcomes would require a study design that can separate the use of STEM experts from other program features. For example, a study would need to compare Program A, which uses STEM experts, to Program B, which has all the same program features *except* for the use of STEM experts. In another hypothetical example, if we wanted to investigate the impact of STEM experts' support in a K-12 engineering program that includes hands-on activities and museum trips, we would need to compare this program with one that has hands-on activities and museum trips, but does *not* have any STEM expert involvement. Under these circumstances, the effect of the STEM experts could potentially be isolated from the effect of the hands-on activities and museum trips. Almost none of the 29 studies used the types of comparisons that would allow us to attribute student outcomes to STEM expert involvement in a clear or causal way.

Because our review included papers about programs where STEM experts played varied roles in STEM activities with K-12 students, the importance of those experts also varied accordingly, and in some cases, we could not discern the specific nature of STEM experts' involvement. Further, none of the articles reported on programs in which STEM experts were the *only* programmatic feature. This may well reflect the fact that when STEM experts are involved in activities with K-12 students, they are interacting with students while engaged in an activity—and it is typically the activity itself that is characterized as being central to student learning. For example, STEM experts might have led students in an inquiry-based learning activity. Consequently, any impacts on student attitudes or other outcomes would confound the role of STEM experts' program involvement with those of the inquiry-based learning activity. Since STEM experts were consistently bundled with other program elements, it is difficult to draw direct conclusions about the "impacts" of STEM experts on student outcomes.

Another key consideration is the types of studies included in the review corpus. Almost half of the articles reported on studies that relied on one-group pre-post comparisons. Pre-post studies allow researchers to compare students' outcomes before and after program participation. If a positive difference is found (i.e., the outcomes are more favorable when measured after participation in an intervention than before), the program may be responsible for the change, but the available evidence is inconclusive.

We characterize the evidence provided by these types of studies as being descriptive, or perhaps suggestive of a program's promise, because they do not provide enough information about what might have occurred absent program participation, and there is no basis for comparison. While observed outcome gains could indeed be the result of a new program or an intervention, such outcomes could also be attributed to other influences (e.g., learning at school, participation in other programs or activities).

These types of studies can also be characterized according to the *Common Guidelines for Education Research and Development* released in 2013 by the U.S. Department of Education's Institute of Educational Sciences (IES) and the National Science Foundation (NSF) as being early stage or development studies. They are well-suited to exploring the associations between outcomes and programs.

To provide stronger evidence that a program causes students to change, we would want studies to rely upon either experimental or well-designed quasi-experimental designs. Robust experimental designs (in which students or classrooms/groups are randomly assigned to program and no-program control status) provide much more convincing evidence that a practice or program is effective, because any positive difference in outcomes found between the two groups being compared can be attributed solely to the program. Only one study in the review corpus used an experimental design.

Rigorous quasi-experimental studies (QEDs) can, under some conditions, also provide evidence of a program's impact, but methodologically, evidence from QEDs is generally considered to be weaker.

Results from QEDs can suggest that a given program has an impact, although such results cannot provide causal evidence of observed impact. Nonetheless, more rigorous quasi-experimental designs, such as well-executed regression discontinuity designs, are generally perceived as having greater methodological credibility because they can reduce the possibility that any positive difference in outcomes found between groups can be attributed to a cause other than the program, but they cannot fully eliminate it. Approximately half of the projects in the review corpus used quasi-experimental designs to investigate the effectiveness of their programs.

The diversity of programs as well as the concerns about research methods limited our capacity to synthesize the findings from the studies we reviewed and to summarize the variation in the strength of the evidence. Recognizing that there may well be interest in which outcomes were reported, however, we provide descriptive information about the domains (and other study features) in Appendix 2.

5. Discussion and Recommendations for Future Research

5.1 Discussion

Several themes emerged from the literature search conducted for this working paper, and from the research findings of the studies included in the final review corpus. First, the literature search yielded numerous articles that focused on STEM experts working with K-12 students. The abundance of research addressing this topic suggests that use of STEM experts, in some fashion, is quite prevalent, and that the inclusion of STEM professionals in STEM activities with K-12 students is a widely implemented educational approach.

In addition, most of the articles in our review describe more formative than summative research on programs using STEM experts, and further, most describe and explore aspects of program implementation. Of the several hundred studies that included a focus on STEM experts initially identified in our literature search, only 29 articles involved comparative research designs, either through the inclusion of a comparison group or a pre- to post-program comparison.

Another theme is that the focus of research varies widely in terms of the levels of detail provided on STEM professionals' roles and importance in program activities. Some articles highlight the roles played by STEM exerts, and explicitly identify them as being a key part of the educational approach of the programs studied. Other articles mention STEM expert involvement in program activities in passing, without describing the nature of adults' involvement, how the experts fit into the larger educational approaches used by the programs, or how the experts are recruited, trained, supported, or reviewed. Consequently, it is difficult to ascertain whether the variation in STEM roles across articles reflects the variation in the importance of their actual roles in programs, or whether it is an artifact of what was described in reports and papers. The variation in details both in reports and in programs themselves makes it difficult to draw substantively meaningful conclusions about adults' contributions across programs.

Additionally, the large majority of studies were not methodologically rigorous efficacy or effectiveness studies. Few used designs that can support casual conclusions about the impacts of the programs on student outcomes, because they employed quasi-experimental and pre-post one group designs that cannot provide conclusive evidence that programs "cause" positive student outcomes. Similarly, quasi-experimental and pre-post designs cannot sufficiently rule out the possibility that differences observed between students at the beginning and end of a program, or between program participants and nonparticipants, are attributable to factors outside of the program itself, such as differences in schools or characteristics of students prior to program attendance.

Holding aside the notion of causality, however, we can look across the studies and speculate that there may be promise in programs based, at least in part, upon the involvement of STEM experts—if we could inject greater consistency in reporting, methodological rigor, or both.

5.2 Recommendations for Future Research

As noted above, we began this project expecting to find a set of papers on studies of programs that rely upon STEM professionals who engage with K-12 students. Our initial search for articles uncovered an immense quantity of written work, clearly reflecting the prevalence of such programs.

The very prevalence underscores why we need to understand whether and how this approach can succeed; however, we uncovered only a limited set of studies that reported on empirically investigated impacts.

The paucity of existing research seriously limits our understanding how STEM professionals are most effectively used with K-12 youth. A further challenge to building the empirical evidence for the effectiveness of using STEM professionals is the breadth of STEM education, which constitutes multiple subfields (e.g., math education, engineering or environmental education, etc.), addresses all ages and education levels, from preschool education through K-12 and beyond, occurs in diverse settings—from informal to formal—and serves a multitude of goals. Indeed, variability was a consistent finding of our review.

While assessing whether a given practice is effective, and which specific practices are most effective remain challenging, we believe these are worthwhile activities that can lead to a deeper understanding of how adults can be deployed most effectively to engage students in STEM subjects. To support the rapid development of knowledge on these types of practices, we propose steps that can be taken to develop a more cohesive and well-articulated research base. These steps include:

1. Articulate the focus and scope of practices involving STEM-trained professional in K-12 educational activities;
    a. Identify the common elements across the roles and programs;
    b. Articulate the ways in which these practices are unique from other practices;
2. Develop a theory of action and logic model (or multiple models) to describe the hypothesized links between the practices and student outcomes;
3. Investigate and refine the hypothesized logic model(s) using the empirical findings from exploratory research;
4. Further develop the research base by conducting research designed to provide tiered evidence of increasing rigor.

Each proposed step is discussed below.

5.2.1 Articulate the focus and scope of the practice

One of the first steps toward establishing a cohesive knowledge base about STEM professionals in education is to articulate what STEM professional involvement in K-12 education actually means. We found substantial variation across programs in terms of the types of STEM experts involved, the roles they played, and their level of involvement.

One strategy might be to catalogue common ways in which specific practices occur. This could be accomplished through a two-step process: first, a literature review focused on a given practice, such as programs that place STEM graduate students in K-12 classroom settings, or programs that use design competitions, and second, a description of the range of programs that use such practices rather than a review of program outcomes. This approach might allow researchers to describe the current landscape of programs that rely upon STEM experts, and to document levels of involvement and specific contributions made by STEM experts.

Once the roles and activities have been described, it will then be possible to identify the common elements across them, and to determine whether various program elements represent subtle variations on a single construct or distinct and separate practices unrelated to one another. For example, it would be important to determine (in theory, at least) whether using STEM faculty to teach courses in summer school differs from using high school teachers (to teach summer school courses), and whether either of these two practices is similar enough to one that relies upon STEM professionals to mentor high school students in design competitions.

Similarly, understanding the extent to which practices *differ* from one another and represent unique practices is important (e.g., whether STEM graduate student classroom support is distinct from classroom teachers' instruction). We found multiple examples of programs in which STEM professionals served as supports for other program elements (e.g., inquiry-based learning activities), and we were unable to distinguish between the relative contributions of the STEM experts or the inquiry-based learning activities in assessing program impact. Having clearly articulated descriptions of the many different practices will help us understand whether STEM experts provide contributions to students' educations over and above other program elements. Examining these aspects of STEM expert activities across programs will allow researchers to identify the unique aspects and contributions made by STEM experts to K-12 education.

Another approach would be to draw lessons from mentoring literature about practices that have been found effective in other contexts. For example, having adults as mentors who are paired with specific students, and who have ongoing structured relationships with students, or purposefully pairing adults whose demographic characteristics mirror those of the students, may provide exemplars of practices that could be examined in terms of how such practices affect STEM attitudes, engagement, or achievement specifically.

5.2.2 Develop a theory of action and logic model

Once the landscape of STEM expert involvement in education has been described more systematically, it will be easier to develop a theory of action and logic model (or multiple models for different practices) that articulate the practices encompassed under the banner of "STEM expert involvement in education." This step would entail describing the many and different ways in which STEM experts are involved in K-12 education, identifying the common elements across them, and articulating how these practices are distinct from other instructional elements. From this process, we could develop a set of theoretical models that can then guide research about implementation of program elements as well as their hypothesized impacts on student outcomes.

5.2.3 Empirically investigate the theory of action and logic model

The theory of action and logic model, in combination, can simultaneously spur and focus development of empirical studies about implementation and impacts of the practices they describe. We might expect some studies to be exploratory, describing how practices depicted as hypothetical in the logic models are actually implemented in educational programs. And while there is already ample information about programs that use STEM experts in myriad ways, reports about these program do not routinely include a logic model that delineates STEM professionals' contributions. Nor does currently available information indicate that researchers consistently explore the associations between elements in the logic models, such as the factors associated with high and low levels of implementation. Examples of this type of research might include studies of how to recruit STEM professionals to work with educational activities, their relative success, and the impact the programs have on the professionals themselves. Guidelines developed by the U. S. Department of Education and the National Science Foundation explicitly recommend such exploratory studies to illuminate associations between program elements, implementation, and outcomes (Institute of Education Sciences & National Science Foundation, 2013). As logic models are developed and described, subsequent studies can focus more on establishing the efficacy of specific practices.

5.2.4 Strengthen the evidence base through purposefully tiered research designs

It will be much easier to design strong studies that investigate the impact(s) of using STEM professionals once the practices have been described systematically, and empirically explored. Effective impact studies require clear articulation of the research conditions being compared as well as precise measurement of the outcomes of interest; it may seem obvious, yet understanding the phenomenon of interest is an important prerequisite for designing a robust study.

The most convincing research designs will support causal conclusions about impacts. In our case, because we would like to understand the specific contributions of STEM experts to student outcomes, a strong design would presumably incorporate strategies to isolate the impacts attributable to STEM experts from those of other program elements (to the extent possible). The available research about the diversity of programs that use STEM experts—and the corresponding diversity of those experts' roles/responsibilities—provides clear indication that the generic practice of using STEM experts is widespread. Given the plethora of studies describing such programs and their implementation, it is reasonable to assume that the field can support more rigorous studies about whether and how different approaches influence such student outcomes as content knowledge, attitudes about STEM, and advancement in STEM career pathways.

Further, both more and large-scale studies of programs that depend on different contributions from STEM experts, and that are purposefully carried out to address different questions, could generate useful information that might advance the field. Because the types of programs vary so widely, conducting studies of different types of programs separately would allow us to assess the impacts of specific types of STEM expert participation more definitively. For example, programs that bring STEM experts from local industry and businesses into K-12 classrooms to lead hands-on activities might be studied separately from university-based programs that offer summer programs and classes taught by university STEM faculty. Separate streams of research with distinct foci would allow us, for example, to learn which aspects of the visiting expert approach or the university-based approach are most effective. Regardless of approach, learning about how these programs vary in implementation and impacts would also be useful. We do not assume, for example, that STEM experts influence student learning similarly across all types of programs, participants, and activities. Only through studies that purposefully examine STEM experts' roles across multiple—and different—programs will we learn which experts and which activities contribute (or do not) to desired changes in student outcomes. The process of conducting such studies will help to isolate the effect of STEM professionals, as well as explore the value-added of relying upon such individuals in multi-faceted programs.

One strategy for pinpointing the effects of using STEM experts to engage K-12 students in STEM learning, coursework or careers might be to conduct a planned variation study in which students, classrooms, or program sites would be randomly assigned to experience different levels of STEM expert involvement. For example, if researchers were interested in learning about the impact of STEM volunteers leading hand-on activities in middle school classrooms, one could design a multi-arm trial in which students, classrooms, or schools are randomly assigned to one of three conditions:

(1) provision of hands-on activities with no STEM expert involvement; (2) provision of the same activities with modest STEM expert involvement, perhaps through one or two visits to classrooms; and (3) provision of the same activities, supported by intensive STEM expert involvement through leading activities and frequent oversight of students' projects. This type of study design would allow researchers to assess whether STEM expert involvement influenced the outcomes, and if so, at what intensity, in providing hands-on activities that had an impact on student outcomes.

Studies that use stronger research designs will contribute substantially to the research base, and can help build more conclusive evidence about which aspects of using STEM experts in K-12 activities are especially useful. Given the extraordinary effort it often takes to establish and maintain programs that bring experts into contact with K-12 students, it is important to understand the benefits of the endeavors more definitively.

5.3 Recommendations for papers on STEM experts

5.3.1 Explicit program components and role of STEM experts

To build our knowledge about the effectiveness of STEM experts involved with K-12 youth, we need sufficient detail about program elements as well as the specific role of the STEM experts. The research papers we reviewed offered little consistent information about key program components, especially in describing who the STEM experts were, whether and how they had been trained, and the frequency, intensity, duration and content of interactions with students.

One strategy for deepening our knowledge base about adults' contributions to STEM-related outcomes for students would be through more systematically reported information on program elements, as well as on the adults or mentors themselves—holding aside who the students are or what the program content is. Specifically, having more consistent data across studies on the following dimensions would be helpful:

- STEM experts' background/prior experience working with K-12 students
- STEM experts' areas of STEM content knowledge/expertise
- Program-specific STEM focus
- Description of program setting
- Description of orientation and/or training provided by program staff to adults or mentors about one or more of the following:
  - ❖ specific program goals
  - ❖ how to interact with students effectively
  - ❖ specific program content/activities
- Type of supervision and/or oversight of STEM experts about one or more of the following:
  - ❖ to ensure consistency of experiences across multiple adults
  - ❖ to provide feedback to adults or program staff about program improvement
  - ❖ to monitor whether students are experiencing the program as intended
  - ❖ to ensure there are effective behavior management procedures in place
- Description of STEM materials, activities, or content used by adults/mentors
- Frequency of interaction between students and STEM experts, and
- Explanation of how programs assign adults/mentors to students

Having similar information across multiple studies would considerably enhance our capacity to synthesize what we know about the effectiveness of STEM experts' involvement in K-12 education across contexts and STEM fields.

We emphasize the need for more detailed information about the adults who serve as mentors or volunteers, although not at the exclusion of sufficient detail about program participants, program activities, and the assumptions underlying programmatic decisions. We found papers with sparse information about program staff, students, the frequency, intensity, or duration of activities, and little or no information about the hypothesized relationships between program activities and desired outcomes. Given our charge to examine the literature for evidence of effectiveness about using STEM mentors, we recognize that we may have overlooked process- or implementation-focused studies that might have presented more detail about program implementation. Nonetheless, even well-executed impact studies can contain sufficient detail about program implementation for reviewers to understand what programs do, how they are staffed, how many individuals or classrooms participate, and whether the activities were implemented as intended.

5.4 Role for program funders

Funders interested in supporting programs that bring STEM professionals into contact with K-12 students also have an important role to play, as they can emphasize the importance of and provide support for studies that evaluate these programs. Over the past several years, program funders have become much more cognizant of the importance of research evidence, and increasingly, federal and philanthropic organizations factor prior research evidence into funding decisions.[8] Programs such as the Department of Education's Investing in Innovation and its recently launched FIRST in the World competitions, the Department of Labor's Youth Career Connect and Workforce Investment Fund programs, and the Corporation for National and Community Service's Social Innovation Fund all represent federal initiatives that use potential grantees' prior evidence of effectiveness to inform funding decisions. Each of these programs requires grantees to participate in evaluation activities designed to generate new knowledge about evidence in their respective fields. Similarly, foundations are increasingly asking their grantees to assess funded programs (e.g., the Robin Hood Foundation, Wallace Foundation, and the W. T. Grant Foundation are among philanthropies that embed rigorous research into funding). Likewise, the reach of social impact investing, in which private investors receive returns on investments in social programs only when programs achieve intended outcomes based on rigorous designs, is rapidly expanding as well (e.g., the Center for High Impact Philanthropy, Social Impact). All of this is to suggest that the integration of evidence-building into funding decisions is increasingly common, and holding programs and/or investors accountable for results is as well. This could easily be a practice that is extended to programs that use STEM experts in K-12 education.

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[8] The Obama administration released a policy memorandum in July 2013, "Next Steps in the Evidence and Innovation Agenda" that outlined its priorities for evidence-based decision making; see http://www.whitehouse.gov/sites/default/files/omb/memoranda/2013/m-13-17.pdf. It notes "Agencies are encouraged to both: (1) draw on existing credible evidence in formulating their budget proposals and performance plans and (2) propose new strategies to develop additional evidence relevant to addressing important policy challenges. Agency requests are more likely to be fully funded if they show a widespread commitment to evidence and innovation." (p.2)

5.5 Summary

Our study was initially designed to learn more about:

- The different purposes programs cite for using adults as mentors or volunteers;
- Which types of adults appear to be most effective in engaging K-12 students;
- Which interactions are effective and for whom; and
- Which settings are most conducive to using STEM experts to improve student outcomes.

However, our collective ambition to address STEM preparation, performance, and interest gaps is considerably ahead of the knowledge base about ***how*** to address some of these gaps. The proliferation of programs—at all levels—to increase student engagement in STEM is proceeding apace, without the benefit of a concurrent or cohesive research agenda. The use of STEM volunteers is broad, and the concept benefits from wide popularity. However, the practice is not uniform, and the effects of using STEM experts are not well documented empirically.

At this time, articulating a research agenda to understand the impacts of STEM experts on student outcomes, targeting resources toward that agenda, and enacting the agenda will help us to make more informed policy and programmatic decisions. These steps will provide important evidence and importation for educators, stakeholders, and policy makers about how we can most effectively capitalize upon volunteer-based organizations that support STEM experts in K-12 education.

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Appendix 1: Summary of Articles in Synthesis

The goal of the literature search was to identify publically available reports of research about programs in which individuals with STEM careers or other adults interact with K-12 students in STEM educational activities, whether in or outside of school settings. While the initial search purposefully sought out papers on STEM professionals or other adults who worked with K-12 students about STEM engagement, the search also deliberately cast a wide net about what types of adults, students, or STEM engagement were described. The reports could (and did) refer to projects, programs, and initiatives that targeted students' general STEM interest, engagement, their retention and academic achievement in STEM subjects and courses, and their aspirations and plans for post-secondary careers and education. Below, we describe the approach used to locate, identify, and obtain relevant research and a detailed description of the procedures used.

Search strategy and approach

The literature review process began with the generation of a list of potential search terms that were used to identify all articles addressing the STEM programs and to limit the articles found to those reporting on studies of the effectiveness or impacts of programs aimed at K-12 students. With these two goals in mind, the list was refined through an initial brief "pilot" search, and augmented by advice from STEM experts. Ultimately, the final list of terms included words and phrases in six categories. Search terms were organized into categories:

1. **Subject**. Words related to the STEM content area addressed;
2. **Role**. Words related to the roles played by STEM professionals in the programs studied;
3. **Student outcomes**. Words related to the student outcomes the programs were targeting (and the ones they studied);
4. **Settings**. Words related to program settings;
5. **Type of research article**. Words describing research activities;
6. **Grades**. Words identifying grade levels and ages of students;
7. **Miscellaneous**. Miscellaneous terms included "hands-on" and "inquiry." Many terms in this category were included because reviewers observed that some reports on programs with STEM professional participation also addressed other program elements, such as inquiry-based learning and a focus on increasing the STEM participation among underrepresented groups (e.g., women and members of minority groups).

Searches were conducted online initially using Google Scholar and the EBSCO database, which covers a wide range of periodical databases, including: Academic Search Complete; Biomedical Reference Collection: Corporate; Business Source Corporate; EconLit; Environment Complete; MEDLINE; SocINDEX; Psychology and Behavioral Sciences Collection. These searches were followed up by manual searches of select online journals, including relevant titles (see Table [X1] below). We also searched a few terms in Google Web (web searches proved to be less useful, due to the large number of results—hundreds of thousands—generated in each search).

- Journal of Women and Minorities in Science and Engineering;
- Journal of STEM Education;
- Journal of Research in Science Teaching;
- International Journal of Science Education;
- Journal of Engineering Education;
- Journal of Science Education and Technology;
- Journal of Adolescent Research.

Initial searches indicated that there were thousands of articles about adjacent and related topics, and relatively fewer articles that could immediately be determined as directly relevant. We then began screening the bibliographic material (e.g., citations, abstracts, etc.) netted, for each separate search term or phrase, and moved onto a new term/phrase if, after screening 30 articles, none had been found to be a directly relevant article.

Ultimately, literature searches generated approximately 474 articles, reports, books, dissertations, and other sources that met the initial screening criteria, and were deemed eligible for inclusion in the literature review.[9]

Screening and obtaining eligible studies

Screening studies for eligibility

The bibliographic information for articles identified as potentially relevant was entered into a screening database. A team of trained screeners using a brief screening protocol conducted an initial screening of articles. Screeners retained articles that met the following criteria:

1. The focus of the article was on a program or programs that engage K-12 students in STEM activities, in and/or outside of school (e.g. afterschool programs, camps, and competitions), using adults or older students as mentors or volunteers to increase student engagement, interest, persistence and achievement in STEM education (and ultimately) STEM careers; and
2. The focus was on programs, practices, activities etc. rather than on discussions of the importance of student engagement in STEM in general, offered guidance or recommendations about how to establish programs to engage K-12 students, or that described policies related to STEM engagement were screened out.

Ultimately, 235 articles met these two screening criteria.

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9 This number includes duplicates of studies that were found in different phases of the search process.

Obtaining full texts of eligible articles

The study team obtained the full text of each study determined to be eligible. Most papers were accessible through Google Scholar, Google Web, the EBSCO Database, or other article archives available free of charge online (such as ERIC), although a small number could only be obtained by purchasing or from libraries.

Review process

The initial stages of review were more thorough than the initial screen described above. Articles that met the criteria received a full review and were entered into the synthesis database. Articles that did not meet the criteria were set aside from the review. The criteria required that studies needed to:

1. Focus on a specific program (or programs) that engaged K-12 students in STEM activities, in and/or outside of school (e.g. afterschool programs , camps, and competitions), using adults or older students as mentors or volunteers to increase student engagement, interest, persistence and achievement in STEM education (and ultimately) STEM careers;[10]
2. Report on empirical research (i.e., data of any kind had been ere collected, analyzed, and were described in sufficient detail).

Ultimately, 29 studies were deemed eligible for review. Only those articles that met these second two criteria were retained in the synthesis database. These articles were reviewed by a team of trained reviewers who coded and summarized key pieces of information into a database following a structured coding protocol.

After the review was completed, reviewers assigned a final disposition to each study:

1. **Use in synthesis.** This disposition was assigned to articles that reported results from effectiveness and impact studies on programs in which STEM professionals worked with K-12 students.
2. **Do not use in synthesis (but complete a full review).** This disposition was assigned to articles that focused on relevant programs, but that had not reported on results from effectiveness and impact studies.
3. **Screened out in review (did not receive full review).** This disposition was assigned to articles that did not include any reporting on studies of relevant programs.

The review resulted in a database containing key information about each article that could be further coded and synthesized.

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[10] To be screened in, program mentors and volunteers could have been K-12, college, or graduate students. In addition, activities could have been be in-person or online.

Appendix 2: Program and Evaluation Characteristics

Table 1: Characteristics of programs described in papers in research corpus

Author(s), date	Program name	Program description (focus on activities including STEM experts)	Content areas	STEM-related program goals for students	Years	Program setting	Program timing	Student populations focused on	STEM experts' professions
Anderson & Gilbride, 2003	Discover Engineering High School Workshop	Female faculty, staff, and engineering students from a university conducted one-time workshops in high school classrooms that included presentations about engineering, a hands-on activity, and a question period.	Engineering	1) Educate students about engineering 2) Raise students' awareness of engineering careers; 3) Provide role models for female students	1999	Classrooms	During school hours	All students participated, female students a particular focus	Female IHE faculty and staff and professionals
Bachrach, Manning & Goodman, 2010	A World In Motion (AWIM)	Industry volunteers (e.g., practicing STEM professionals) participated in classroom activities. The program also provided curriculum that featured authentic design activities.	Physical Science and math and science literacy	1) Increase interest, excitement, engagement, desire to learn 2) Increase STEM content knowledge or skills	2005-2009	Classrooms	During school hours	All students	Industry volunteers (e.g., practicing STEM professionals)
Clewell, de Cohen, Tsui, Forcier, Gao, Young, Deterding & West, 2005	Louis Stokes Alliances for Minority Participation Program (LSAMP)	The LSAMP Program created partnerships among IHEs, national research laboratories, businesses, and federal agencies to provide students with services designed to increase the number of minority students who attain STEM college and graduate degrees. The services provided were diverse, characterized in the evaluation as falling into the following categories: "precollege development, student academic development, student professional development,faculty development, curriculum development, graduate studies development and linkages with community colleges" (p. 22).	STEM	Increase the number of students to pursue STEM in college, graduate school, and careers	1992-1997	Diverse	Diverse	Students in underrepresented minority groups	Diverse
Countryman & Olmsted, 2012	Technovation Challenge	Teachers and mentors (female technology professionals) led teams creating phone apps in ten-week sessions. Students learned business- and technology-related skills, attended field trips to high-tech companies, worked with industry professional and participated in a final competition in which the winning team sold its app for Android phones. The program was hosted by high-tech companies.	Technology	1) Learn about design and technology 2) Become self-aware as makers of technology 3) Increase interest in technology careers	2011-2012	High-tech businesses	Out-of-school time	Female students	Professionals in technology companies
Demetry, Hubelbank, Blaisdell, Sontgerath, Nicholson, Rosentha, & Quinn, 2009	Camp Reach	Camp Reach was two-week summer program in which teams of girls were taught by female camp staff, which also functioned as role models. Students participated in collaborative service-learning projects that required engineering knowledge. Staff members were chosen to provide an array of potential role models to students including teachers, high school students, undergraduate engineering students and graduate engineering students.	Engineering	1) Increase interest and self-confidence in engineering and technology 2) Motivate students to take STEM classes	1997-2001	IHE Campus	Summer (primarily)	Female students	Graduate and undergraduate students in engineering

Author(s), date	Program name	Program description (focus on activities including STEM experts)	Content areas	STEM-related program goals for students	Years	Program setting	Program timing	Student populations focused on	STEM experts' professions
Duran, Höft, Lawson, Medjahed & Orady, 2013	Fostering Interest in Information Technology (FI³T)	The program created teams of adults and students who collaboratively worked on hands-on inquiry-based problems and activities. The teams included high school students, a STEM teacher from the school district, a postsecondary faculty member with content expertise, and a graduate or undergraduate student assistant. Several types of activities were facilitated by the teams including: workshops with hands-on activities and design-based projects during the school year; a techno/career fair; two-week summer externships in STEM workplaces; summer collaborative learning sessions, student-based projects which are developed through the summer and the school year.	Tools used in each of the four STEM areas.	Increase opportunities for high school students to learn about and use STEM tools, especially those from underrepresented group and from "disadvantaged urban communities" (p. 2)	2008-2011	Diverse	Summer and after school during the school year	All students could participate, with focus on students from underrepresented groups and from "disadvantaged urban communities" (p. 2).	STEM IHE faculty, graduate and undergraduate students; In addition, partnerships were made with STEM businesses; however, the specific roles played by individuals for the businesses were not specified.
Gibson & Chase, 2002	Summer Science Exploration Program (SSEP)	The Summer Science Exploration Program was a two-week science camp for middle school students held on a college campus. The camp aimed to increase students' interest in science and related careers through inquiry-based learning.	Biology and health-related science	Increase students' interest in science and related careers	1992-1994	IHE Campus	Summer	All students	IHE faculty and students
Hirsch, Carpinelli, Kimmel, Rockland & Bloom, 2007	Woman in Engineering and Technology (FEMME)	The article described ten programs, one of which explicitly was described as including STEM experts. This program (FEMME) included five sites that offered multidimensional programs for female students that included classes and lab experiences, field trips, and counseling. STEM experts were brought in to meet participating students (e.g., female engineers came in to discuss engineering career options).	Science, math, and engineering	1) Increase STEM content knowledge or skills 2) Increase interest engineering and technology 3) Motivate students to take STEM classes	2006	IHE Campus	Summer	Female students	IHE faculty and professionals in STEM workforce
Karp, Gale, Lowe, Medina & Beutlich, 2010	Get Excited About Robotics (GEAR)	GEAR was a six-week program in which students engaged in hands-on LEGO robotics activities. In teams, students collaboratively prepared for robotics competitions.	Technology	Increase interest, excitement, and engagement	2007	On IHE campus and at schools	Out-of-school time and during school (varies by school)	All students	IHE freshmen in electrical and computer engineering.
Karp & Schneider, 2011	Get Excited About Robotics (GEAR)	GEAR was a six-week program in which students engaged in hands-on LEGO robotics activities. In teams, students collaboratively prepared for robotics competitions.	Technology	Increase students' interest in robotics and technology careers	2010	On IHE campus and at schools	Out-of-school time and during school (varies by school)	All students	IHE freshmen in electrical and computer engineering.

Author(s), date	Program name	Program description (focus on activities including STEM experts)	Content areas	STEM-related program goals for students	Years	Program setting	Program timing	Student populations focused on	STEM experts' professions
Knox, Moynihan & Markowitz, 2003	Summer Science Academy (SSA)	SSA was a summer science program that took place in research facilities of a university. Classes featured hands-on inquiry-based activities, lab work, library research, discussions, computer work, and field trips.	Science (microbiology, molecular biology, environmental health, and genetics)	1) Increase interest, excitement, engagement 2) Increase STEM content knowledge, skills	1999-2002	IHE Campus	Summer	All students	IHE staff
Koch, Georges, Gorges & Fujii, 2010	Build IT	The Build IT program took place afterschool and in summers. In the program, girls worked with technology in a variety of forms, engaged with IT professionals, and participated in field trips and problem-solving activities.	Technology	1) Increase interest, excitement, engagement 2) Motivate students to pursue STEM college, graduate school, or careers 3) Increase STEM content knowledge, skills	2005-2009	Unspecified	Out-of-school time and summer	Female students from families with low incomes	Information technology
Lee-Pearce, Plowman & Touchstone, 1998	Starbase-Atlantis	Starbase-Atlantis was a school-year program that took place over the course of five weeks. Students learned technology, math and science with real-world activities such as ship maintenance, meteorology and navigation onboard a Navy training center. Students worked with hands-on activities, computer software, and equipment (such as simulators).	Science and technology	1) Increase confidence, self-efficacy 2) Provide exposure to STEM content	1995-1997	Navy training center	During school hours	All students (with a particular focus on at-risk urban students)	Not specified (assume Navy staff are included)
Li, Moorman, & Dyjur, 2010	Inquiry-Based Learning with E-mentoring (IBLE)	IBLE was a program for rural students that included graduate engineering students who served as e-mentors for students engaged in inquiry-based research project. The e-mentors scheduled time with students via videoconferences to both share their research and give students an opportunity to present their own research results and receive feedback.	Science and math	Improve student achievement, interest, and opportunities to engage in math and science	Not specified	Classrooms	During school hours	Students in rural areas	Graduate students
Lyons & Thompson, 2006	GK-12 Engineering Fellows Program	In this Program (an NSF GK-12 project), graduate students in computer science and engineering students worked alongside middle and elementary science teachers, serving as co-teachers and co-curriculum developers for 20 hours per week. Students learned problem solving and engineering design skills.	Engineering	Increase knowledge of engineering	Not specified	Classrooms	During school hours	All students	Graduate students
Lyons, 2011	NSF Graduate STEM Fellowship in K-12 Education program	In this program, graduate students majoring in engineering, science, mathematics and other technology-related majors served as fellows in middle school classrooms with the goal of enriching STEM content and instruction in K-12 schools. Fellows worked directly with teachers and students over a sustained period of time.	Science and engineering	1) Improve attitudes, perceptions toward STEM and/or STEM professionals 2) Increase STEM content knowledge, skills	Not specified	Classrooms	During school hours	All students	Graduate students

Author(s), date	Program name	Program description (focus on activities including STEM experts)	Content areas	STEM-related program goals for students	Years	Program setting	Program timing	Student populations focused on	STEM experts' professions
Melchior, Cohen, Cutter & Leavitt, 2005	FIRST Robotics Competition (FRC)	The FIRST Robotics Competition was a robotics competition for high school students aimed at increasing student engagement, confidence, and achievement in STEM field, as well as motivating students to pursue post-secondary opportunities in STEM. Students joined teams and worked with mentors to create robots to be used in competitions.	Science and technology	1) Increase interest and confidence 2) Motivate students to pursue STEM degrees 3) Increase STEM content knowledge, skills	1999-2003	In schools and other sites (e.g., IHEs)	Out-of-school time	All students	Professionals
Nadelson & Callahan, 2011	e-Girls and e-Camp College of Engineering	The first program, e-Camp, was a day-long outreach event in engineering, targeted at students entering the 9th and 10th grade. Students joined teams and took part in hands-on science and technology activities led by engineering undergraduates who served as mentors. e-Girls was a two-day overnight science exploration program for girls interested in technology and engineering fields. Students took part in workshops and lessons led by college students and professionals from the Society of Women Engineers.	Engineering	1) Increase interest 2) Motivate students to pursue STEM degrees 3) Increase STEM content knowledge, skills	Not specified	IHE Campus	Summer	All students (e-Girls focused on female students)	Undergraduates and engineering professionals
Orr, Quinn, & Rulfs, 2007	GK-12, K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)	In this program, engineering graduate teaching fellows and undergraduates partnered with K-6 classrooms in an urban school district to help teach engineering and technology.	Engineering	1) Increase interest, excitement, engagement 2) Increase STEM content knowledge, skills	2003-2006	Classrooms	During school hours	All students	Graduate teaching fellows and undergraduates in engineering
Paris, Yambor & Packard, 1998	Hands-On Biology curriculum	This program provided interdisciplinary life science instruction for 3rd through 5th grade students over a six-week period. Students took part in research, experiments and games in order to "explore science beyond the classroom" (pp. 271-272). University students participated as teaching assistants and provided support during lab activities.	Science (life science)	1) Increase interest 2) Motivate students to pursue STEM degrees 3) Increase STEM content knowledge, skills	Not specified	Schools	During school hours	All students (with a special focus on female students and students from minority groups)	Museum employees and undergraduate students
Redmond, Thomas, High, Scott, Jordan & Dockers, 2011	Get a Grip + mentoring	This was a two-year project that included hands-on engineering activities (Get a Grip) during the school day for all students and a weekly afterschool mentoring program for girls (with undergraduate engineering students as mentors).	Engineering, science, and math	Increase interest in math and science and related careers	2006-2007	Schools	Out-of-school time and during school hours	The program that included mentors was aimed at female students.	Engineering undergraduates

Author(s), date	Program name	Program description (focus on activities including STEM experts)	Content areas	STEM-related program goals for students	Years	Program setting	Program timing	Student populations focused on	STEM experts' professions
Richardson, Hammrich, & Livingston, 2003	Sisters in Science (SIS)	SIS was a multi-dimensional two-year program that included afterschool programs, summer camps, teacher training and preservice programs, family education, and a volunteer corps. Activities provided to students included: in-school weekly programs, afterschool and Saturday academies, summer camps, and retired professionals from science-related careers serving as mentors to students.	Science and mathematics	Improve elementary school female students' attitudes, self-confidence, perceptions, and achievement in science and mathematics	1997-1999	Classrooms and afterschool programs	During school hours, afterschool, Saturdays, and summers	All students (with a special focus on female students)	A "volunteer corps" of "retired professionals" from science-related fields.
Schnittka, Evans, Drape & Won, 2013	STEM Club	This was an afterschool program in a studio setting in which students learned science concepts through an engineering design curriculum that was facilitated by undergraduates. In the program, students used the Save the Penguins curriculum in which they learned about concepts such as heat transfer by engaging in problem-solving activities around penguins' environments.	Science and engineering	Increase students' knowledge of science, technology, and engineering focused on the concept of energy.	Not specified	School library	Out-of-school time	All students	Undergraduates
Smith & Erb, 1986	No name (based on COMETS Science)	In this program, women working in scientific fields visited classrooms, answered questions, discussed their careers, and led interactive science activities. Students also learned about women in science in general during class. The program lasted two months and approximately three volunteers visited each class.	Science	Change attitudes about scientists and female scientists	Not specified	Classrooms	During school	All students	Female professionals in scientific fields
Smith, Hollebrands, Parry, Bottomley, Smith & Albers, 2009	Recognizing Accelerated Math Potential in Underrepresented People (RAMP-UP)	In this program, graduate and undergraduate students in engineering and math education, as well as mathematics and computer science, from a historically Black university were placed into local public schools to be mentors and role models and to support teachers in developing and implementing hands-on enrichment experiences for K-12 students.	Math	Increase the number and diversity of students who enroll in and successfully complete high-level mathematics courses	2005-2007	Classroom and schools	Before, during, and after school	All students	Graduate and undergraduate students in engineering and math education, as well as mathematics and computer science
Sorge, Newsom & Hagerty, 2000	Space Science Education Program (SSEP)	In SSEP, middle school students from New Mexico's MESA (Math, Engineering, and Science Achievement) Program took part in interactive science activities, including a field trip to the University of New Mexico. Students were exposed to laboratory activities and experiments at UNM.	Science and technology	1) Improve attitudes, perceptions, and knowledge of STEM and/or STEM professionals 2) Increase STEM content knowledge, skills 3) increase students' interest in pursuing science or technology careers.	Not specified	Classrooms, IHE campus	During school hours	All students (with a particular focus on Hispanic students)	IHE faculty, graduate students, undergraduates, and lab technicians

Author(s), date	Program name	Program description (focus on activities including STEM experts)	Content areas	STEM-related program goals for students	Years	Program setting	Program timing	Student populations focused on	STEM experts' professions
Stake & Mares, 2001	No names	The article described two summer programs at a university. The first program was a four-week summer program in which students learned via inquiry-based activities about scientific research, laboratory work and scientific writing, while being mentored and receiving exposure to career scientists. In the second program, students took part in a six-week summer program similar to the first one, with an additional component allowing for students to conduct their own research.	Science	1) Improve students'' attitudes and confidence 2) Increase STEM content knowledge, skills 3) increase students' interest in pursuing science or technology careers.	Not specified	IHE campus	Summer	Gifted students	Not specified
Syed, Goza, Chemers, & Zurbriggen 2012	California State Summer School for Mathematics and Sciences (COSMOS)	This was a study of mentoring. It took place in a four-week residential summer science program at a university which included hands-on coursework, field trips, and social activities. No formal mentoring pairs were established—students were placed in the program to interact with university researchers and faculty, teachers, and advanced graduate students with the implicit assumption that mentoring relationships would develop over the course of activities. Researchers were particularly interested in whether students would establish mentoring relationships with adults with backgrounds similar to their own.	Science	Motivate students to pursue STEM education and careers	Not specified	IHE campus	Summer	Students who were judged by their teachers as being motivated and talented	IHE professors, researchers, and advanced graduate students
Trotman Reid & Roberts, 2006	Gaining Options: Girls Investigate Real Life (GO-GIRL)	Seventh grade female students judged to be "at-risk" participated in ten Saturday sessions in which they worked in small groups in cooperative math activities and research projects with two university students as leaders. Students also used the university computer lab and toured other university facilities.	Math	Increase math interest, confidence and skills	Not specified	IHE campus	Saturdays	Female students from urban schools	Undergraduates in math education

Table 2: Characteristics of research described in reviewed papers

Author(s), date	Program name	Grade range	Approximate number of students served per year	Study type	Student outcome domains studied (STEM-related)	Approximate sample size
Anderson & Gilbride, 2003	Discover Engineering High School Workshop	High school	1000+	QED	1) Interest in pursuing engineering career 2) Knowledge about engineering	200+
Bachrach, Manning, & Goodman, 2010	A World In Motion (AWIM)	Grades 4-10	500+	RCT and QED	1) Knowledge about engineering 2) Student attitudes 3) Interest in pursuing a STEM career 4) High school STEM courses taken 5) STEM-related college plans	500+
Clewell, de Cohen, Tsui, Forcier, Gao, Young, Deterding, & West, 2005	Louis Stokes Alliances for Minority Participation Program (LSAMP)	High school	When this evaluation was conducted, the program was implemented in 34 multi-institution Alliances and more than 450 institutions across the country.	QED	1) Student content knowledge, skills 2) Enrollment/persistence in college STEM courses 3) Other STEM post-secondary education characteristics	1,000+
Countryman & Olmsted, 2012	Technovation Challenge	High school	Not specified	One group pre-post	1) Student attitudes 2) Knowledge about a technology and what scientists and computer engineers do	100+
Demetry, Hubelbank, Blaisdell, Sontgerath, Nicholson, Rosenthal, & Quinn, 2009	Camp Reach	Grade 7	30	QED	1) Interest in pursuing engineering career 2) Knowledge about engineering 3) High school academic experience 4) Student attitudes 5) College majors	100+
Duran, Höft, Lawson, Medjahed, & Orady, 2013	Fostering Interest in Information Technology (FI³T)	High school	Not specified	One group pre-post	1) Student content knowledge, skills 2) Student attitudes 3) Knowledge about use of technology in STEM fields	70+
Gibson & Chase, 2002	Summer Science Exploration Program (SSEP)	Middle school	100+	QED	Student attitudes	100+
Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007	Woman in Engineering and Technology (FEMME)	Grades 4-8	Not specified	QED	1) Student attitudes 2) Knowledge about engineering	200+
Karp, Gale, Lowe, Medina, & Beutlich, 2010	Get Excited About Robotics (GEAR)	Elementary school	Not specified	QED	Student attitudes	100+
Karp & Schneider, 2011	Get Excited About Robotics (GEAR)	Elementary and middle school	400+	One group pre-post	Student attitudes	200+
Knox, Moynihan, & Markowitz, 2003	Summer Science Academy (SSA)	High school	30+	One group pre-post	1) Student content knowledge, skills 2) Student attitudes	100+
Koch, Georges, Gorges, & Fujii, 2010	Build IT	Middle school	100+	QED	Student attitudes	400+
Lee-Pearce, Plowman, & Touchstone, 1998	Starbase-Atlantis	Grade 5	500+	QED	Student content knowledge, skills	100+
Li, Moorman, & Dyjur, 2010	Inquiry-Based Learning with E-mentoring (IBLE)	Grade 8	40+	QED	1) Student content knowledge, skills 2) Student attitudes	40+
Lyons & Thompson, 2006	GK-12 Engineering Fellows Program	Grades 3-8	Not specified	QED	Knowledge about engineering	100+
Lyons, 2011	NSF Graduate STEM Fellowship in K-12 Education program	Middle school	Not specified	One group pre-post	Knowledge about engineering and science	1,000+

Author(s), date	Program name	Grade range	Approximate number of students served per year	Study type	Student outcome domains studied (STEM-related)	Approximate sample size
Melchior, Cohen, Cutter, & Leavitt, 2005	FIRST Robotics Competition (FRC)	High school	Not specified	QED	1) Student content knowledge, skills 2) Student attitudes 3) Enrollment/persistence in college STEM courses 4) Other STEM college outcomes (e.g., receipt of scholarships) 5) Career outcomes (e.g., expectations to go into a STEM career)	200+
Nadelson & Callahan, 2011	e-Girls and e-Camp College of Engineering	Grades 9-10	Not specified	One group pre-post	Student attitudes	50+
Orr, Quinn, & Rulfs, 2007	GK-12, K-6 Gets a Piece of the PIEE (Partnerships Implementing Engineering Education)	Elementary school	Not specified	QED	Student attitudes and interest	200+
Paris, Yambor, & Packard, 1998	Hands-On Biology curriculum	Grades 3-5	100+	One group pre-post	1) Student content knowledge, skills 2) Student attitudes	100+
Redmond, Thomas, High, Scott, Jordan, & Dockers, 2011	Get a Grip + mentoring	Grades 6-7	700+ (60+ students were in the mentoring program)	QED	Student attitudes and confidence	700+ (60+students were in the mentoring program)
Richardson, Hammrich, & Livingston, 2003	Sisters in Science (SiS)	Grades 4-5	2,000+	One group pre-post	1) Student content knowledge, skills 2) Student attitudes 3) Knowledge about science and scientists	2,000+
Schnittka, Evans, Drape, & Won, 2013	STEM Club	Middle school	60+	One group pre-post	1) Student content knowledge, skills	40+
Smith & Erb, 1986	No name (based on COMETS Science)	Grades 5-8	Not specified	QED	Attitudes toward scientists	200+
Smith, Hollebrands, Parry, Bottomley, Smith, & Albers, 2009	Recognizing Accelerated Math Potential in Underrepresented People (RAMP-UP)	K-12	2,000+	QED	1) Student content knowledge, skills 2) Student attitudes	1,000+
Sorge, Newsom, & Hagerty, 2000	Space Science Education Program (SSEP)	Middle school	Not specified	One group pre-post	Attitudes toward science and scientists	80+
Stake & Mares, 2001	No names	Grade 12	300+	One group pre-post	1) Attitudes toward science and scientists 2) Career goals	300+
Syed, Goza, Chemers, & Zurbriggen 2012	California State Summer School for Mathematics and Sciences (COSMOS)	High school	200+	One group pre-post, hierarchical cluster analysis	Student attitudes	200+
Trotman Reid & Roberts, 2006	Gaining Options: Girls Investigate Real Life (GO-GIRL)	Grade 7	70+	One group pre-post	1) Student content knowledge, skills 2) Student attitudes 3) Interest in pursuing engineering career	70+