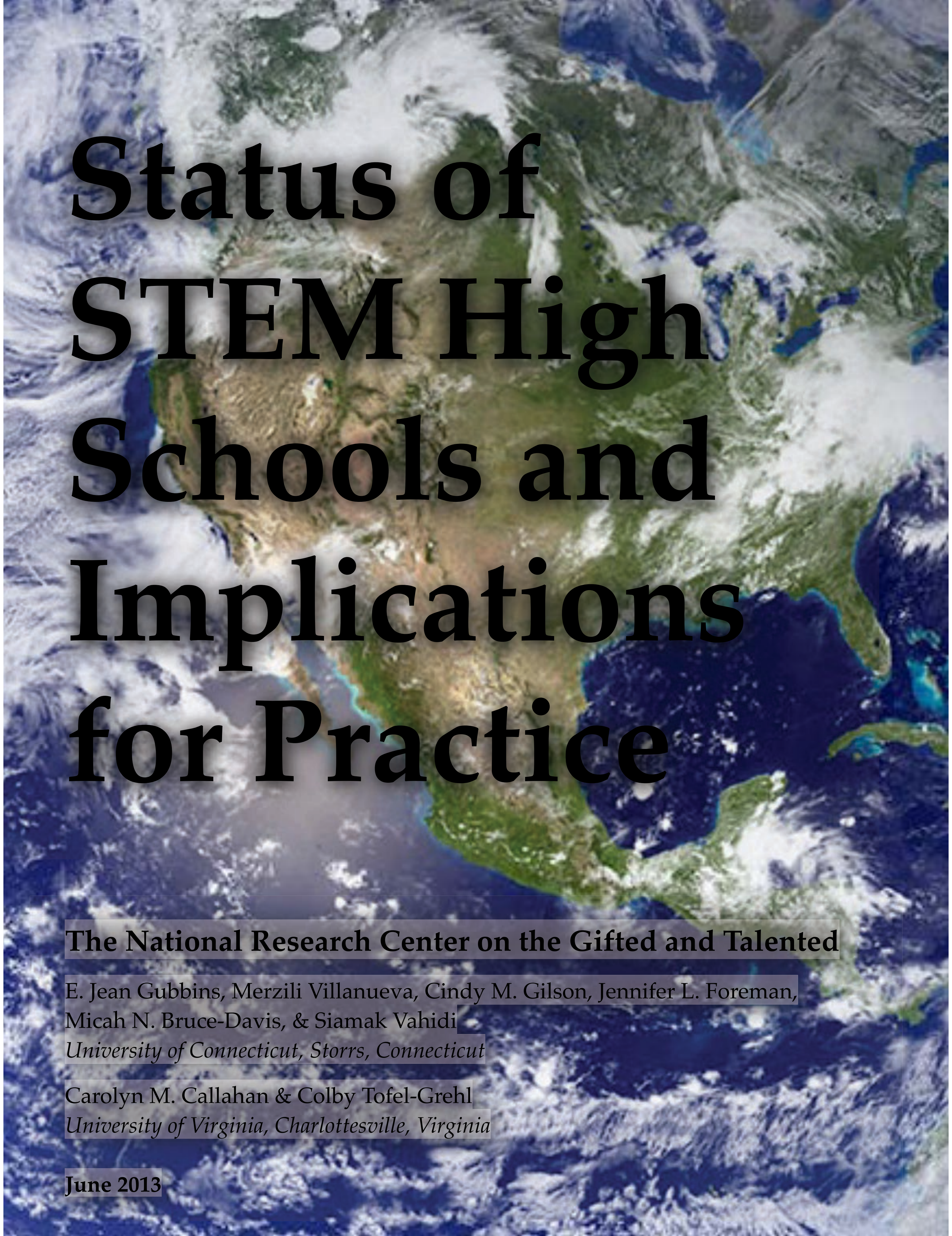

Status of STEM High Schools and Implications for Practice

The National Research Center on the Gifted and Talented

E. Jean Gubbins, Merzili Villanueva, Cindy M. Gilson, Jennifer L. Foreman, Micah N. Bruce-Davis, & Siamak Vahidi
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THE NATIONAL RESEARCH CENTER ON THE GIFTED AND TALENTED

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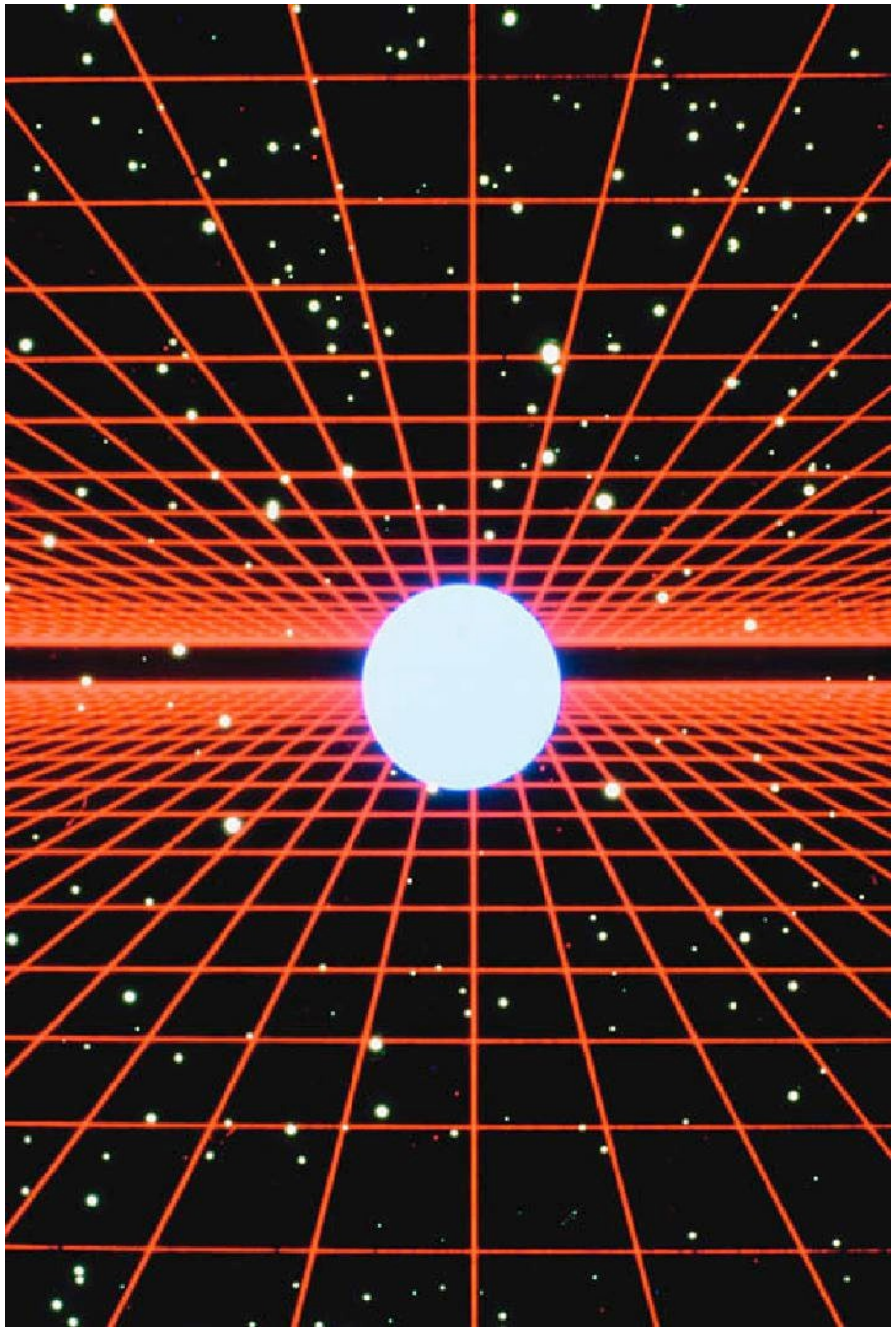
Chapter 1

Introduction to the Status of STEM High Schools

Educating Our High School Students



As a nation, society benefits from an educated populace. At a time when economic, environmental, social, and security issues are the focus of many conversations in businesses, industries, government offices, schools, and homes, policymakers turn their attention to the further development of human capital. Educators acknowledge that they have key responsibilities to develop the talents and abilities of all students to live in a global community that is increasingly accessible through technological advances. They also want students to become life-long learners who know how to learn and who are motivated to continue learning. How do we, as educators, create dynamic learning opportunities for high school students? How do we address issues related to high school students' perceptions of learning environments when recent high school survey data included the following results:

> Fewer than half of the survey respondents (48%) claimed that they are challenged academically in "Most" or "All" of their classes. One out of four (25%) reported being challenged academically in "None" or "1 or 2" classes. A majority of students (63%) reported that they are not required to work hard in either "None" of their classes or only "1 or 2" of their classes; fewer than one out of five students (17%) claimed that they are

> not required to work hard in "Most" or "All" of their classes. (Yazzie-Mintz, 2010, p. 9)

Student voices may be sources of guidance and reflection as we consider the reported lack of academic challenge in contrast to rhetoric about the importance of offering rigorous curricula. One student commented: "High school seems like it can be a lot more challenging. I wish that more classes did document analysis and independent research papers. I LOVE education but lose interest when I'm not challenged and there is not independent thought" (Yazzie-Mintz, 2010, p. 16). Another student said, "When I am not engaged, it is because the work is not intellectually engaging (Yazzie-Mintz, 2010, p. 1).

Boser and Rosenthal (2012) confirmed this lack of challenge and engagement in high schools. They documented results from two student surveys in a report entitled, *Do Schools Challenge Our Students?: What Student Surveys Tell Us About the State of Education in the United States*. Survey items from the National Assessment of Educational Progress and Tripod surveys provided the data sources. The researchers contended "if students are going to succeed in college or the modern global economy, they need to be exposed to rigorous curriculum" (p. 15). Highlights from the recent report follow:

★ We found, for instance, the 21 percent of 12th graders said their math work was often or always too easy, and 56 percent reported their civics work was too easy. Another 55 percent reported that their U.S. History work was too easy.

★ For instance, nearly one-third of 12th grade reading students say they rarely are asked to identify main themes of a passage when reading. Almost 20 percent say they never or hardly ever summarize a passage. A third of 12th graders report that they have a class discussion about what they have read two times a month or less.

★ Just under 50 percent of 12th-grade math students said they always or almost always felt like they were learning in their math class.

★ Thirty-six percent of 12th graders report they sometimes or hardly ever understand what their teacher asks. (pp. 15-17)

Response to Lack of Academic Challenge

Researchers and educators alike should be alarmed at the national survey results. We need to foster student engagement and develop their talents and abilities through challenging intellectual pursuits. One way to approach involvement with rigorous and engaging curricula is to capitalize on domains of interest. There has been considerable emphasis on developing science, technology, engineering, and mathematics (STEM) focused schools at all grade levels. The number of STEM high schools alone has tripled in the last decade (2000-2009), with over 300 schools self-identifying as STEM high schools (see Part II: NRC/GT STEM High School Database). This interest in STEM, resulting from federal and state educational initiatives as well as business, industry, and technology demands, may reflect "... the belief that American productivity in these fields is tantamount to the nation's long-term viability" (Bruce-Davis, Gubbins, Gilson, Villanueva, & Foreman, 2013, p. 6).

Researchers and educators are responding to recommendations from several national reports (e.g., Committee on Highly Successful Schools or Programs in K-12 STEM Education, 2011; Committee on Prospering in the Global Economy of 21st Century, 2007; National Academy of Sciences, 2010) and acknowledging the President's Council of Advisors on Science and

Technology (PCAST, 2010) initiative of increasing STEM education services to prepare students for future careers.

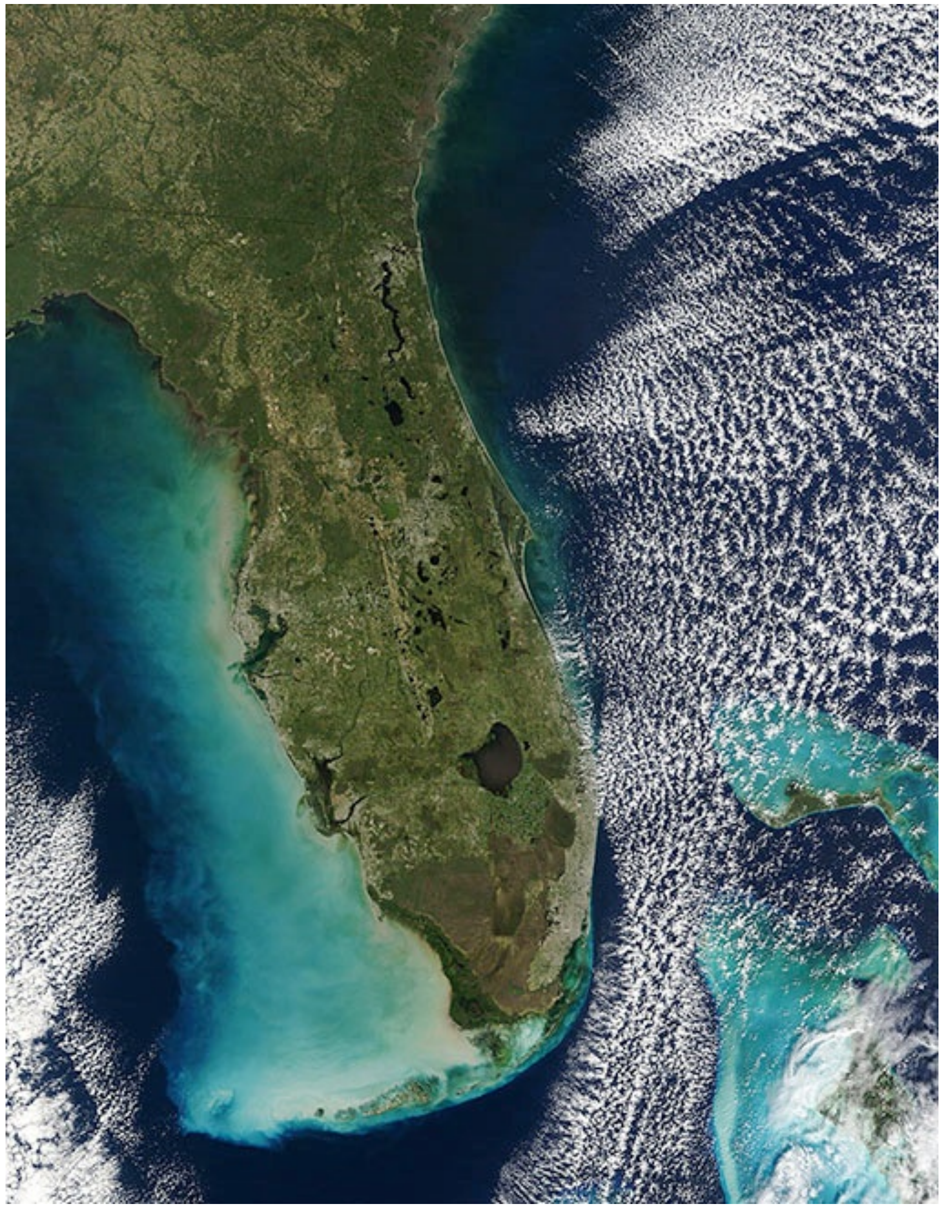
To learn more about current STEM high schools across the country, the United States Department of Education commissioned The National Research Center on the Gifted and Talented (NRC/GT) to design and implement a study of STEM high schools. The University of Connecticut and the University of Virginia collaborated to address the following project objectives:

1. To create a searchable matrix of STEM high schools throughout the country listing pertinent variables about the identification, curricular, instructional, and professional development variables.

2. To document the common and unique curricular and instructional strategies used in STEM high schools by conducting onsite observations, interviews, and focus groups of selected high schools.

3. To create and disseminate an online or mail surveys for high school administrators and teachers documenting the curricular and instructional strategies used in high schools throughout the country.

STEM Education and STEM Schools: Definitions?



The first question we confronted centered about the designation or identification as a STEM school. Gerlach noted, "most educators know what STEM stands for, but how many really know what it means?" (para. 1). Do STEM schools offer an integrated approach to the multiple disciplines? Are all disciplines equally represented and championed in schools? Would all schools support the following definition of STEM education?

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (Pennsylvania STEM Initiative as cited in Tsupros, Kohler, & Hallinen, 2009, slide 10)

Educators may have viewed their schools as addressing the four disciplines separately or an integrated approach to curriculum development and implementation. Perhaps they even viewed STEM as a meta-discipline or ". . . transdisciplinary in that it offers a multi-faceted whole with greater complexities and new spheres of understanding that ensure the integration of disciplines" (Lantz, 2009, p. 1). Given the lack of consensus about STEM education or important variables that classify schools as STEM, we relied on self-designations and information from reports, journal articles, and organizations.

Sampler of Mission Statements

Sample mission statements from residential, magnet, charter, and STEM-focused comprehensive high schools serve as exemplars of the goals for their students and their communities. Schools emphasize the importance of educating their students to

- become leaders in STEM,
- maximize their potential,
- engage in rigorous, real-world projects,
- achieve success in navigating our technology-dependent world, and
- demonstrate college readiness through mastery of academically rigorous curriculum.

One commonality among this sampler of mission statements for exclusive schools with admissions criteria and inclusive schools with minimal or no admissions criteria is the intent to ensure that students are educated in environments that prepare them for college and post-secondary opportunities.

South Carolina Governor’s School for Science and Mathematics (Hartsville, SC) (Governor, Residential, Exclusive)

Homepage: http://www.scgssm.org

Mission: http://www.scgssm.org/mission-and-history

Mission Statement

The mission of the South Carolina Governor’s School for Science & Mathematics (GSSM) is to offer our state's most academically motivated students a unique learning environment that strengthens their ability to think critically, stimulates the joy of learning and fosters the excitement of discovery through hands-on scientific research.

The purpose of GSSM is to positively impact South Carolina’s economic development through the cultivation of our current students and alumni, who are our state's future political and business leaders.

Stuyvesant High School (New York, NY) (Specialized, Day, Exclusive)

Homepage: http://www.stuy.edu

Mission: http://www.stuy.edu

Mission Statement

Stuyvesant High School has been a symbol of excellence in education for over a century. Our mission is to continue and enhance that commitment by providing an environment which will nurture and enhance the special academic talents of the students admitted to Stuyvesant. The educational heritage of Stuyvesant is deeply rooted in the tradition of Science, Mathematics and Technology. This has been the foundation of our educational success and must remain the cornerstone of our educational program. Within this context, the goal of this institution is to instill the intellectual, moral and humanistic values necessary for each child to achieve his/her maximum potential as a student and as a caring citizen of the world.

Academy of Technology, Engineering, Math & Science (Abilene, TX) (Specialized Day, Inclusive)

Homepage: http://www.abileneisd.org/Domain/189

Mission: http://www.abileneisd.org/domain/195

Mission Statement

Our mission is to prepare students for success in the global community as lifelong learners. A.T.E.M.S. will foster an environment focused on innovative science, technology, engineering, and mathematics curriculum. Working independently and in teams, students will complete rigorous, real-world assignments and projects that prepare them for post-secondary ambitions.

Advanced Math & Science Academy Charter School (Marlboro, MA) (Charter, Day, Inclusive)

Homepage: http://www.amsacs.org

Mission: http://www.amsacs.org/about-amsa/mission-statement

Mission Statement

The Advanced Math and Science Academy Charter School (the Academy) will create an atmosphere of celebration of knowledge where children of all backgrounds and abilities excel in all subjects, especially in math, science and technology, empowering them to succeed in the workplace in our modern high-tech world.

To prepare our students for college by creating an effective learning community of high standards and expectations with a rigorous curriculum focusing on science, math, and technology.

Alliance Marc & Eva Stern Math and Science School (Los Angeles, CA) (Comprehensive, Day, Inclusive)

Homepage: http://sternmass.org

Mission: http://www.sternmass.org/vision.jsp

Mission Statement

MASS students will appreciate the practicality and complexities of the math and sciences, become college-ready through an academically rigorous curriculum in a student-centered environment filled with high expectations, and graduate as self advocates who are empowered individually, socially, and academically.

PS 197 Math Science Technology Preparatory School@51 (Buffalo, NY) (Comprehensive, Day, Inclusive)

Homepage: http://www.buffaloschools.org/seneca.cfm

Mission: http://www.buffaloschools.org/Seneca.cfm?subpage=3959

Mission Statement

Our mission is to provide students with an unprecedented foundation in math, science and technology. Students will leave with the academic foundation to be successful in college. The Math, Science and Technology Preparatory School at Seneca is a community of learners providing enrichment activities that nurture creativity and growth, caring teachers and staff, community partnerships, and an emphasis on values and citizenship.

Central Virginia Governor's School for Science and Technology (Lynchburg, VA) (Governor, Partial Day, Exclusive)

Homepage: http://www.cvgs.k12.va.us

Mission: http://www.cvgs.k12.va.us/about-us

Mission Statement

The mission of the Central Virginia Governor's School for Science and Technology, a dynamic educational community exploring the connections among mathematics, science and technology, is to develop leaders who possess the research and technical skills, the global perspective, and the vision needed to address the challenges of a rapidly changing society.

Lindblom Math and Science Academy (Chicago, IL) (Magnet, Day, Exclusive)

Homepage: http://lindblomeagles.org

Mission: http://lindblomeagles.org/about/mission.jsp

Mission Statement

Through a dynamic curriculum, incorporating unique math and science opportunities, our mission is to empower students to become independent thinkers in a collaborative learning environment. We will nurture each student's contributions to local and global communities by promoting personal responsibility, service, and intellectual and social growth.

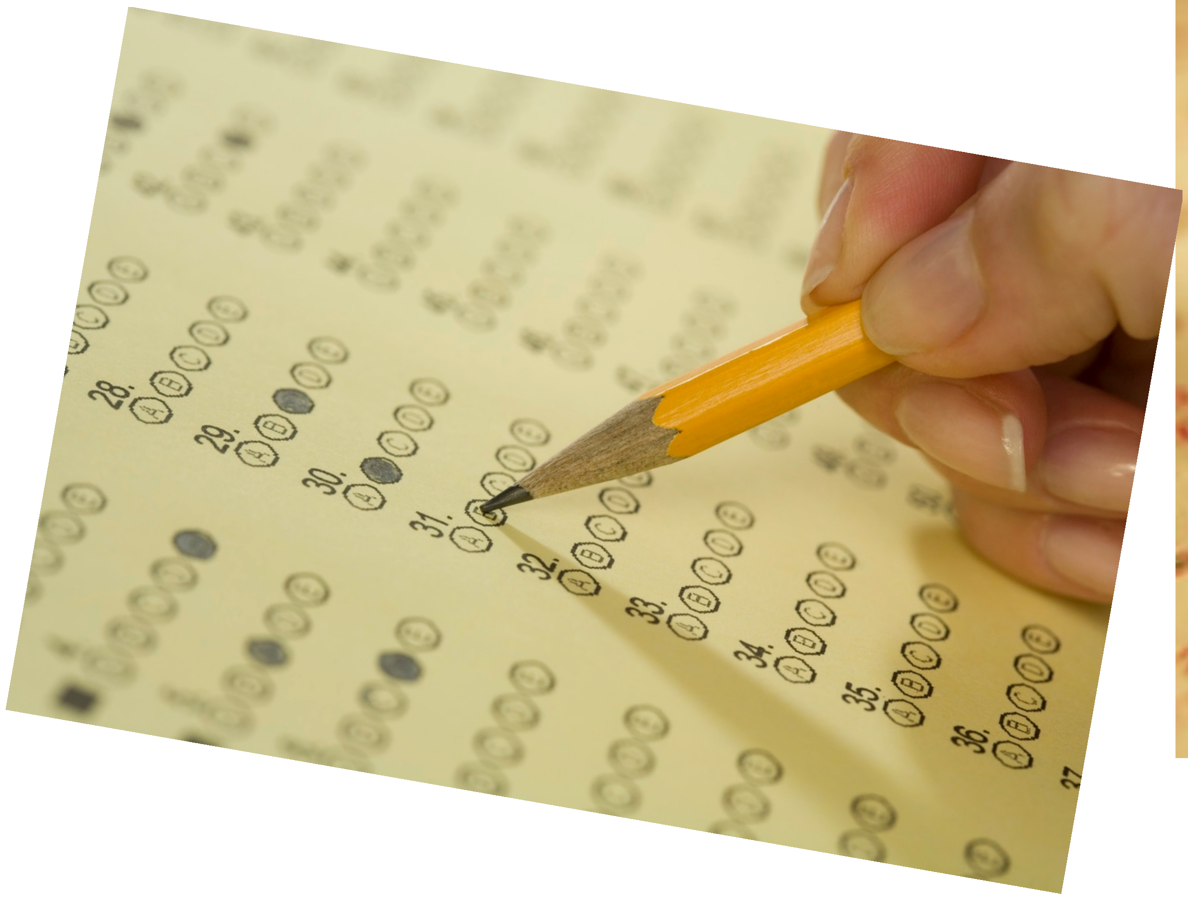
Primary, Secondary, and Tertiary Knowledge of STEM High Schools

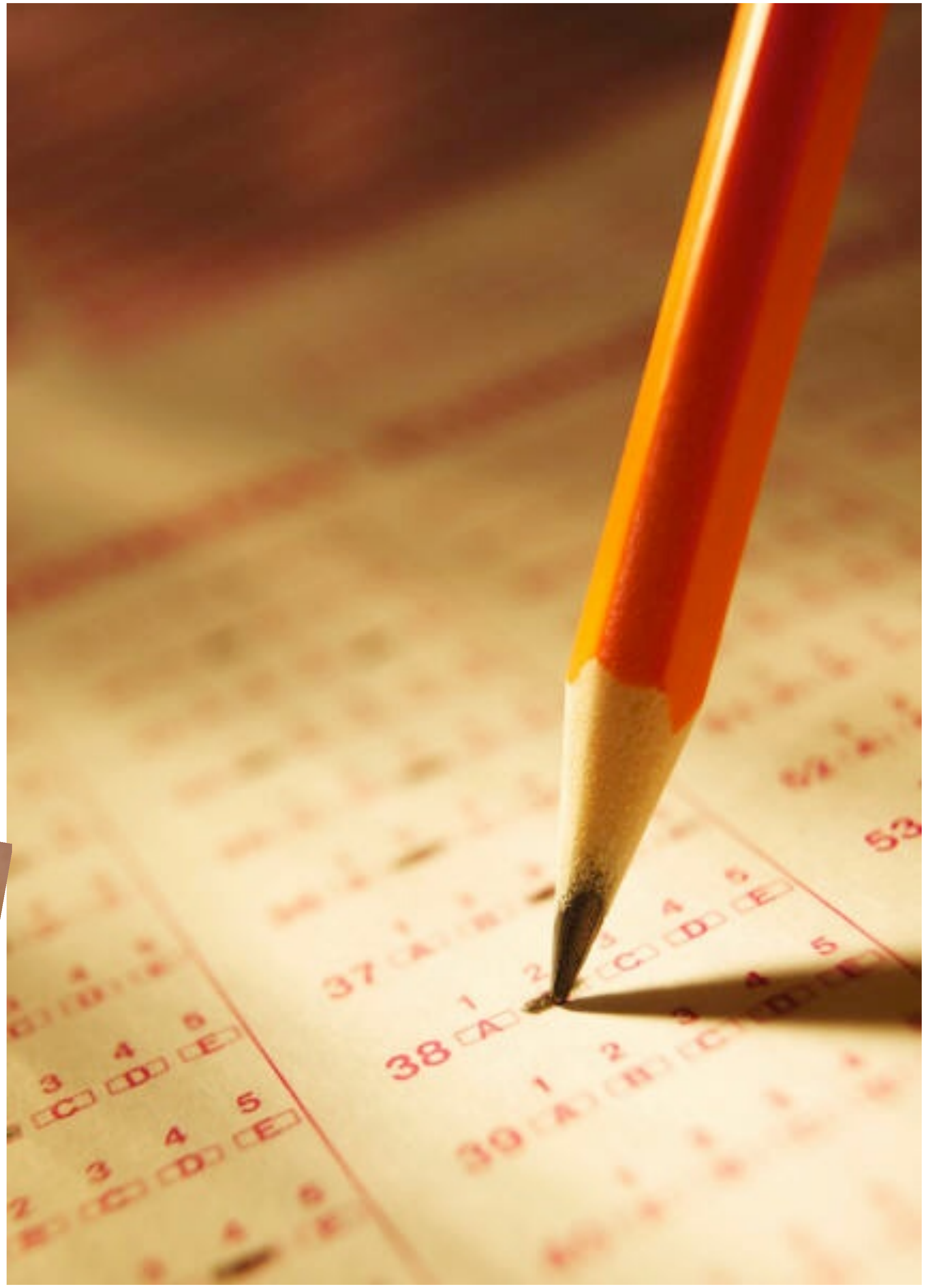
Information from websites and various publications and reports helped us to amass considerable tertiary knowledge of STEM high schools. To gather primary knowledge of STEM schools, we selected 12 STEM high schools and conducted interviews and focus groups with administrators, teachers, and students and observed the teaching and learning dynamics in classrooms. Knowledge from these sources may be viewed as primary knowledge. A secondary source of knowledge was data from administrator and teacher surveys.

Highlights of what we learned about STEM high schools from multiple sources of data are summarized for educators interested in reflecting on their current instructional and curricular strategies and reviewing policies and procedures. The highlights and commentaries also serve as guidance for educators and policymakers who are considering designing and developing new STEM high schools.

The remainder of this document is organized as follows:

- PART II: NRC/GT STEM High School Database
- PART III: STEM High School Administrator Survey
- PART IV: STEM High School Teacher Survey
- PART V: STEM High Schools: Administrator, Teacher, and Student Perceptions
- PART VI: Conclusions and Future Directions: What Is Known and Unknown About STEM High Schools
- PART VII: STEM High Schools' Interactive Matrix





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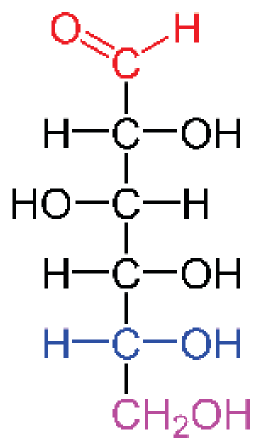
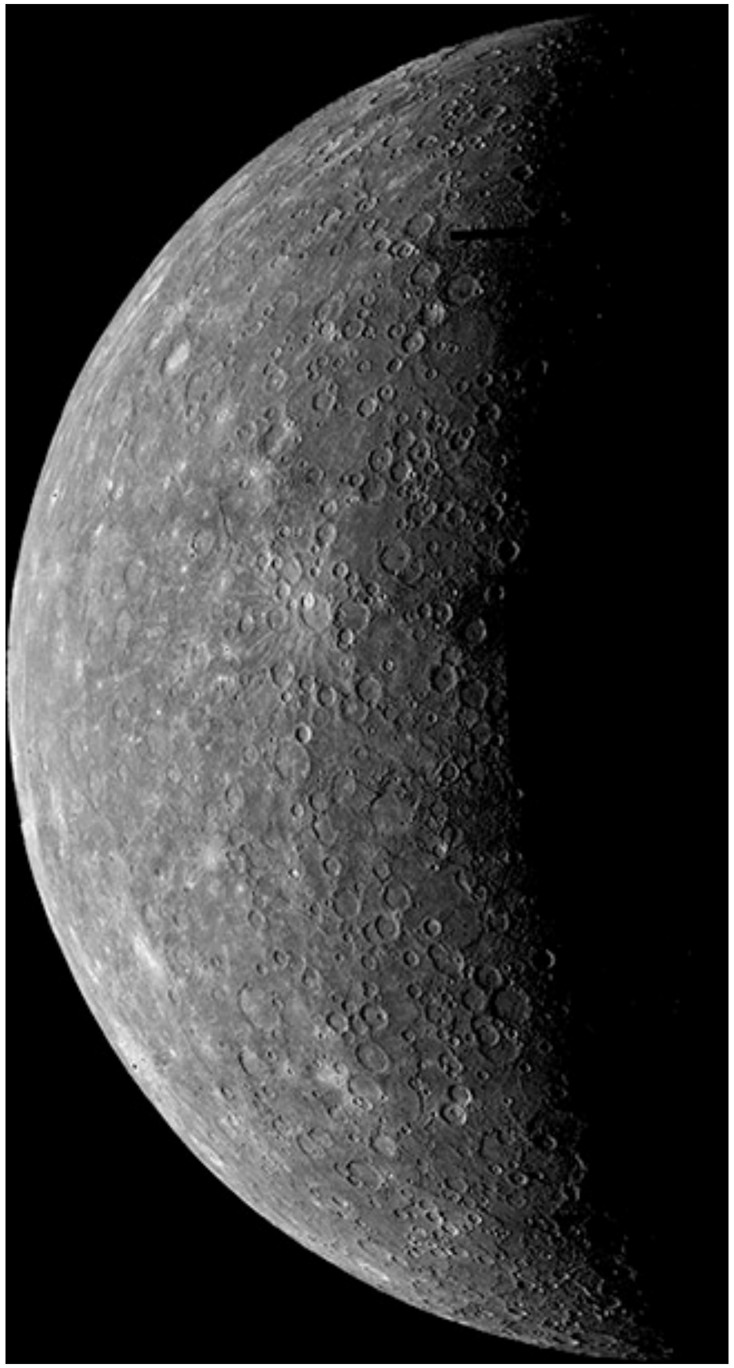
Glucose = $C_6H_{12}O_6$



Chapter 2

NRC/GT STEM High School Database

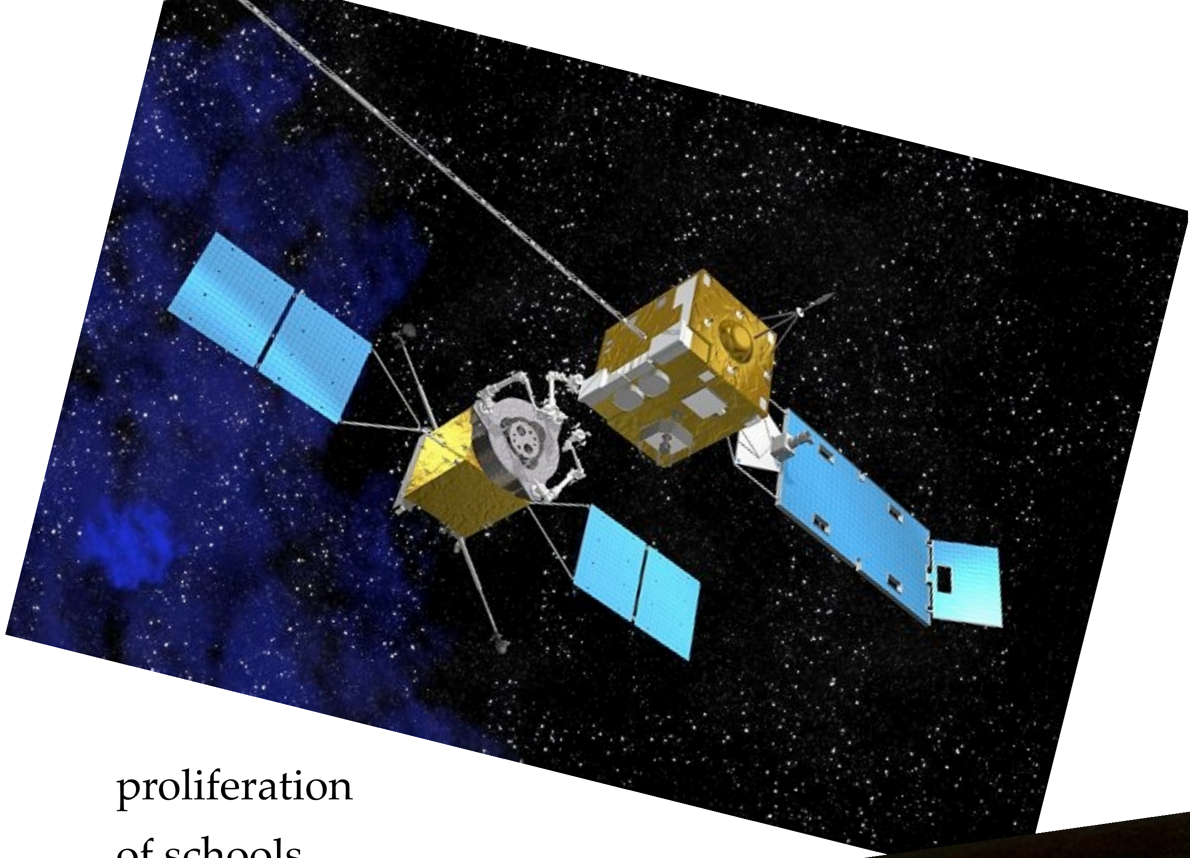
NRC/GT STEM High School Database



The University of Connecticut (UConn) and the University of Virginia (UVA) conducted a thorough search of STEM schools across the country by checking websites, reviewing articles and reports, contacting state departments of education, and accessing a list of schools belonging to the National Consortium of Specialized Secondary Schools of Mathematics, Science, and Technology. During our search of 916 STEM high schools, we classified schools according to several variables and created a database, which we refer to as the NRC/GT (The National Research Center on the Gifted and Talented) STEM high school database. Information about several variables provide the current status of U.S. STEM high schools:

- Year STEM school established—pre 1900-2012 (*N*=916)
    - Year STEM school established—1990-2012 (*n*=491)
- Geographic location of different types of STEM high schools by state and region
    - specialized high schools
    - magnet high schools

- charter high schools
- Governor's high schools
- other classifications of schools (i.e., STEM-focused comprehensive, college preparatory, and alternative high schools)



- Type of community
- Type of school organization
- Entry criteria

The results of these data are depicted in a series of figures in the form of U.S. maps, bar graphs, and circle graphs to support our visual analysis of the data and to provide readers with an effective and efficient way of accessing the results. We created bar graphs to show how many STEM high schools were established within certain intervals of years from pre 1900 to 2012, highlighting the proliferation of schools established within the years 1990 and 2010. Circle graphs were used to report results calculated in percentages (i.e., schools by type of community, organization, and entry criteria). A brief description accompanies each figure, along with insights that surfaced from our analyses.

Section I: Number of STEM High Schools Established by Year

Included in our STEM high schools database are data for the year each school was established. Our primary intention for grouping the schools by year of establishment was to examine the proliferation of STEM schools over time, and the possible relationship to national events and the resulting economic and educational policies. Figure 2.1 documents information available from the schools' websites and other online resources (*n*=853). Data are displayed in intervals of 10 years, ranging from pre 1900 to 2010. The 27 schools established between 1844 and 1900 were grouped into one interval for our graphical representation, and the 56 schools established between 2010 and 2012 were grouped into one interval because 2012 was the end year for data collection.

It is important to note that not all schools were founded as STEM schools; some schools self-identified as STEM at a later date. If we knew the year the STEM program was developed, we documented that year as the year the school was established. If we did not know the year the school started to identify as STEM, we documented the year the school was founded.

Of the 916 schools in our NRC/GT STEM high school database, we were unable to obtain information for 63 schools; thus, data for these schools are not displayed in the figure.

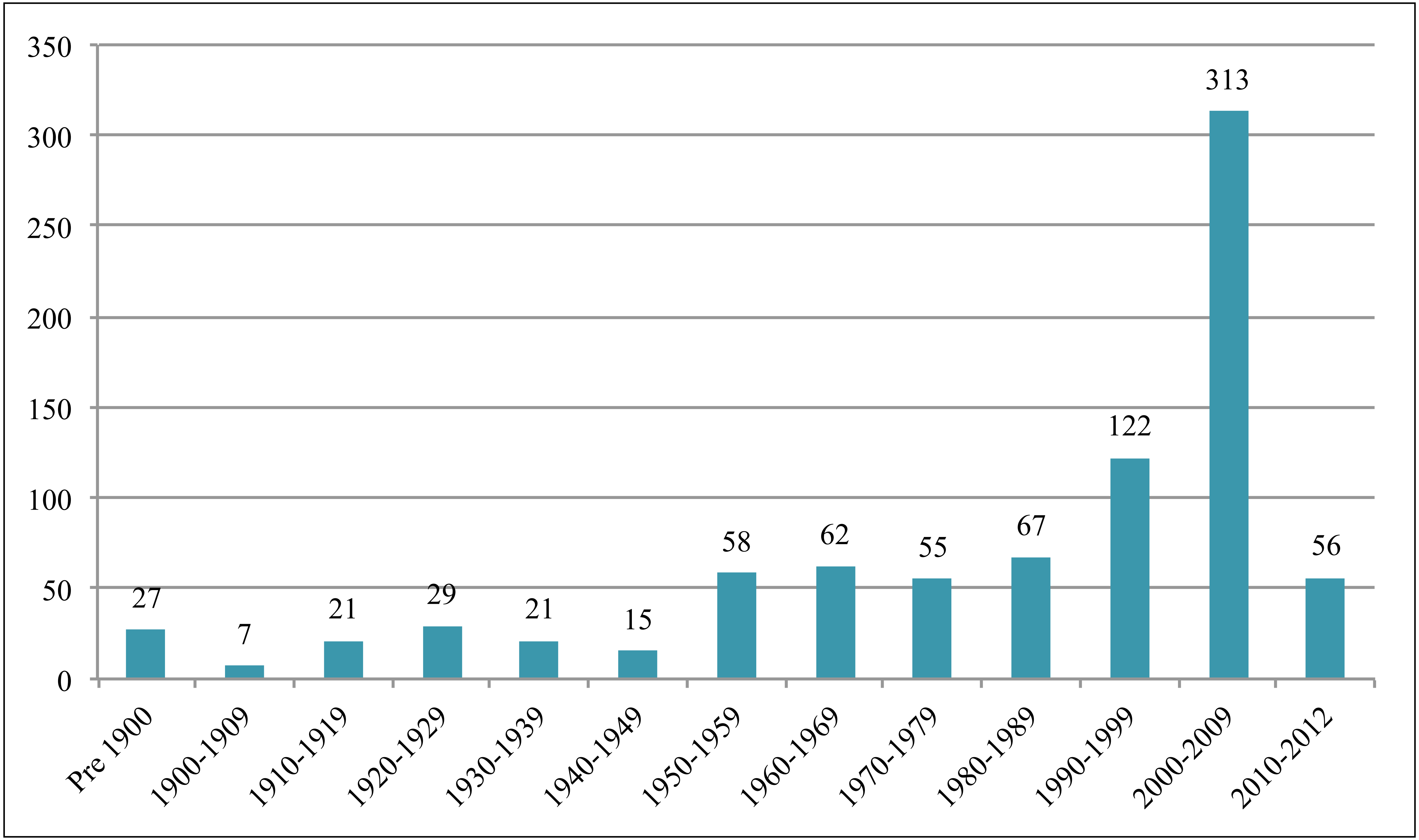


Figure 2.1. Year school/STEM high school established (*n*=853).

General Trends in the Establishment of STEM High Schools

Though we did not observe a steady increase in the number of STEM high schools established, we identified three periods of gradual increase—the first from pre 1910 to 1929, the second from 1950 to 1969, and the third from 1980 to 2009, with a significant increase from 1980 to 2009. We also observed a rise in the number of STEM high schools established during intervals of approximately 50 years: 27 schools were established over the course of 56 years (1844-1900), compared to 120 over the course of 50 years (1900-1949), 364 over the course of the following 50 years (1950-1999), and 369 from 2000-2012.

Industrial Revolution to Sputnik

From the data displayed in Figure 2.1, it appears that the advent and proliferation of STEM high schools in the U.S. have occurred in conjunction with economic initiatives and federal mandates directed at strengthening STEM education in the U.S. STEM high schools that emerged pre 1900, during the Second Industrial Revolution, might have been a direct response to the nation's need for developing a skilled workforce to meet the burgeoning industry demands for economic modernization. During every interval thereafter, 7 to 29 STEM high schools were established until 1950-1959, when the number of schools established quadrupled from the interval prior. This increase may be connected launch of Sputnik in 1957 by the Soviet Union, which has been recognized as the catalyst for the STEM education movement. Once the U.S. discovered the Soviet Union's successful strategy of linking education to the development of human capital to strengthen national security, STEM education services became a national priority (Dewitt, 1961; Sobel, 1978). The National Defense Education Act (1958) and various National Science Foundation Programs were highlights during this larger wave of STEM high schools (1950-1959).

Though the number of STEM high schools established was on the rise after Sputnik, the number established per decade nearly plateaued from 1950 to 1989—58, 62, 55, and 67 schools, respectively. The peak interval in Figure 2.1 occurred between 2000 and 2009, during which 313 schools were established. Approximately five times the number of schools were established between 1980 and 1989, nearly doubling from 67 (years 1980-1989) to 122 (years 1990-1999), and then again from 122 (years 1990-1999) to 313 (years 2000-2009). The doubling that occurred during the 1980-1989 and 1990-1999 intervals might have resulted from the rapid technological advances and the need to enhance the science, technology, engineering, and mathematical skills among school-age students Economic, political, and educational events as well as the concern for maintaining global influence after events such as the fall of the Berlin Wall and the Persian Gulf War might have increased the support received for STEM education from the H. W. Bush Administration (1989-1993). Support during the Clinton Administration (1993-2001) might have resulted from their national agenda to develop career and technical education opportunities to give more students a competitive edge in the job market.

Former President G. W. Bush served two terms of office during the interval for which the number of STEM high schools established was the greatest (2000-2009). From pre 1900 to the current day, most STEM high schools can be traced back to G. W. Bush's presidential years. Federal educational mandates that were implemented to improve STEM education included the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES Act, 2007) to support innovation in the 21st century.

America Competing in a Global Economy

It is important to consider how changes in the competitiveness of America's educational system, the decreased number of students pursuing careers in science, technology, engineering, and mathematics (STEM) fields, the fluctuating influence in a global economy were potential motivators for renewed interest in STEM (Members of the 2005 Rising Above the Gathering Storm Committee, 2010; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007), as noted below from *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*.

- In 2000 the number of foreign students studying the physical sciences and engineering in United States graduate schools for the first time surpassed the number of United States students. (p. 7)
- The United States ranks 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering. (p. 8)
- Sixty-nine percent of United States public school students in fifth through eighth grade are taught mathematics by a teacher without a degree or certificate in mathematics. (p. 7)
- The United States has fallen from first to eleventh place in the OECD in the fraction [of] 25-34 year olds

that has graduated high school. The older portion of the U.S. workforce ranks first among OECD populations of the same age. (p. 9)

- According to the ACT College Readiness report, 78 percent of high school graduates did not meet the readiness benchmark levels for one or more entry-level college courses in mathematics, science, reading, and English. (p. 11)

- Only four of the top ten companies receiving United States patents last year were United States companies. (p. 6)

Recent Policies and Trends in STEM Education

Fifty-six STEM high schools were created between 2010 and 2012. Though we are unable to accurately predict how many more schools will be established within the next few years, we anticipate a significant increase. In 2010, the President's Council of Advisors on Science and Technology (PCAST) developed an initiative to create 800 elementary schools and 200 high schools (PCAST, 2010); and in the same year, President Obama signed the America COMPETES Reauthorization Act (2010) into law. Furthermore, in 2012, PCAST followed-up with a recommendation to produce one million STEM college graduates, which implies the need for increasing the number of STEM high schools to prepare and inspire students to enter STEM college majors. In the next section, we continue our discussion of the economic trends that have influenced the continued trend in STEM education from 1990 until the present day.

Section II: Number of STEM High Schools Established Since 1990

To further examine the proliferation of STEM high schools, we decreased the intervals from 10 to 5 years for the time period ranging from 1990 to 2012 (see Figure 2.2). Just as in Figure 2.1, we observed a gradual increase in the number of STEM high schools established, nearly doubling from 70 schools (1995-1999) to 131 schools (2000-2004), and more than tripling from 52 schools (1990-1994) to 182 schools (2005-2009).

Several events may have influenced a renewed emphasis in STEM education to encourage students to enter STEM fields, such as the desire for rapid technological advancements, the rise of the Internet, and the focus on the achievement of U.S. students compared to students in other countries.

The Effects of Technology on Globalization

We are currently living in a world where, for some, technology is essential for economic and creative productivity. What might our world be like today if Apple and Google Inc. were never developed? The innovative corporations serve as examples of how technological advancements in our society have increased the need for STEM education, and subsequently, the establishment of STEM high schools. For example, as the Internet's influence increased, so did the creation of Internet-related jobs, and the necessity for training

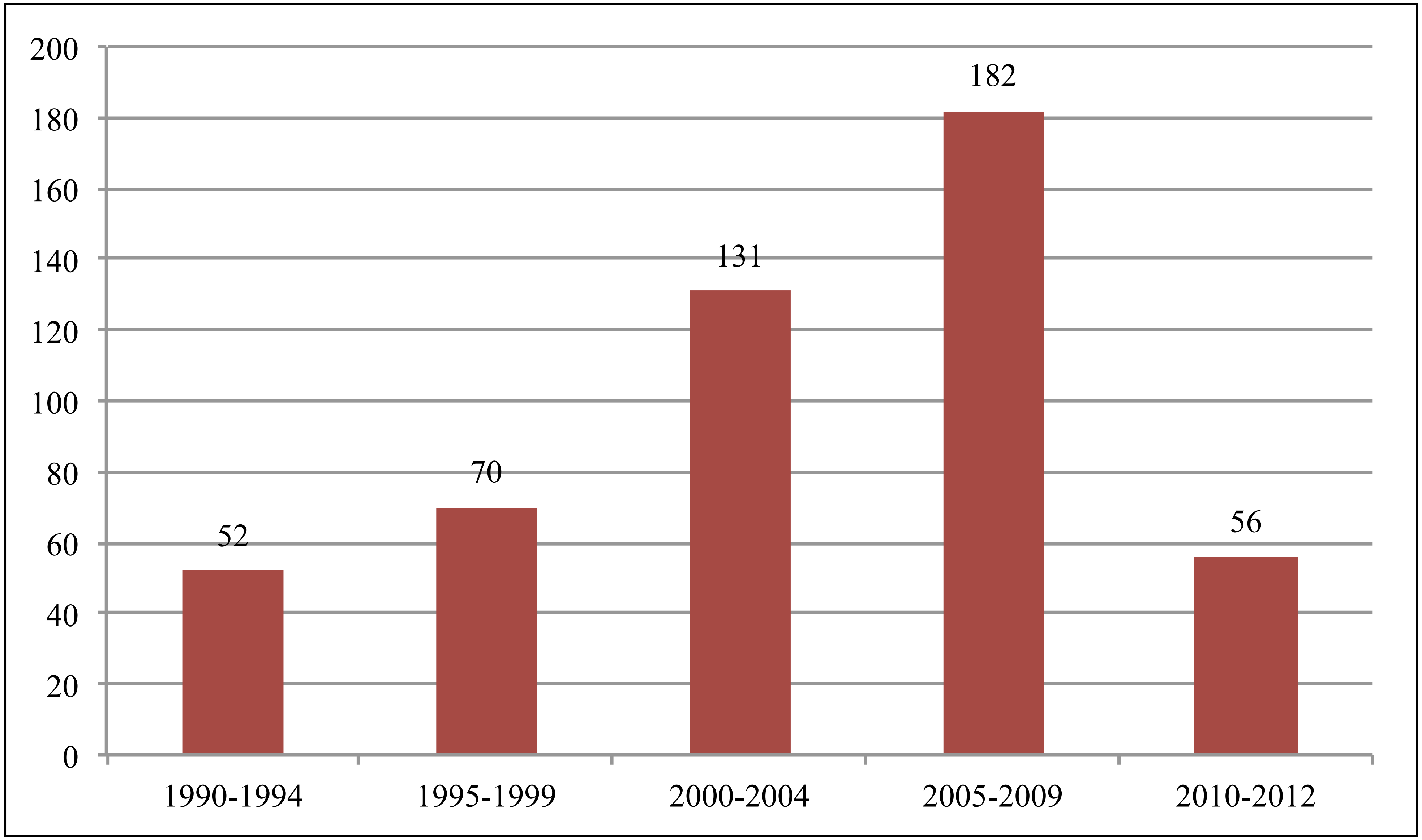


Figure 2.2. Year STEM high school established [1990-2012] (*n*=491).

individuals to develop the skill-set to work in those jobs. And, as the ability to connect with people via the Internet around the globe increased, so did ideas for further technological advancements. Globalization aside, the increase in STEM schools over the past 20 years might has also been attributed to the need to increase the supply of STEM professionals, and correspondingly, the creation of STEM high schools.

A Vision for STEM Education

President Obama has emphasized the need to reduce U.S.'s dependency on foreign fuel by seeking energy alternatives, to promote the creation of jobs, and to address the effects of climate change. His Administration has supported PCAST's recommendations to establish 800 STEM elementary schools and 200 STEM high schools on the premise that it will benefit the individual and society. In his February 2013 State of the Union address, President Obama discussed his vision for creating more avenues to prepare students for STEM professions. He shared his interest in STEM high schools—calling to "redesign America's high schools so they better equip graduates for the demands of a high-tech economy," and providing incentives to schools that develop curricular options focusing on STEM disciplines to equip students with "the skills today's employers are looking for to fill the jobs that are there right now and will be there in the future" (Obama's State of the Union Address, 2013). He also discussed his priority to revitalize American manufacturing, which for educational policy and STEM education, might suggest the need for developing more career and technical high schools across the country.

STEM High Schools Then and Now

We presented historical and current perspectives on the increasing number of STEM high schools. In the next sections, we highlight additional information from our database. The figures, some in the form of a U.S. map, provide a current snapshot of STEM high schools in the U.S. with regard to geographic location of different types of STEM high schools by state and region, the types of communities, types of school organization, and entry criteria.

Section III: Number of STEM High Schools Across the U.S.

Though our search for STEM high schools was extensive, we acknowledge that we did not find all schools that currently identify themselves as STEM schools, and that new sites have opened since our last update to the database in December 2012. Figure 2.3 provides a pictorial representation of the location of STEM high schools in the NRC/GT database.

Examining Figure 2.3, it appears that the states with higher population densities (e.g., California, Texas, New York, Florida) have the most STEM high schools. This finding aligns with population estimates reported by the United States Census Bureau in 2012. The states with the remaining ranges of schools (e.g., 26-50 and 16-25), however, do not correspond with the Census statistics.

Furthermore, 6 states had 26-50 STEM high schools, which were all located in the Midwest and eastern regions of the country. Several states had 15 or fewer STEM schools. Montana and West Virginia were the only states that did not have any STEM high schools, according to our available data sources.

Type of STEM High Schools by Region

One of the demographic variables we examined was the type of STEM high schools, which we classified as specialized, magnet, charter, and Governor's

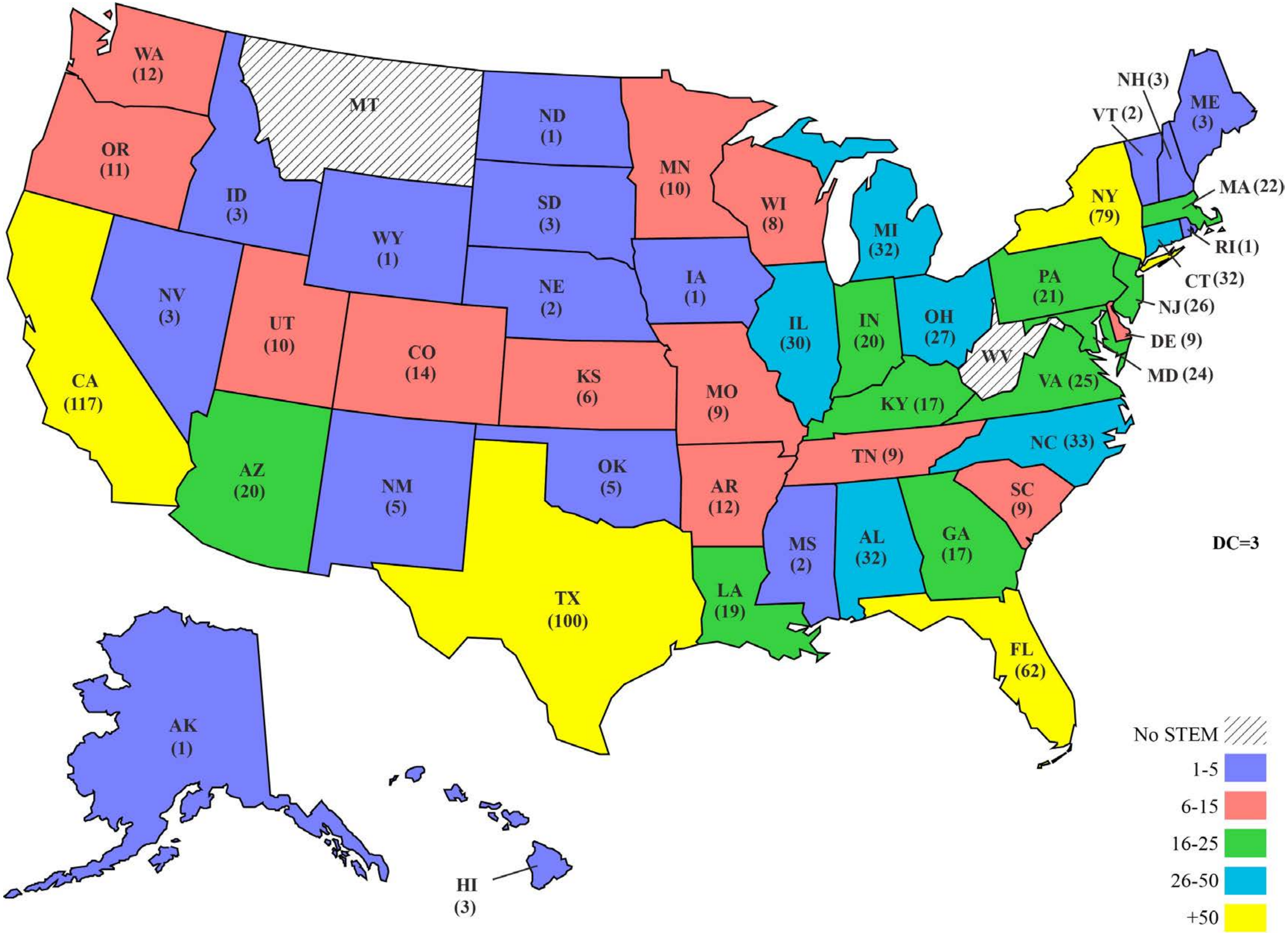


Figure 2.3. Total number of STEM high schools in NRC/GT database (N=916).

based on available data. In our database, we also classified STEM schools as *other* (i.e., STEM-focused comprehensive, college preparatory, and alternative high schools). Figure 2.4 displays the types of STEM high schools by region.

Across all U.S. regions, there was considerable variation among the number of specialized, magnet, and charter schools. Though, most were in the *other* category and the fewest were in the *Governor's* category. Knowing that most of the schools were classified as *other*, it might be of interest to researchers to examine the different outcomes that may result from the services provided.

Type of STEM High Schools by State

Figures 2.5-2.9 display the distribution of each type of STEM high school: specialized, magnet, charter, Governor's, and *other* (i.e., STEM-focused comprehensive, college preparatory, and alternative high schools).

Distribution of STEM Specialized High Schools

Figure 2.5 displays the distribution of STEM specialized high schools by state. The Northeast had the greatest number of specialized schools (*n*=62). Most of the STEM specialized high schools were located in New York (*n*=38), followed by Alabama (*n*=18) and Connecticut (*n*=15). Three of the 4 schools that had 6-10 specialized schools were located in the Midwest. Several states had 5 schools or less, with 21 schools having no STEM specialized schools based on the available data from multiple sources.

Distribution of STEM Magnet High Schools

Figure 2.6 depicts the distribution of STEM magnet high schools state. States with 6-10 schools were dispersed primarily along the east coast and throughout Midwest. Several of the states that had only one STEM magnet school were in the Midwest. Fourteen of the 21 schools that did not have any STEM specialized schools also did not have STEM magnet schools. Florida had 29 magnet schools, which may reflect local or state initiatives.

Distribution of STEM Charter High Schools

Figure 2.7 depicts the distribution of STEM charter high schools by state. California and Texas had the greatest number

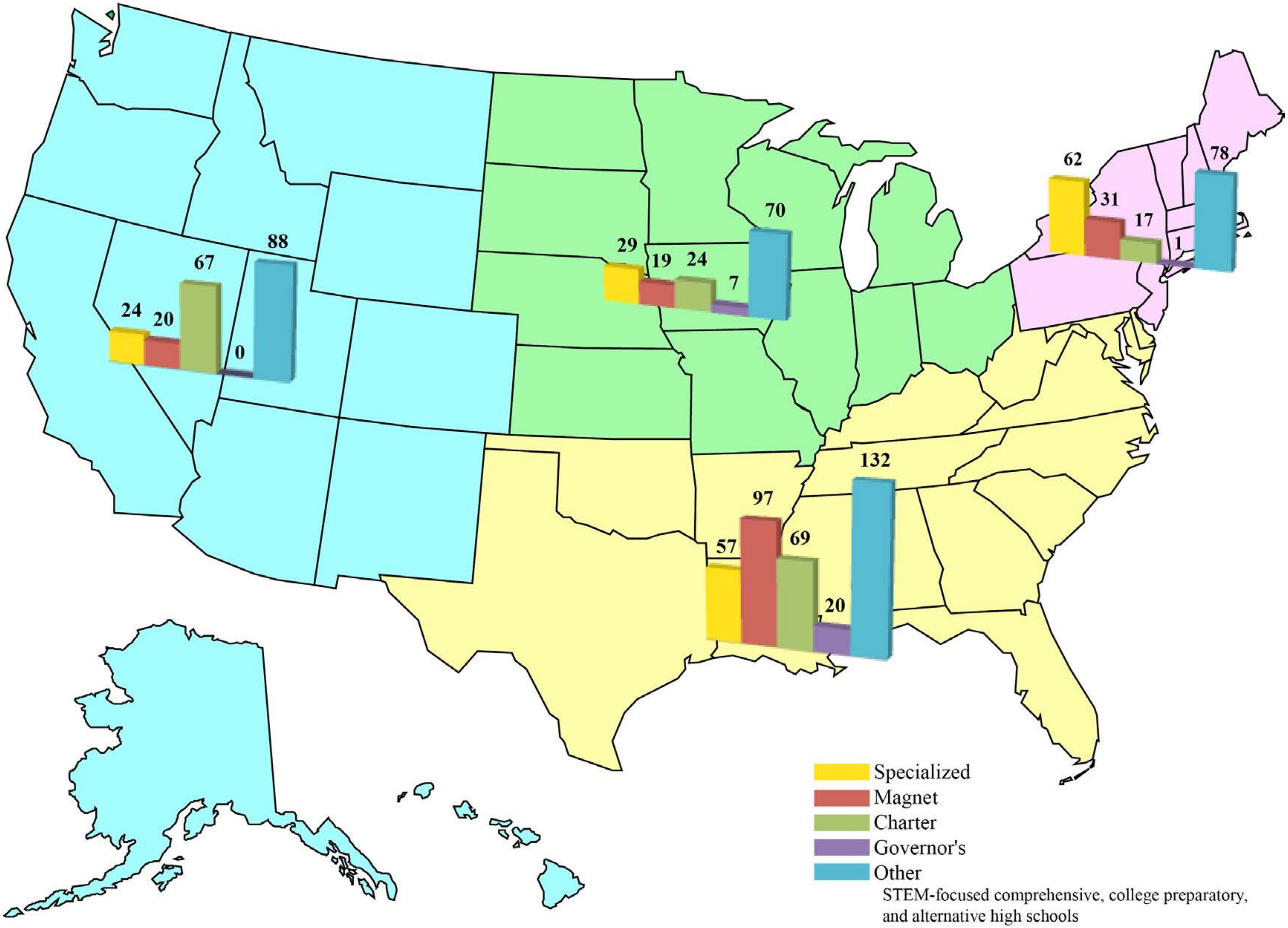


Figure 2.4. Type and number of STEM high schools by region in NRC/GT database.

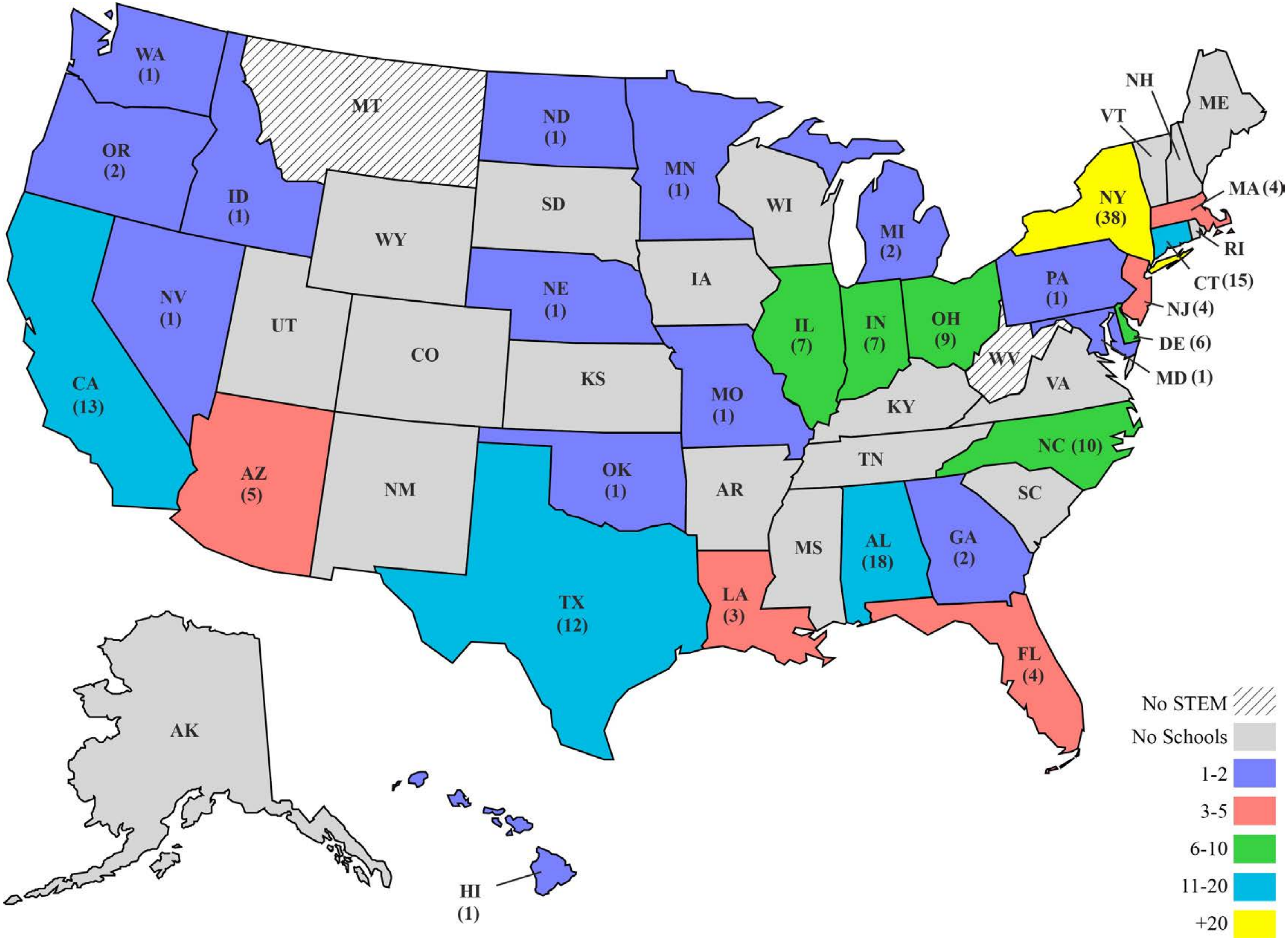


Figure 2.5. Distribution of STEM specialized high schools in NRC/GT database (n=172).

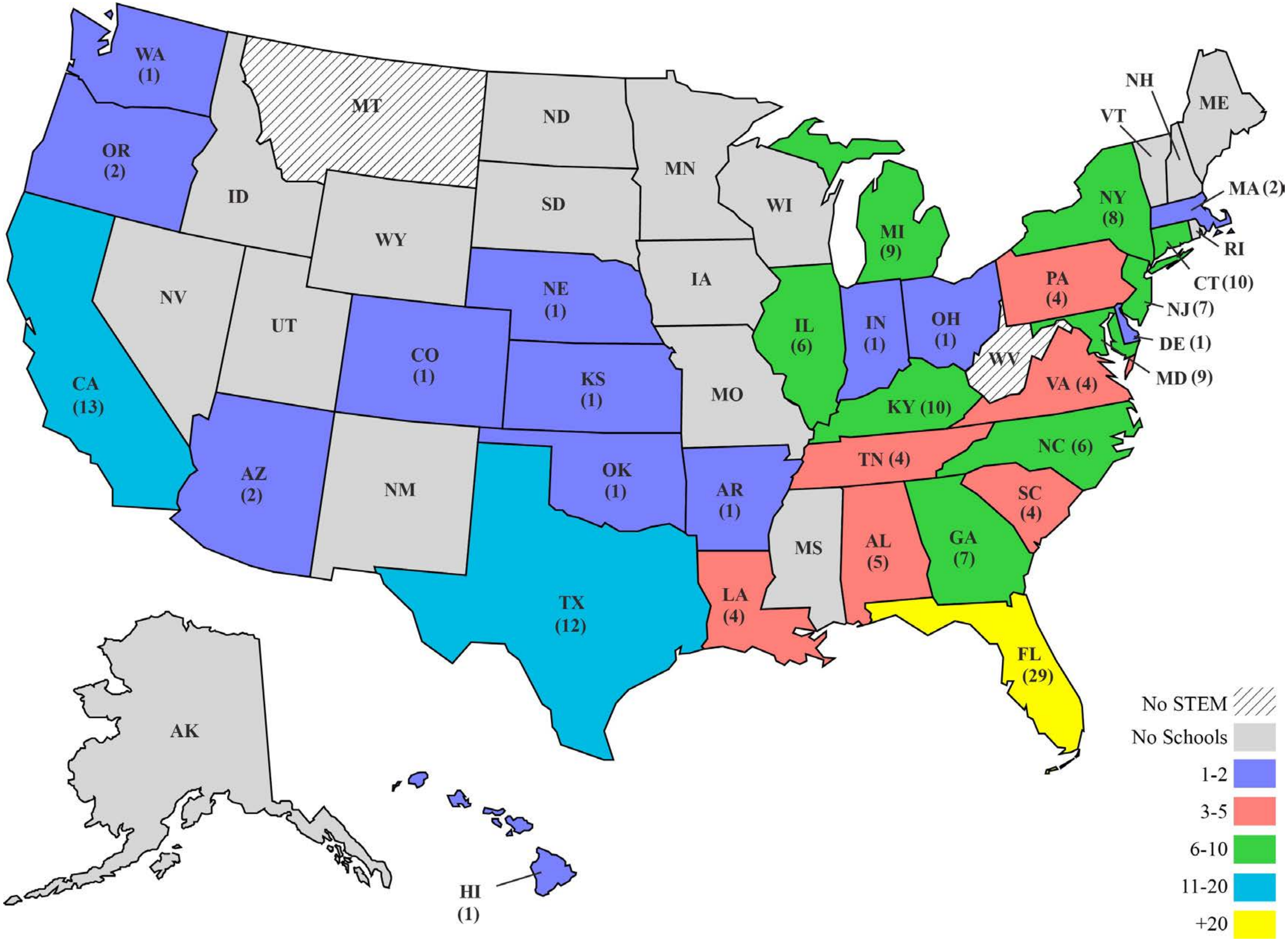


Figure 2.6. Distribution of STEM magnet high schools in NRC/GT database (n=167).

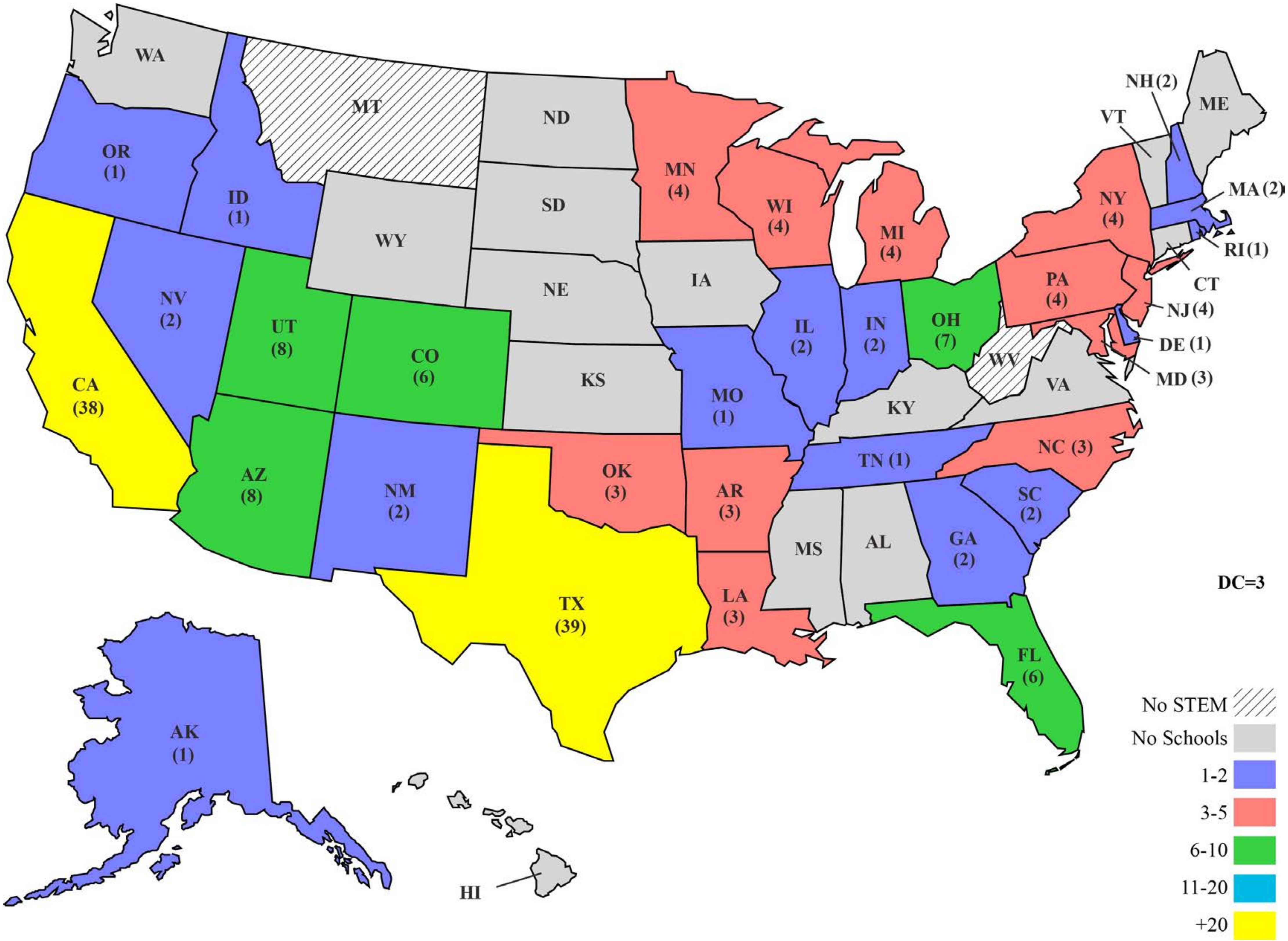


Figure 2.7. Distribution of STEM charter high schools in NRC/GT database (n=177).

of STEM charter high schools (n=38 and n=39, respectively). Five states had 6-10 STEM high schools; 16 states had 5 or fewer STEM schools. Most of the states that did not have STEM charter schools were located in the Midwest.

Distribution of STEM Governor's High Schools

Figure 2.8 depicts the distribution of STEM Governor's high schools state. Most of the STEM Governor's high schools were located in Virginia (13), followed by Wisconsin, which had one third less (4). Eleven states had one school, which were mostly in the Midwest and South; and the remaining states had no STEM Governor's high schools.

The prevalence of STEM Governor's schools in Virginia is a reflection of the financial and maintenance support received from the Virginia Department of Education and Office of Secondary Instructional Services, in collaboration with local school districts, and surrounding colleges and universities. The Governor's schools model was established in Virginia in 1973, which was created to provide Virginia's academically and artistically gifted students with extended and enriched educational opportunities. For STEM high school students, the Governor's School experience consists of learning with professional mentors and instructors. Three types of Governor's Schools exist throughout Virginia's commonwealth: Academic-Year Governor's Schools, Summer Residential Governor's Schools, and the Summer Regional Governor's Schools (Virginia Department of Education Governor's Programs, 2012).

Distribution of All Other STEM High Schools

Figure 2.9 depicts the distribution of STEM high schools by state in the *other* category (e.g., STEM-focused comprehensive, college preparatory, and alternative high schools).

The most highly populated states had the greatest number of STEM high schools in the *other* category—that is, California (n=53), Texas (n=37), New York (n=29), and Florida (n=23), respectively. Twelve states had 6-10 STEM high schools in the *other* category, 7 states had 3-5, and the remaining states had 2 or less.

Additional STEM High School Demographics

Percentage of STEM High Schools by Type of Community

Figures 2.10-2.12 present the data on STEM high schools by type of community, school organization, and entry criteria. We created a circle graph to depict the percentage of STEM high schools that were in varying types of communities, namely urban, suburban, and rural. Most of the STEM high schools in

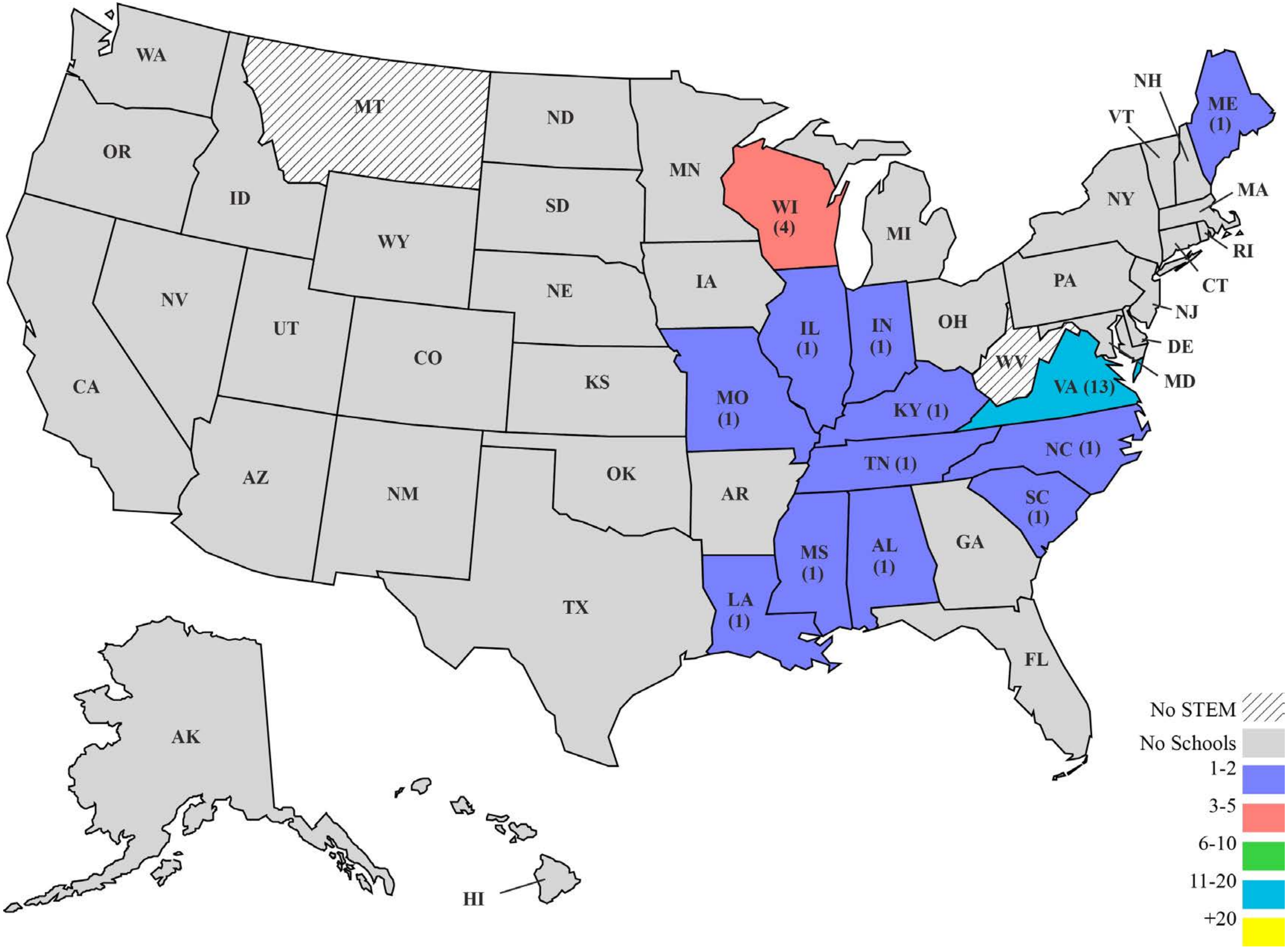


Figure 2.8. Distribution of STEM Governor's high schools in NRC/GT database (n=28).

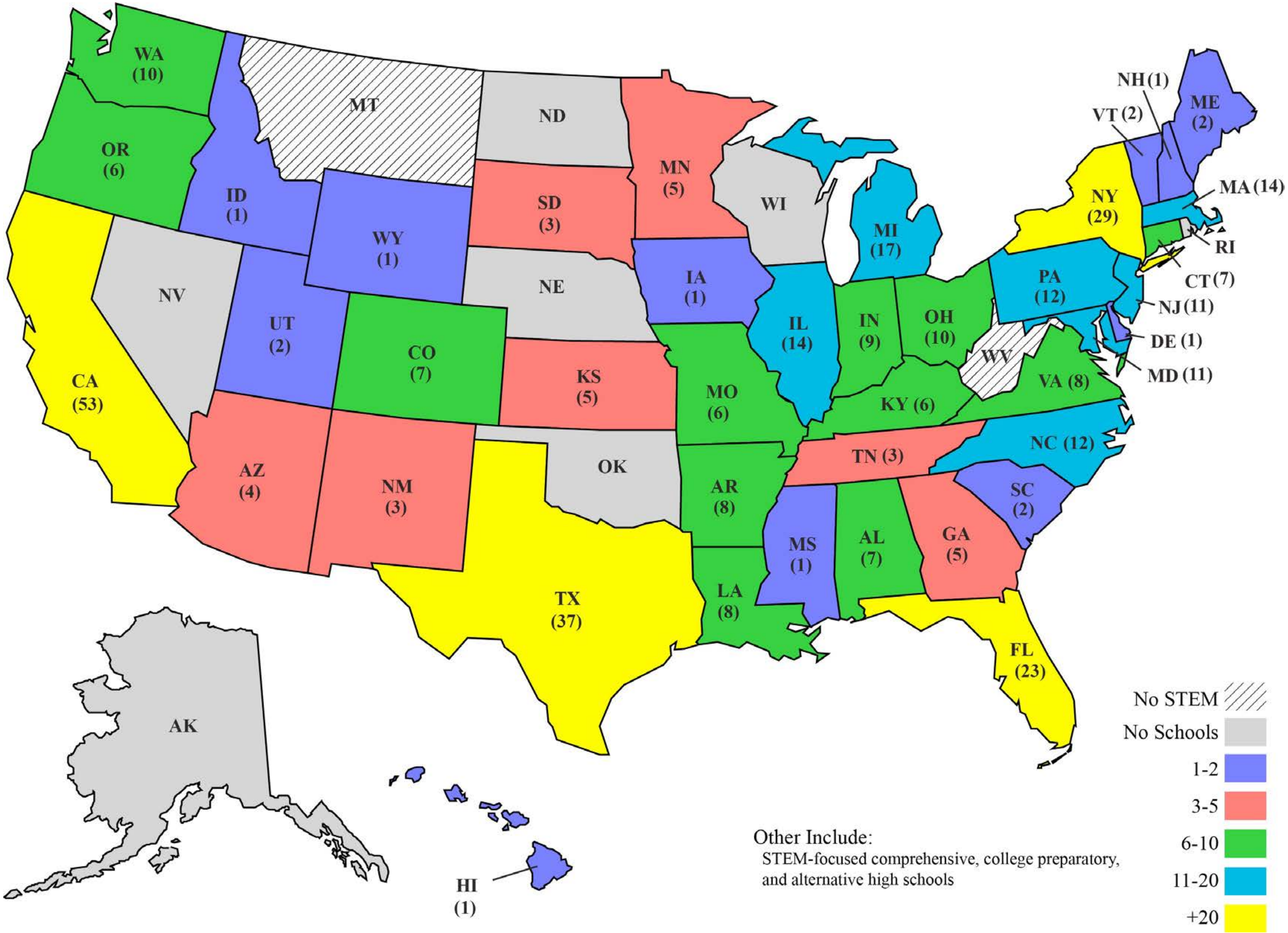


Figure 2.9. Distribution of all other STEM high schools in NRC/GT database (*n*=368).

the NRC/GT database were located in suburban communities (58%), which was more than twice the percentage located in urban communities (26%). Even fewer STEM high schools were located in rural communities (16%) and 1% remained unidentified. Students with obvious or emergent interests in STEM fields living in different types of communities may not have access to STEM high schools.

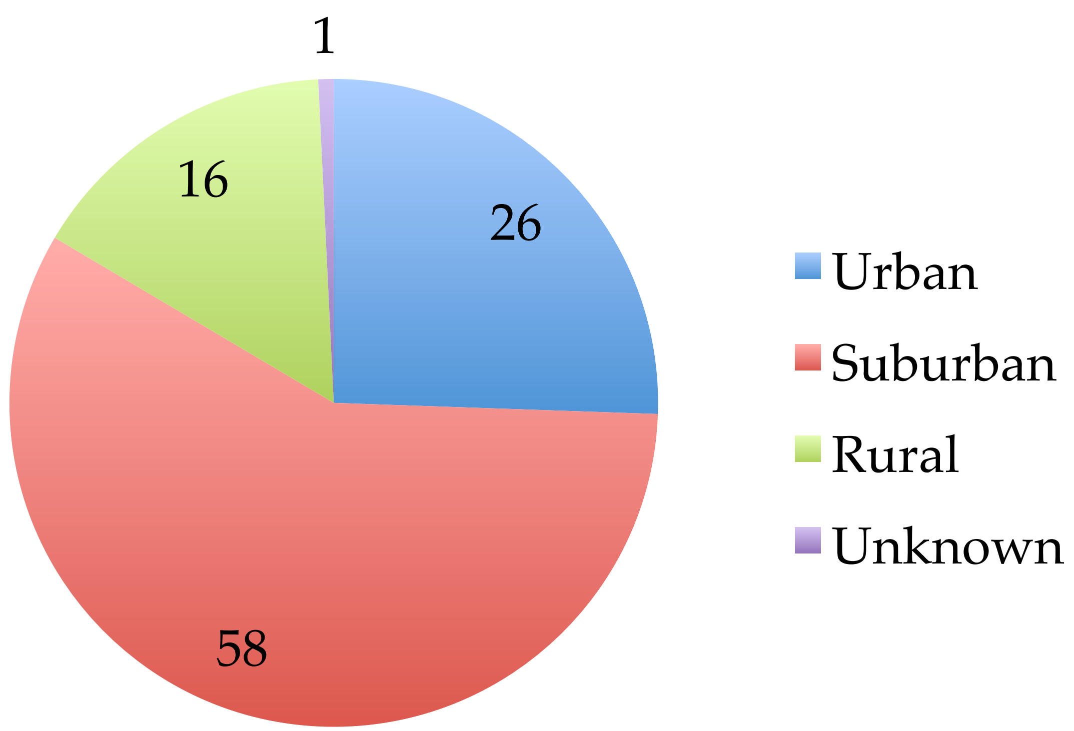


Figure 2.10. Percentage of STEM high schools by type of community (numbers rounded to whole numbers).

Percentage of STEM High Schools by School Organization

We recorded demographic data for the STEM high schools' organizations (i.e., day, residential, and partial day). Figure 2.11 depicts the percentage of STEM high schools for each type of organization. There was a notable difference between the percentage of schools identified as Day (94%) and the percentage of Residential, Partial Day, Multiple, and Unknown, combined (7%).

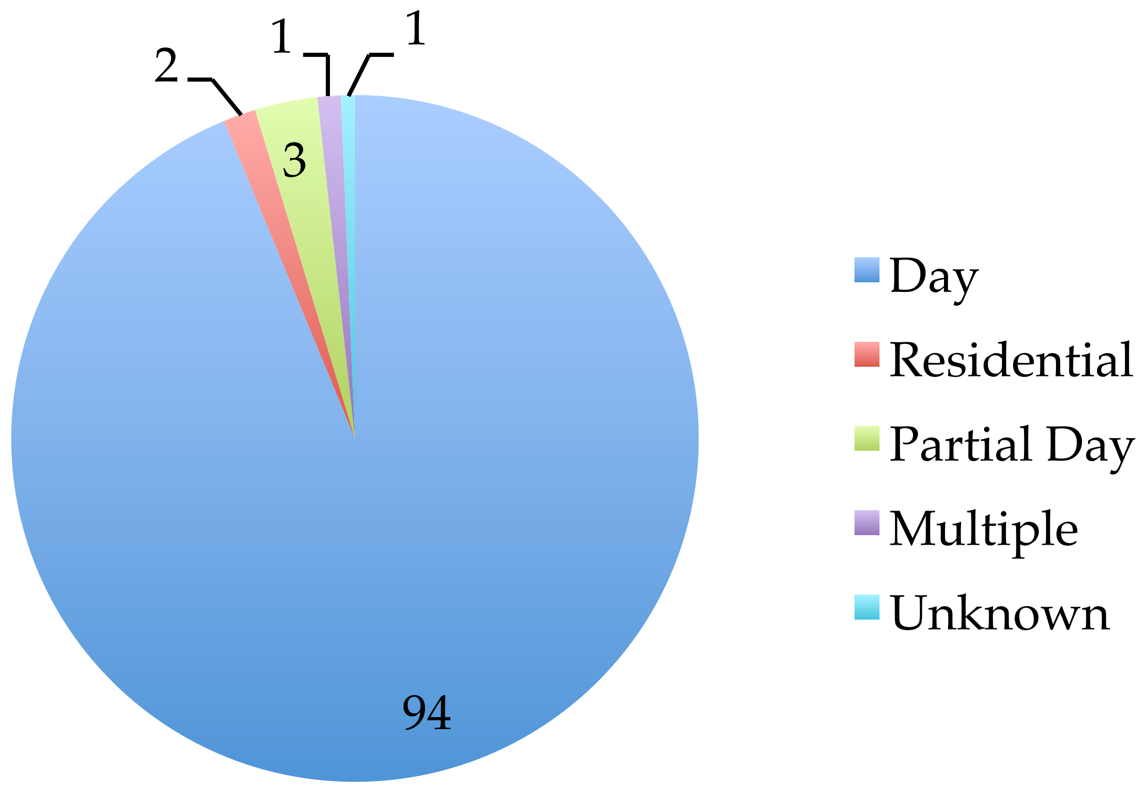


Figure 2.11. Percentage of schools by school organization (numbers rounded to whole numbers).

Percentage of STEM High Schools With Exclusive or Inclusive Entry Criteria

Figure 2.12 displays the results of the demographic data we recorded for entry criteria to STEM high schools. As discussed in a prior section, schools with exclusive criteria are more selective in their admissions process, whereas schools with inclusive criteria may allow students entry solely on the basis of their interest in STEM. Most STEM high schools in the database established inclusive entry criteria (80%) in comparison to exclusive criteria (20%). One percent remained unknown based on the available sources.

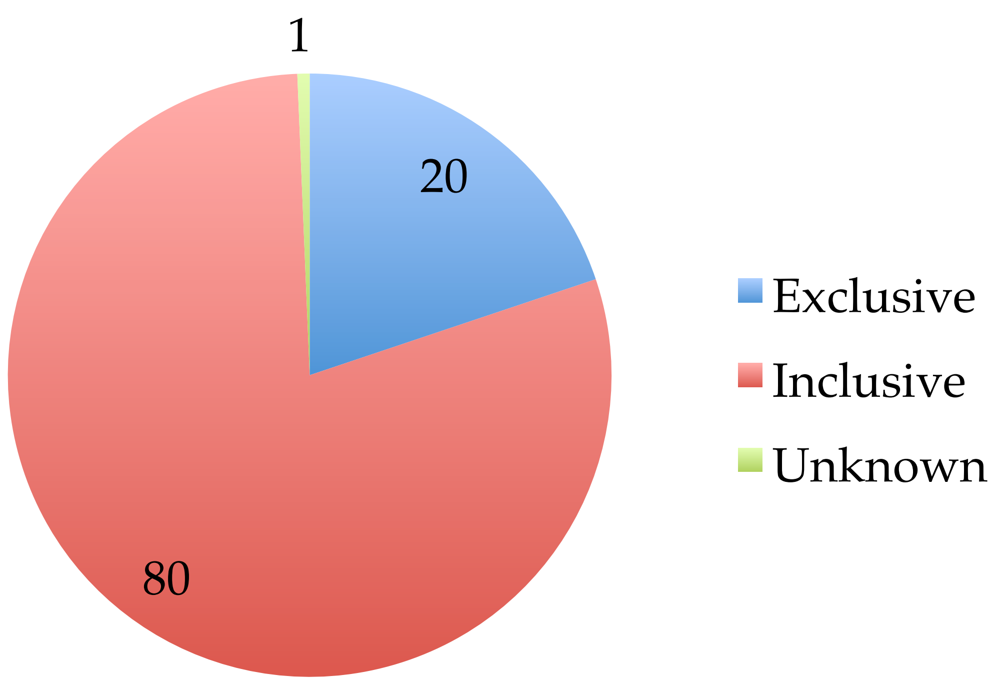
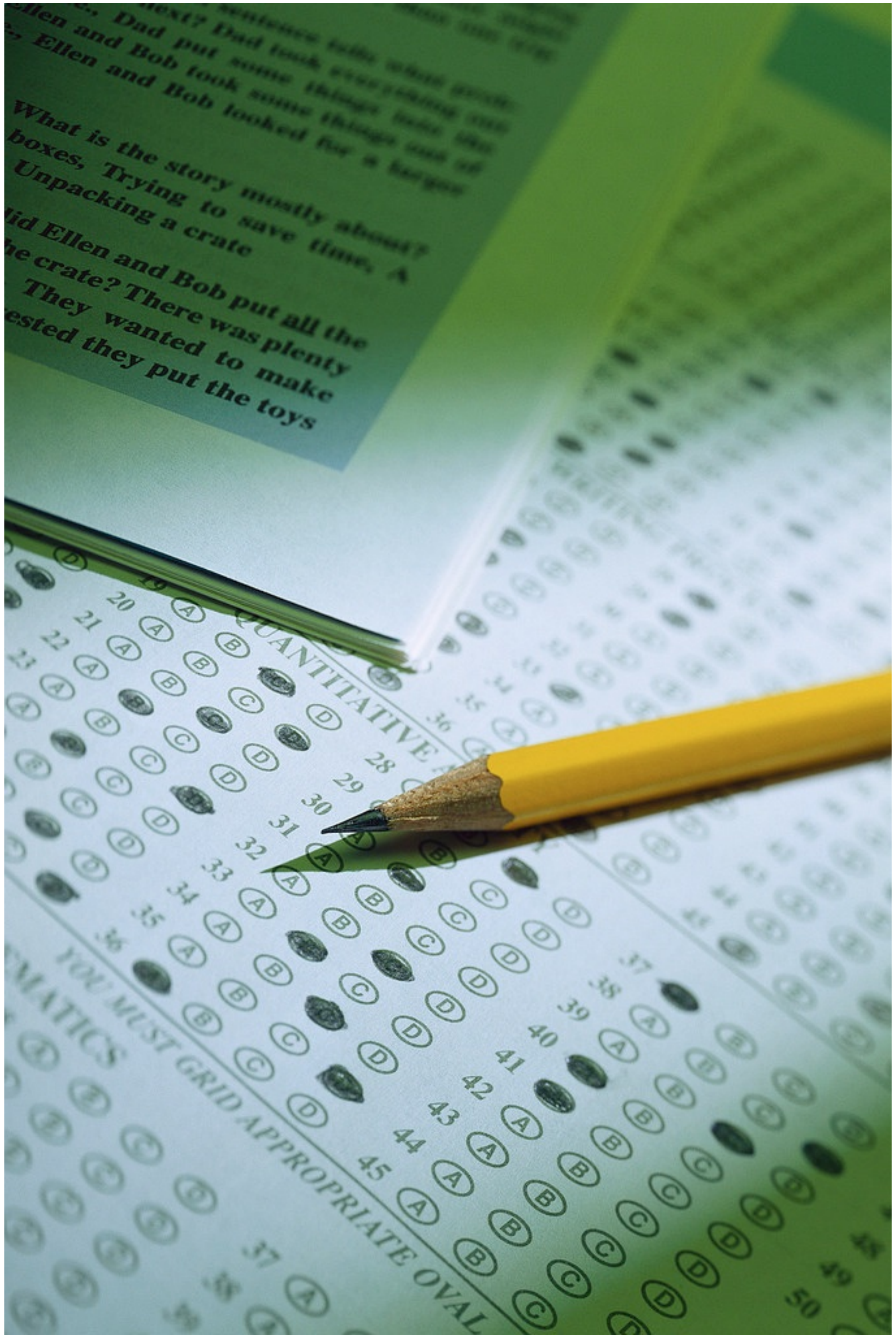


Figure 2.12. Percentage of schools with exclusive or inclusive entry criteria (numbers rounded to whole numbers).



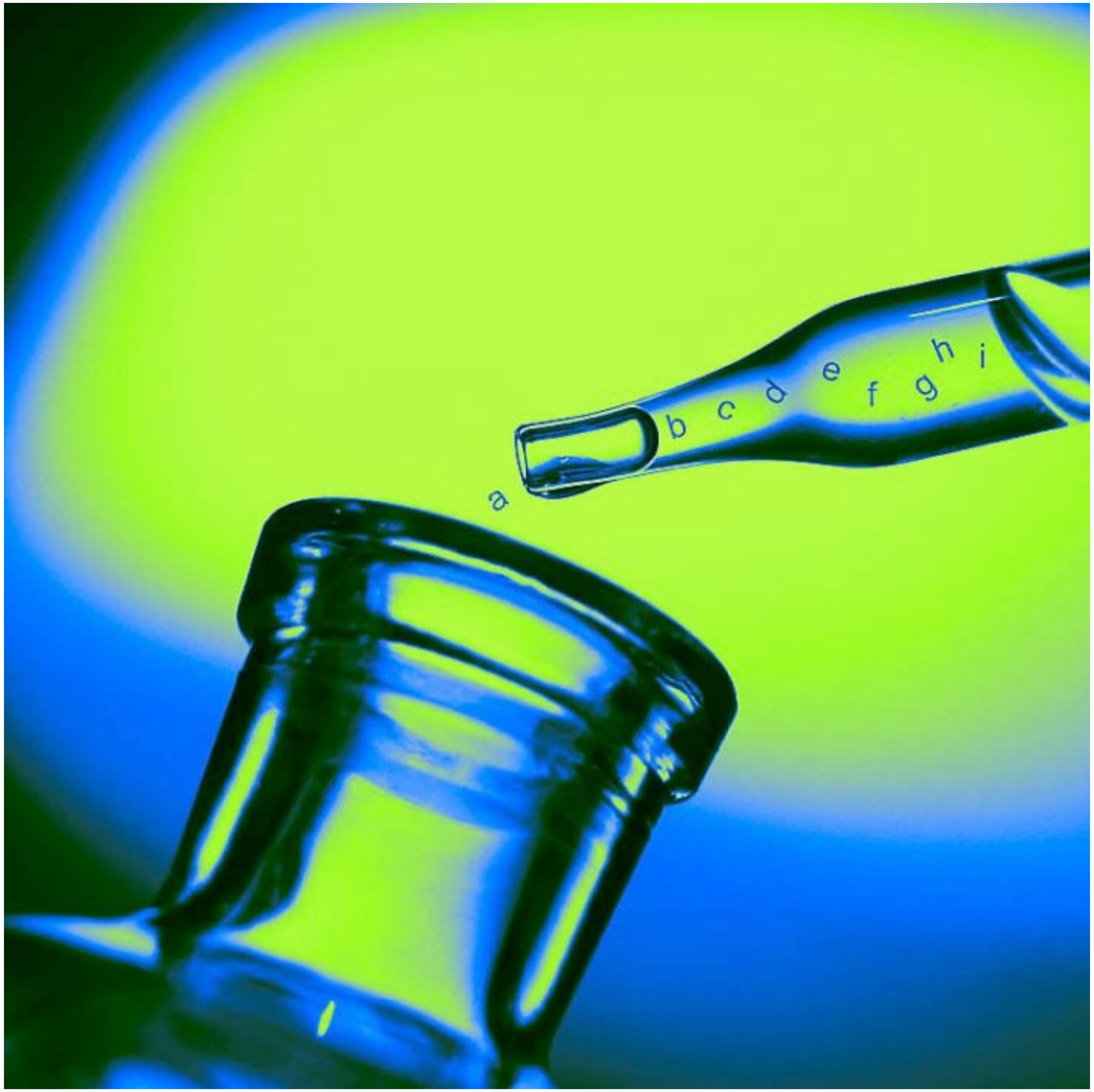
Summary

As of 2012, the University of Connecticut and the University of Virginia documented the existence of 916 STEM high schools. The creation of the NRC/GT STEM High Schools' Database allowed us to classify schools according to several demographic variables. During the 20th century, the number of STEM high schools ranged from 7 to 122. An increased interest in STEM high schools was evident in the 21st century, as 313 were established from 2000 to 2009 and 56 from 2010 to 2012. *(Date of establishment or identification as a STEM high school was unavailable for 63 schools.)*

Renewed emphasis on the importance of preparing students in science, technology, engineering, and mathematics may be related to economic, political, and educational influences and events. Four states have more than 50 STEM high schools (California, Texas, New York, and Florida). Five states (North Carolina, Alabama, Michigan, Ohio, and Connecticut) have 26-50 STEM high schools, and two states (Montana, West Virginia) do not have any STEM high schools. We classified schools as specialized, magnet, charter, Governor's, or other depending on available information. The majority of schools were located in suburban communities (58%), followed by urban (26%) and rural (16%) locations. Day schools (94%) predominate the school organization format. Most of the STEM schools are described as inclusive

(80%), as students with an interest in STEM or a desire to attend the school are welcome.

Continued interest in the STEM fields will most likely spur the creation of more STEM schools throughout the country. To provide a closer look at STEM high schools, the results of survey data from administrators and teachers are described in Parts III and IV. The presentation of the data and the related commentary may provide guidance to those interested in creating STEM schools or redesigning current schools as STEM high schools. The administrators' responses about their schools' policies and procedures as well as the administrators' and teachers' ratings of an array of curricular and instructional practices offer a snapshot of the school environments focusing on science, technology, engineering, and mathematics.



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Chapter 3

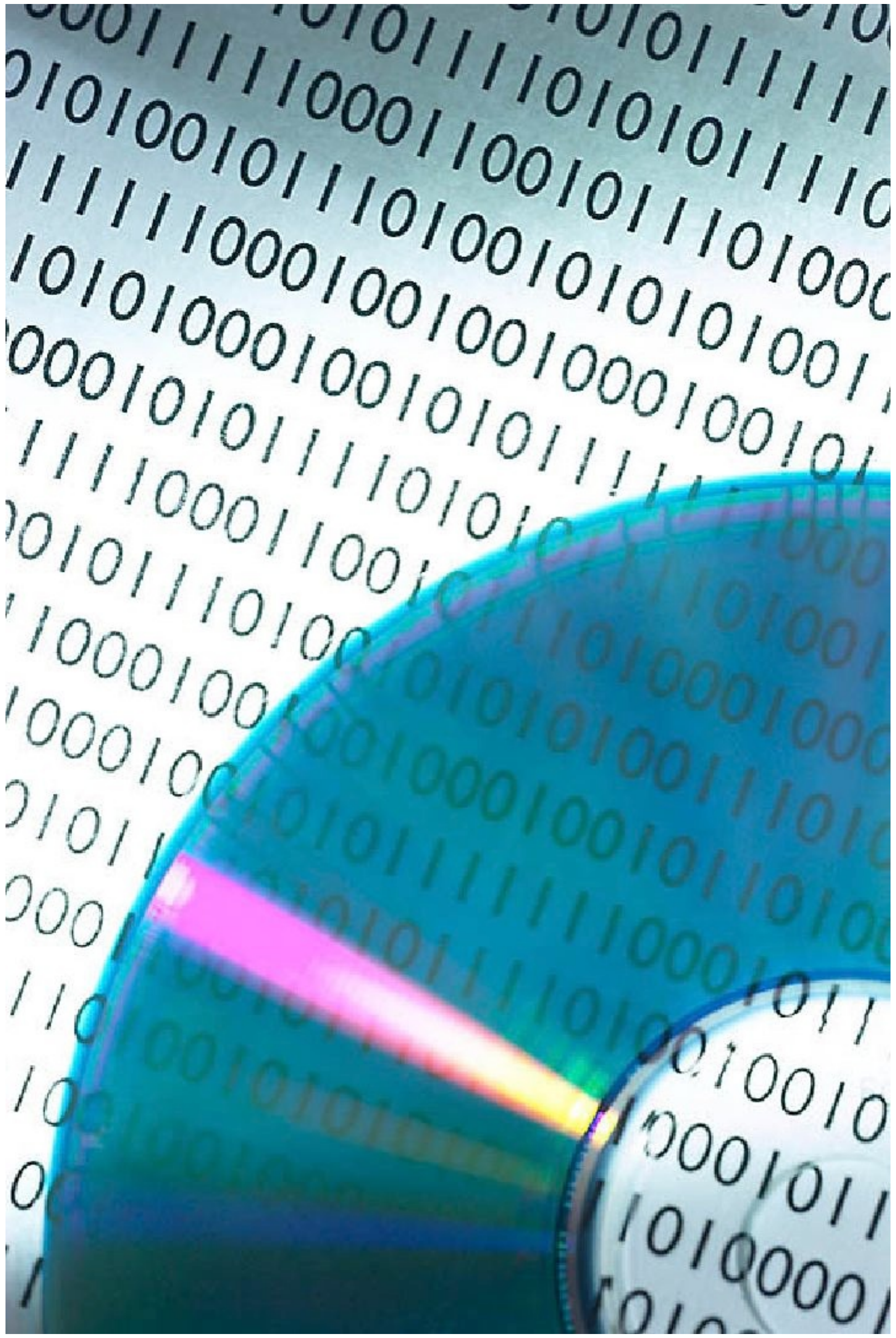
STEM High School Administrator Survey

STEM High Schools: Administrators' Survey Results

To learn more about how STEM high schools were organized and how educators implemented specific strategies and practices, we selected 12 STEM high schools across the country for site visits. During the site visits, we interviewed administrators, observed classrooms, and conducted focus groups with teachers, students, and administrators. We analyzed these qualitative data by and across schools with the goal of creating an item pool for a survey for administrators. The research team generated items representative of curricular and instructional practices of the majority of school visits. As items were created, we referred to the literature to ensure that practices reflected the findings in the literature on STEM education and "best practices" in general education.

This section of the report presents a summary of survey data from 205 high school administrators. Highlights of the demographics from the survey respondents are presented first followed by a description of the STEM High School Administrator Survey, summary of the results, and commentary on practices suggested for STEM high schools.

Section I: Demographics



Overview of Results

We asked administrators to provide descriptive information about their schools, such as the geographical location of their school's community, type of community, classification of STEM high school, admissions criteria, eligibility for free and reduced lunch, and number of STEM courses offered.

Geographic Distribution of Respondents

Figure 3.1 displays the geographic distribution of the administrator respondents from 31 states. Texas was the only state with more than 20 respondents; 11-20 surveys were available from California, Florida, and North Carolina; and 11 states did not provide any data.

Type of Community

Administrators indicated that their schools served urban (38%), suburban (31.2%), and rural (19%) communities. There appears to be widespread interest in STEM schools. Some schools' catchment areas represented different types of communities as indicated in Figure 3.2.

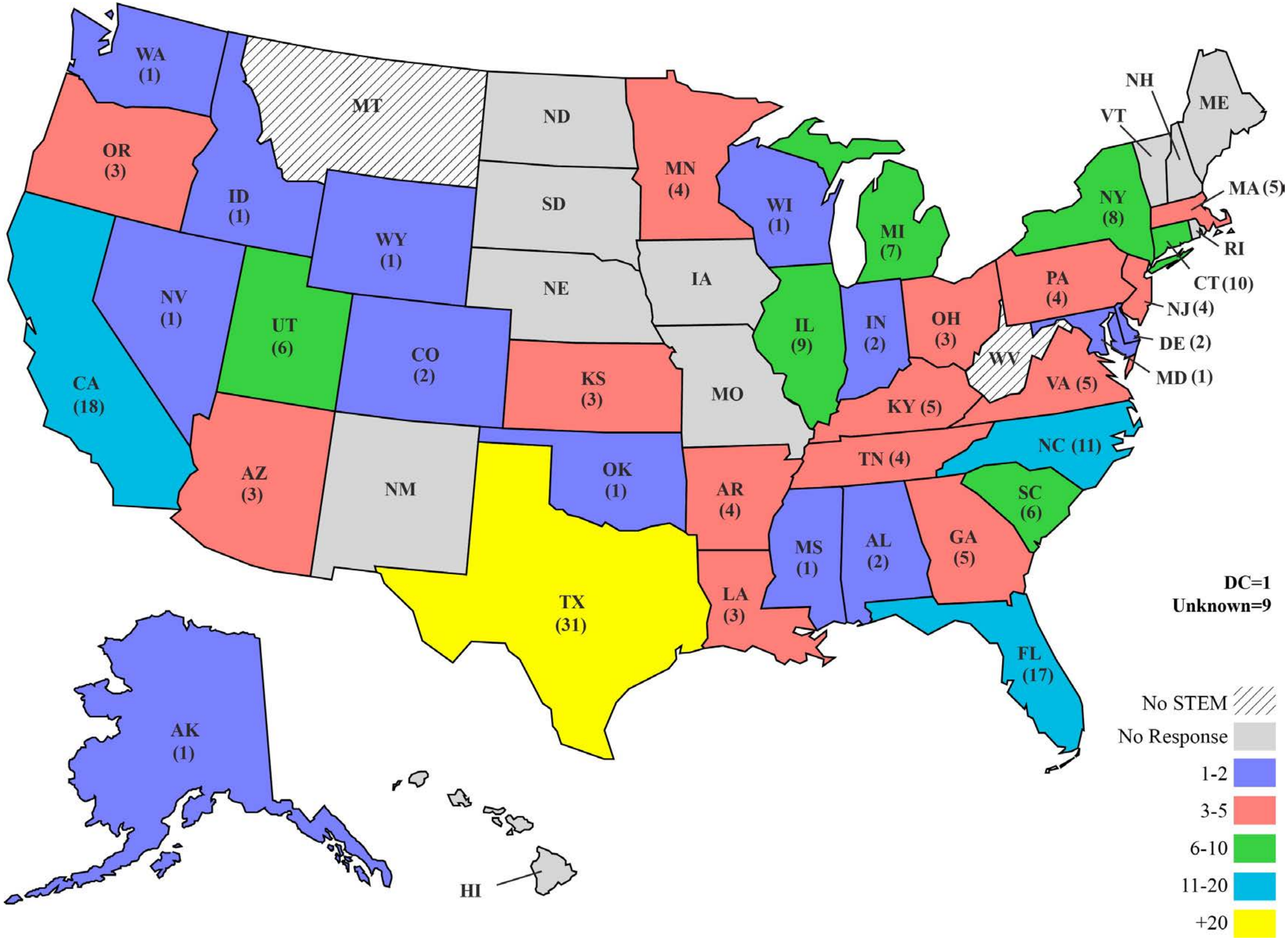


Figure 3.1. Geographic distribution of administrator respondents (*n*=205).

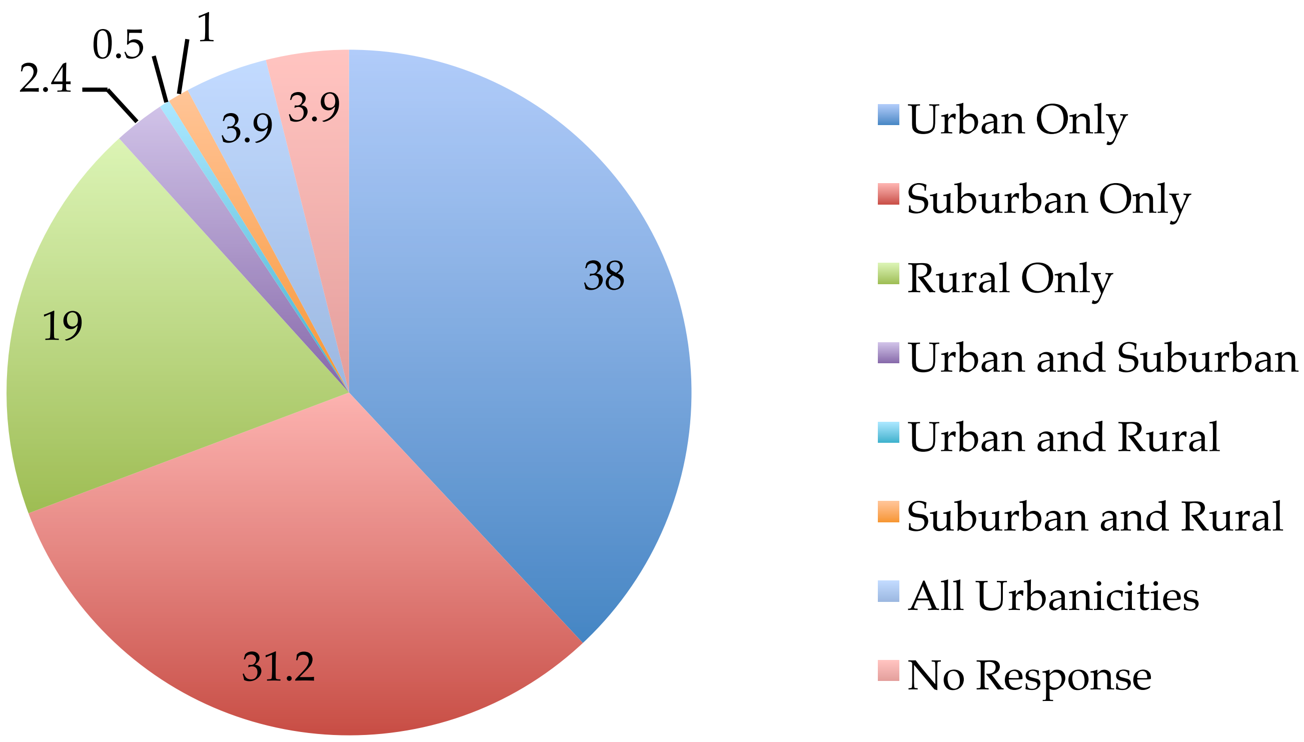


Figure 3.2. Percentage of student populations served by STEM high schools.

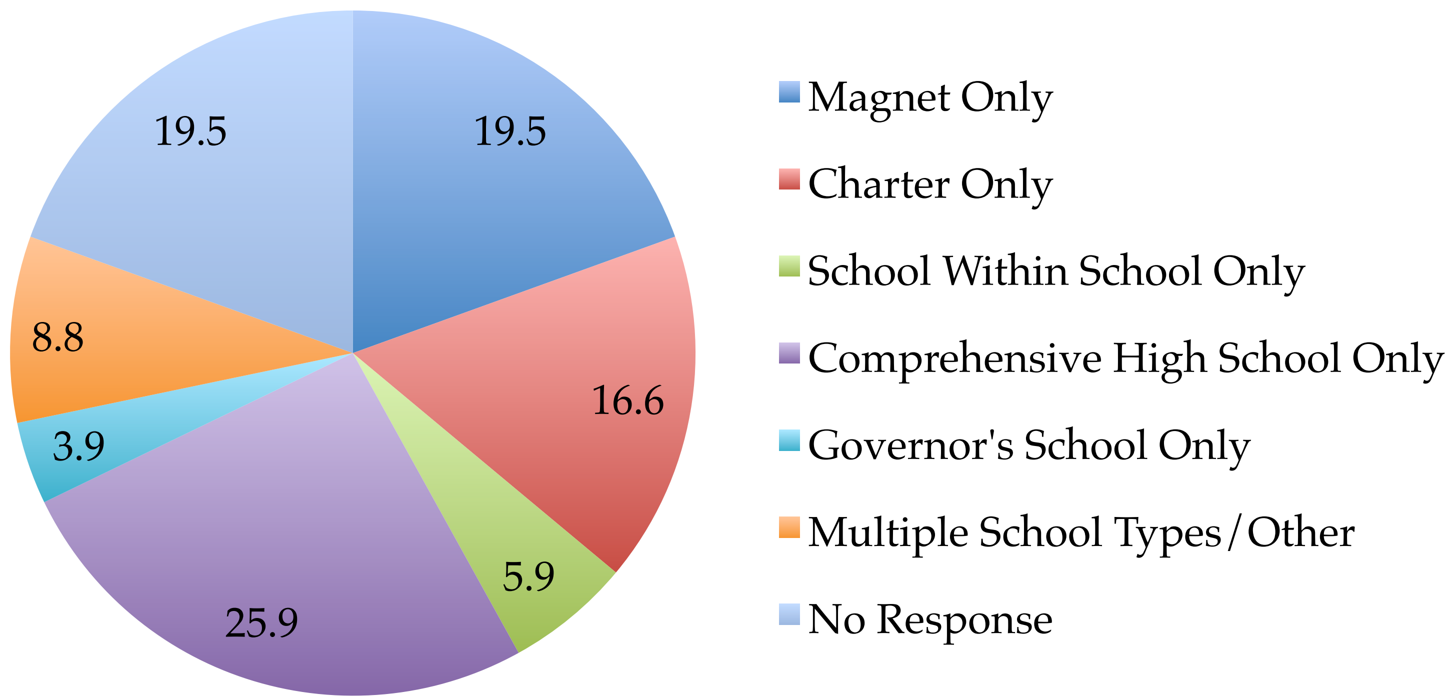


Figure 3.3. Percentage of each type of STEM high school reported by administrators.

Classification of STEM High School

Administrators classified their schools according to one or more of the following types: magnet, charter, school-within-a-school, comprehensive high school, or Governor's school. They also had the option of naming another organizational format. Of the administrators who responded to the survey, 25.9% selected comprehensive high school, while magnet schools (19.5%) and charter schools (16.6%) also were represented. It should also be noted that 19.5% did not choose to declare a school type.

From the types of high schools we listed in the STEM administrator survey, most respondents reported their school as Comprehensive High School Only. The remaining types of schools, in descending order, were Magnet Only, Charter Only, Multiple School Types/Other, School Within a School Only, and Governor's School Only. Of the administrators, 19.5% did not respond to this item (see Figure 3.3).

Admissions Criteria

Administrators within these various school types selected multiple options for admitting students to their schools. Figure 3.4 depicts the descending order of frequency of use of specific criteria with grades/report cards/transcripts selected by 45.4% of respondents and no selection criteria for 40%. In schools with admissions criteria, the types of data ranged from teacher recommendations to essays and tests. Fewer administrators selected attendance records, interviews, ability tests, work samples/portfolios, and behavioral or psychological records as considerations for admission to their schools.

Eligibility for Free and Reduced Lunch

Students involved in the various types of schools with exclusive or inclusive admissions criteria represented different levels of eligibility for free and reduced lunch. Figure 3.5 illustrates that as the percentage of eligibility for free and reduced lunch increased, the percentage of administrators who chose the specific range decreased. Of the respondents, 28% selected 0-25% eligibility and 27% chose 26-50%. As eligibility for free and reduced lunch is often

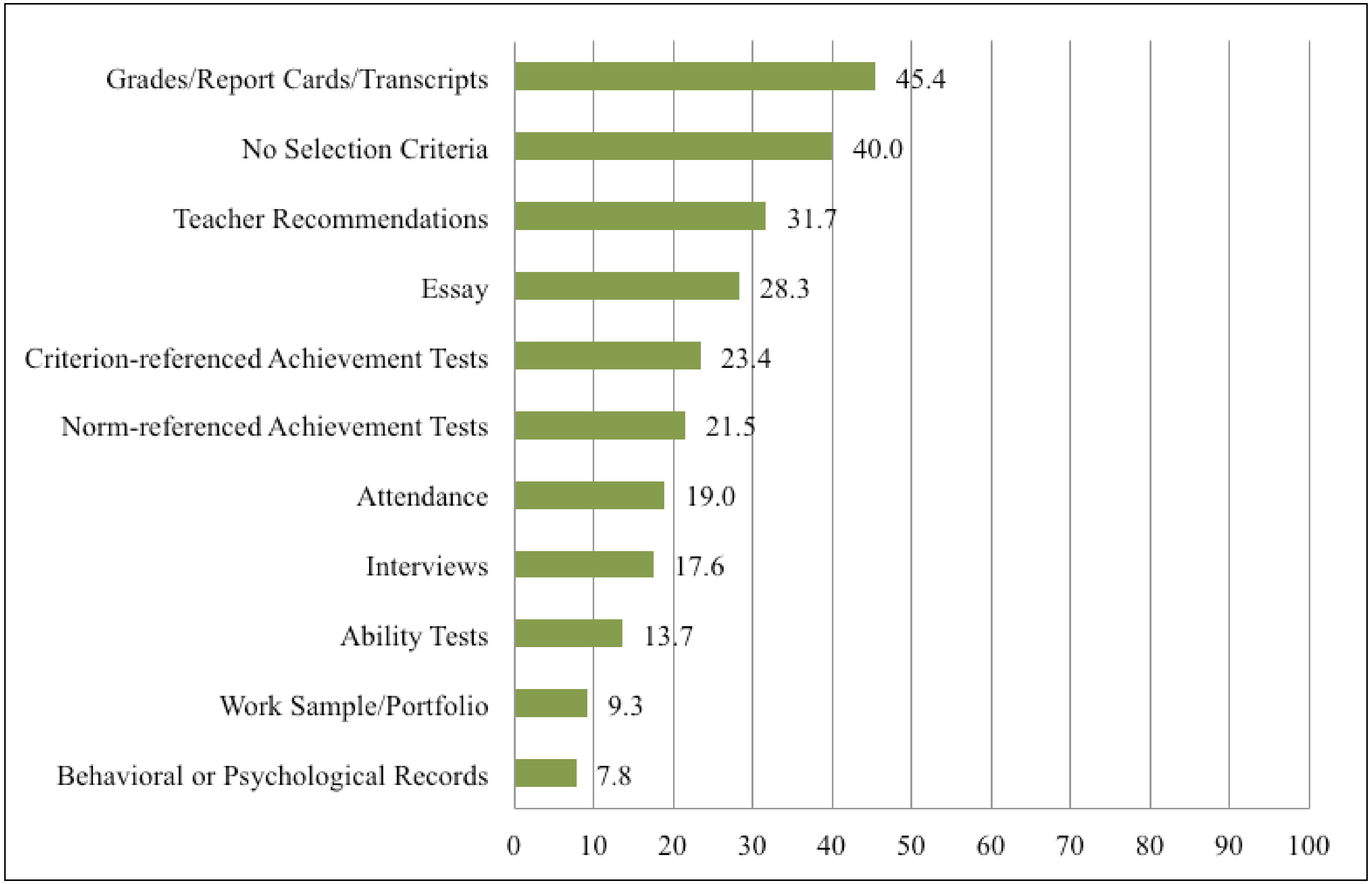


Figure 3.4. Admissions criteria percentage of use reported by administrators.

regarded as a proxy for the socio-economic status of the community surrounding the school, it was evident that the diversity of schools among the respondents varied.

STEM Course Offerings

A final demographic item serves as descriptive data on the representation of STEM disciplines in schools. While it is acknowledged that the size of the school population and the number of teachers is related to course availability, the data in Table 3.1 can be viewed as a preliminary perspective on STEM

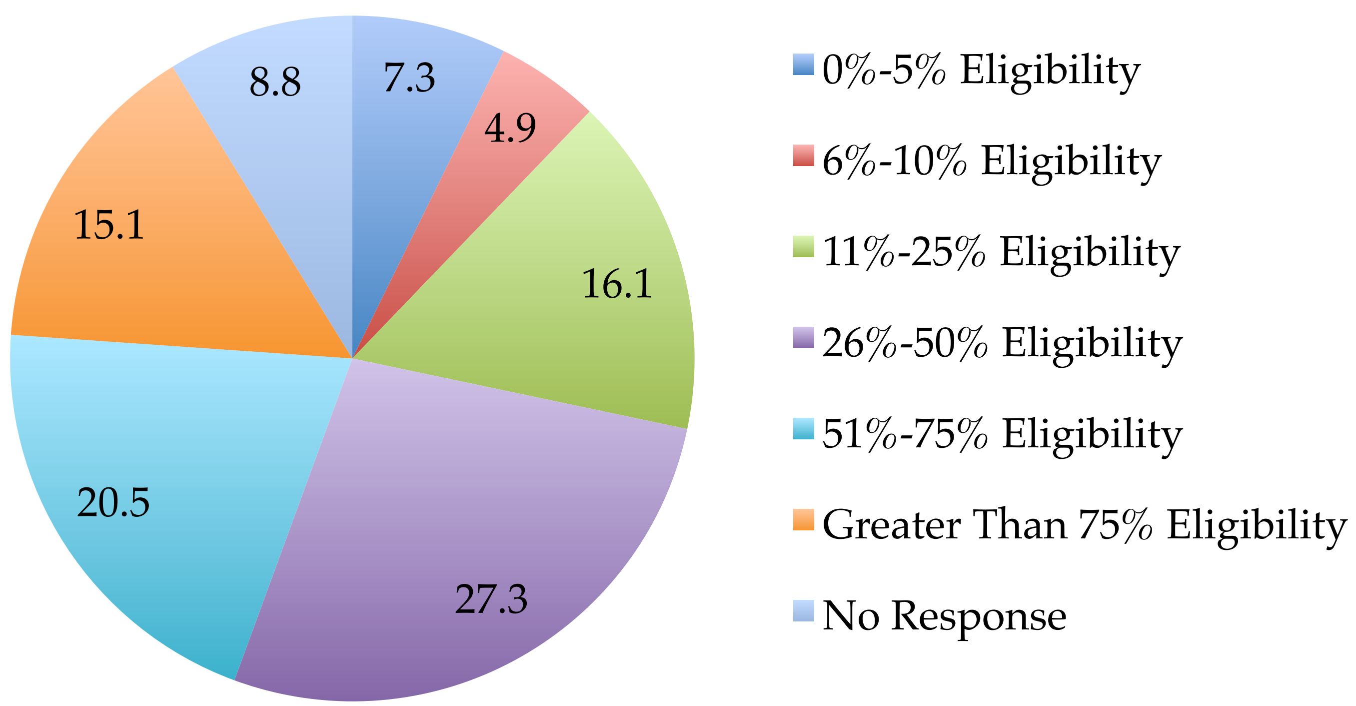


Figure 3.5. Percentage breakdown of eligibility for free and reduced priced meals.

as a descriptor of schools that chose the moniker. It appears that more science and mathematics courses than technology and engineering courses were typically offered annually. Another viable interpretation of these data on technology courses is that technology may be subsumed within courses as opposed to operating as uniquely named courses. It is obvious that more data are needed to define schools as STEM or STEM-focused based on the course disciplines or the number of courses within the disciplines, and to consider the size of the school population as a factor that can influence the number of available courses. It is also acknowledged that additional criteria or guidelines need to be developed to classify schools at STEM or STEM-focused schools (Lynch, 2008).

Format of the STEM High School Administrator Survey

The administrator survey consisted of 48 items subdivided into four sections. The first three sections were dedicated to closed-ended items about school practices: Professional Culture (14 items), Curricular and Instructional Practices (16 items), and Policies and Procedures (5 items). The next section, Description of Practices (4 items), included open-

Table 3.1

Percentage of Administrator Responses to Different Ranges of Courses Offered Each Year in the Four STEM Disciplines

Range of courses	Science	Technology	Engineering	Mathematics
Fewer than 10 courses	49.8	74.1	82.0	50.7
Between 10 and 20 courses	32.7	14.6	4.8	32.2
More than 20 courses	10.7	2.4	0.0	9.2
No response	6.8	8.8	12.7	7.8

ended response items about faculty development and program evaluation.

We asked administrators to rate the importance and/or frequency of each of the close-ended items on a 6-point response scale ranging from *unimportant* (1) to *essential* (6) including a *not applicable* option (see Table 3.2 for response options). Importance indicated the degree to which administrators perceived the practices were important, and *frequency* indicated how often the administrators perceived the practices were implemented.

Results of STEM High School Administrator Survey

The results of the first three sections of the STEM High School Administrator Survey with means equal to or greater than 5 are presented: Professional Culture, Curricular and Instructional Practices, and Policies and Procedures. To meet this criterion, administrators would have selected *very important* or *essential* as their response choice on the Importance Scale. Items that met this criterion are displayed in the figures with their corresponding ratings on the Frequency Scale. The mean importance ratings are the focus of this report; the frequency ratings are portrayed for the reader's information only. Commentary on the results and the implications for developing effective schools and recommended practices are offered for review and consideration by educators and policymakers, as the trend for creating STEM or STEM-focused high schools continues to gain considerable attention.

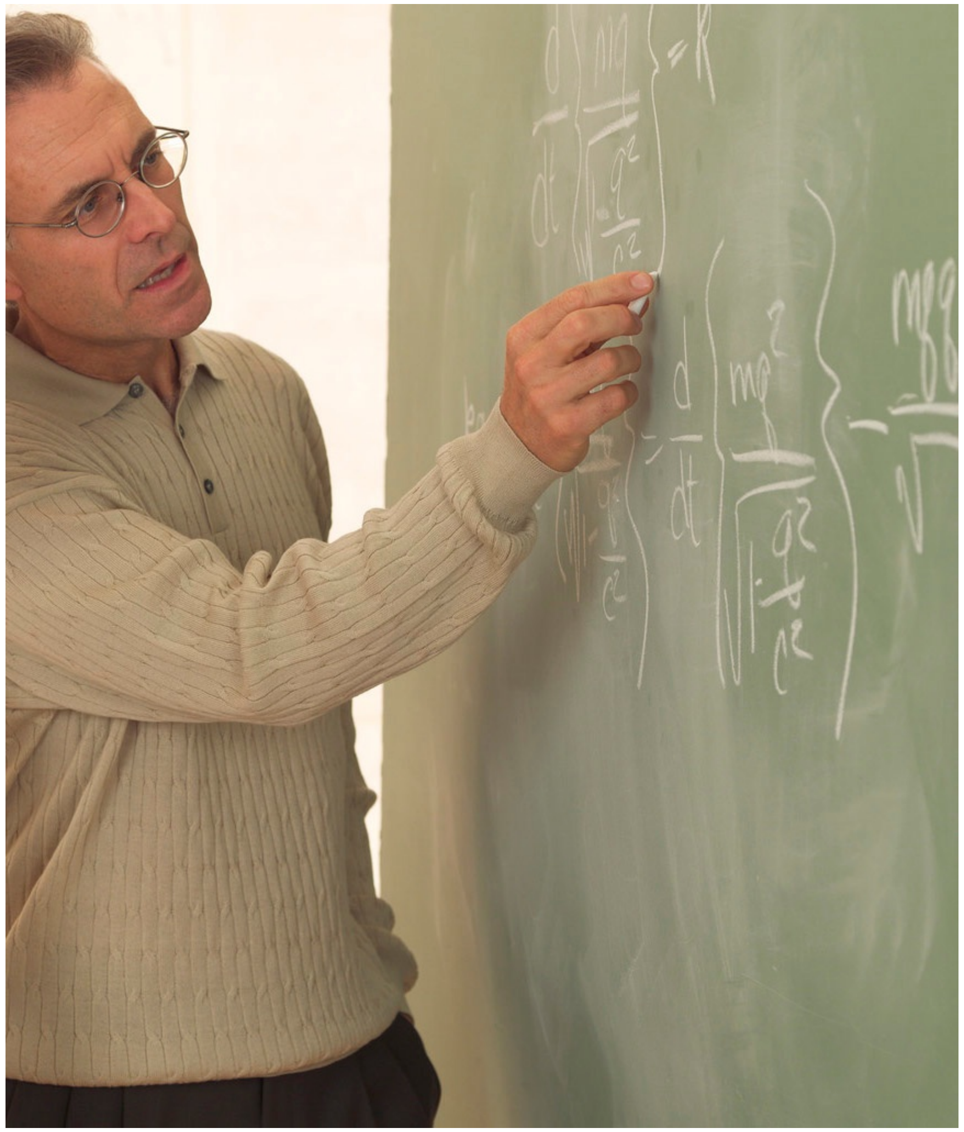
Table 3.2

Importance and Frequency Scales for Administrator Survey

Importance Scale	Frequency Scale
(1) Unimportant	(1) Never
(2) Not very important	(2) Once or twice a year
(3) Moderately important	(3) Once or twice a grading period
(4) Important	(4) Once or twice a month
(5) Very important	(5) At least once a week
(6) Essential	(6) Every day
(N/A) Not applicable	(N/A) Not Applicable

The Description of Practices section, allowed for analysis of open-ended responses as administrators explained their practices in more detail than specific item responses.

Section II: Professional Culture



Overview of Results

On average, STEM administrators rated 8 of the 14 items in the Professional Culture section of the survey as *very important* or *essential* (see Figure 3.6). Interested stakeholders might consider how implementing these practices at their STEM school can create a personally fulfilling and caring environment for teachers and students. Implications of the findings are provided in the areas of guidance and counseling services, student recruitment, and support for teachers.

Professional Culture: Implications for Practice

Guidance and Counseling Services

Providing students with guidance and counseling services to meet their academic and social-emotional needs, and with opportunities to take part in extra-curricular activities, were also perceived by the administrators as *very important*. These findings yield potential implications for addressing student needs.

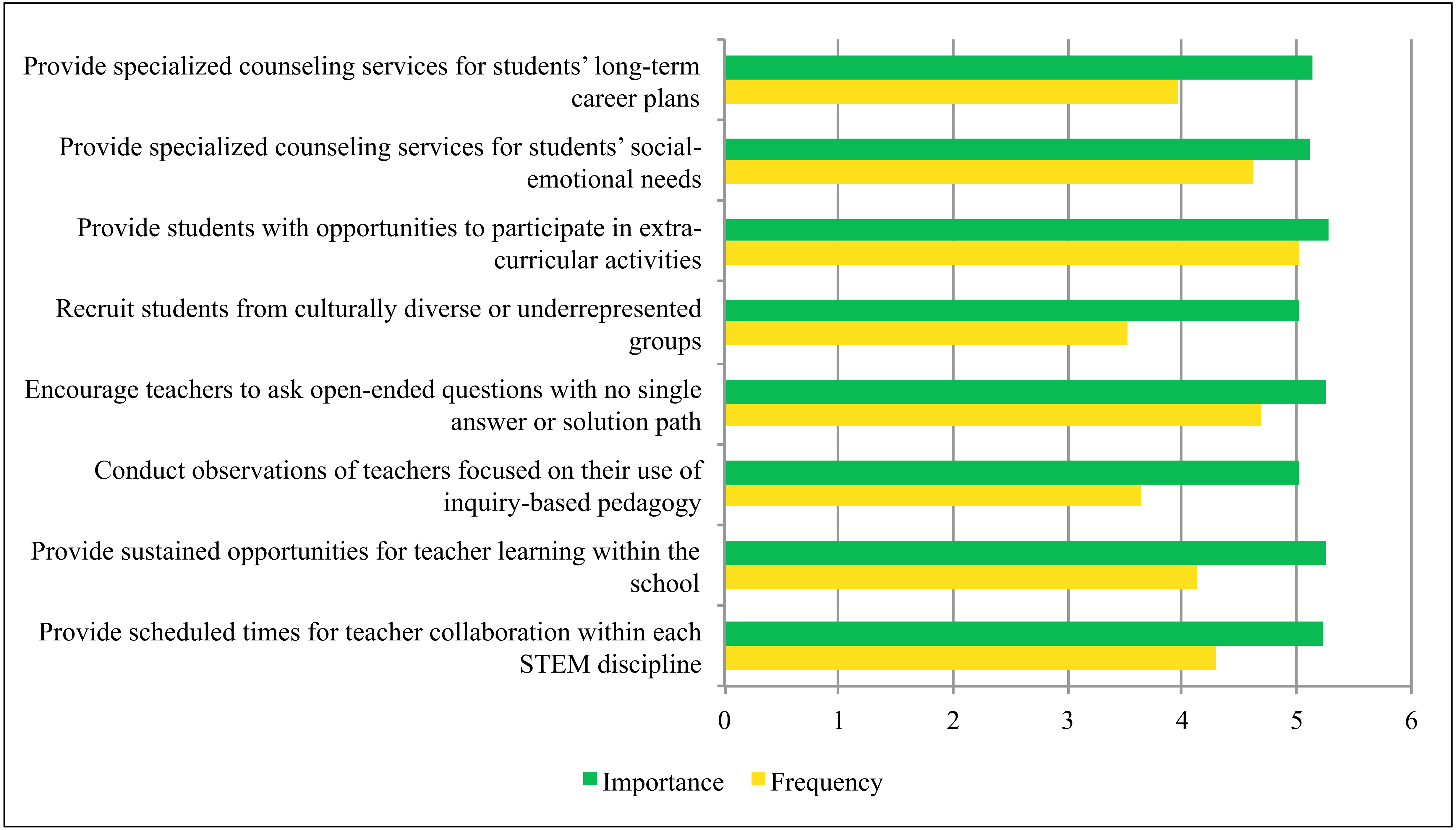
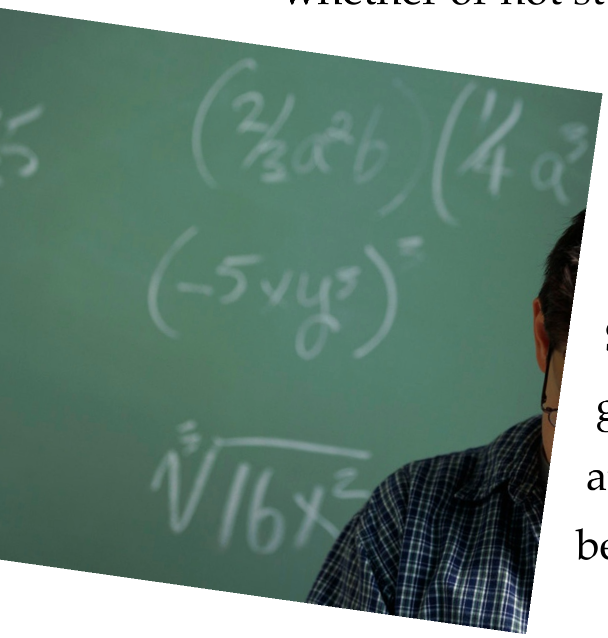


Figure 3.6. Administrators' mean importance and mean frequency ratings of Professional Culture items.

First, curriculum and instruction have a direct impact on student performance, but attending to students' affective needs are just as important and may have a positive, indirect impact (Bransford, Brown, & Cocking, 2013; Hamilton et al., 2009). High school students are in a developmental stage where they are grappling with external and internal pressures that influence their identity formation (Erikson, 1968). Offering counseling services for students' social-emotional needs can support their affective development, which can positively influence their performance in school, their relationships with others, and their overall well being.

Additionally, students who attend a STEM-focused program or school may have an interest in pursuing STEM-related majors in college and/or STEM-related careers thereafter (Subotnik, Tai, Rickoff, & Almarode, 2010). Regardless of whether or not students envision themselves pursuing STEM degrees, they should receive appropriate guidance services to help them plan for successful future college and career experiences. Setting short-term and long-term goals can help students learn to plan appropriately for their education beyond high school.



Extra-curricular Activities

Providing opportunities to participate in interest-based, extra-curricular activities outside of school time has the potential to develop affective qualities in students that might subsequently increase their motivation and feelings of personal success and well being (Yazzie-Mintz, 2010).

Student Recruitment

On average, STEM administrators who completed the survey valued recruiting students from culturally diverse or underrepresented groups. Efforts should be made to provide equal opportunities for all groups to receive the benefits of a STEM education. However, this certainly may be challenging if students from these groups do not have parental/guardian support to complete applications for enrollment. STEM administrators might consider offering open houses that feature the STEM school opportunities and provide guidance on the application process.

Support for Teachers

STEM high school administrators also rated a school culture supportive of teachers' professional development and students' affective and academic development as *very important* or *essential*. Providing teachers ongoing opportunities to learn within the school environment and time to collaborate with colleagues within each STEM discipline were most valued. Administrators believed it was *very important* to conduct classroom observations to examine teachers' use of inquiry practices, and to encourage use of strategies such as asking open-ended questions.

STEM administrators should strive to create an environment with a professional culture by providing sustained support for their teachers. Helping teachers strengthen their teaching practice through professional development and teacher collaboration can support their mission to provide a high quality educational experience for students (Guskey & Yoon, 2009). Administrators may accomplish this by offering quality professional development opportunities that align with teachers' interests and needs through workshops, webinars, and conferences; coaching and mentoring programs within the school known as job-embedded professional development (Croft, Coggshall, Dolan, Powers, & Killion, 2010; Fullan, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2005); and conducting informal and formal observations of their classroom teaching practice. Formal observations with a pre- and post-conference can support teachers' development by evaluating their practices throughout the cycle of teaching. For example, Danielson's Framework for Teaching (2013) presents 22 components clustered into four domains of the teacher's role: Planning and Preparation, The Classroom Environment, Instruction, and Professional Responsibilities. During these conferences and observations, STEM administrators may focus on evaluating teachers' implementation of open-ended questioning and inquiry-based pedagogy. Encouraging teachers to use these instructional strategies is a way for administrators to support the development of skills and qualities needed for innovative and creative thought and productivity.

Professional Culture Items of Interest: Overview of Results

Six of the 14 Professional Culture items were not rated *very important* or *essential* (5 and above):

- Communicate a STEM-specific vision of the school
- Provide scheduled times for teacher collaboration across STEM disciplines
- Provide scheduled times for teacher collaboration between STEM and non-STEM disciplines
- Promote change through faculty involvement in decision-making
- Allow teacher flexibility in modifying curriculum

- Require students to complete community service

Although administrators' mean ratings for this set of items did not meet the selected criterion for efficiency of reporting national administrator survey results, all items received mean ratings of at least 4 (*important*). These high ratings were expected as all items were purposely created to reflect best practice. The lowest mean rating of 4.41 was recorded for *Promote scheduled times for teacher collaboration between STEM and non-STEM discipline*. Foreman et al. (2013) report additional specifics of the administrator survey results.

We offer commentary on STEM-Specific School Vision, Teacher Collaboration, and Community Service as this set of items may be important considerations for persons interested in creating a STEM high school or modifying current practices.

Professional Culture Items of Interest: Implications for Practice

STEM-specific School Vision

Administrators rated a school vision as *important*. For some schools, vision and mission statements reflect the school's philosophy in response to questions such as the following: What are the goals and objectives of educating their students? What are the best methods for achieving these educational goals and objectives? Perhaps schools can operate successfully without a specific, codified vision; however, a written statement accompanied by a mission statement can offer a course of action for the schools' long-term goals and inform the public about the essence of what students are expected to accomplish throughout their educational experiences (Gabriel & Farmer, 2009).

Teacher Collaboration

Whether across STEM disciplines or between STEM and non-STEM disciplines, administrators viewed time for teacher collaboration as *important* as well. Establishing a professional culture within schools sets the stage for how administrators and teachers communicate and collaborate to create effective teaching and learning environments. Providing teachers time to collaborate during their school day, inviting faculty to become part of the decision-making process to create change, and allowing teachers to modify curriculum can provide teachers with an increased sense of autonomy, which can directly influence their level of engagement in their teaching, the quality of their teaching, and feelings of fulfillment with their profession (Darling-Hammond, Chung Wei, Andree, Richardson, & Orphanos, 2009).

Professional cultures within schools may be viewed as microcosms of the types of societies we envision for our students and for ourselves. As administrators, teachers, and students communicate and collaborate throughout the day to promote positive academic and affective outcomes, they recognize that there are opportunities within the regular and extended school day that are beneficial and rewarding. Expectations differ for teacher involvement in school community activities, such as collaborating with colleagues and assuming the role of active participant within a democratic institution.

Community Service

On average, administrators who completed the survey valued student participation in community service. Schools might consider offering students opportunities to acquire knowledge and skills by engaging in civic activities, such as community service (Billing, 2007; Vega, 2012). Some schools have community service projects for students as a graduation requirement. Different levels of civic engagement may exist at schools. For example, some schools that promote community service require students to seek opportunities on their own. Other schools that do provide opportunities may have after-school clubs where students can engage in collaborative projects or teachers create curricula that integrates service-learning components. The objective should be for students to develop personal characteristics and acquire skills that prepare them for assuming roles as leaders, innovators, and contributors to social capital (Renzulli, 2002, 2012; Renzulli, Koehler, & Fogarty, 2006; Renzulli, Sytsma, & Berman, 2002; Sytsma, Renzulli, & Berman, 2002). As an influential institution in our democratic society, schools provide structured opportunities for students to develop traits that will promote civic participation, such as empathy and compassion, and skills such as planning and evaluating service-oriented projects.

Section III: Curricular and Instructional Practices

Overview of Results

On average, STEM high school administrators rated 6 of the 16 items in the Curricular and Instructional Practices section of the survey as *very important* or *essential* (see Figure 3.7). Interested stakeholders might consider how implementing these practices at their STEM school can maximize students' learning. Commentary about enriched learning opportunities and evaluating student performance for implementation are presented.

Curricular and Instructional Practices: Implications for Practice

Enriched Learning Opportunities

STEM administrators' recognized the importance of providing students access to resources for research and projects and enriched learning opportunities. Providing basic resources to engage in STEM-related tasks was perceived as the most important curricular and instructional practice, while providing advanced resources, arts classes, and dual enrollment courses were seen as very important.

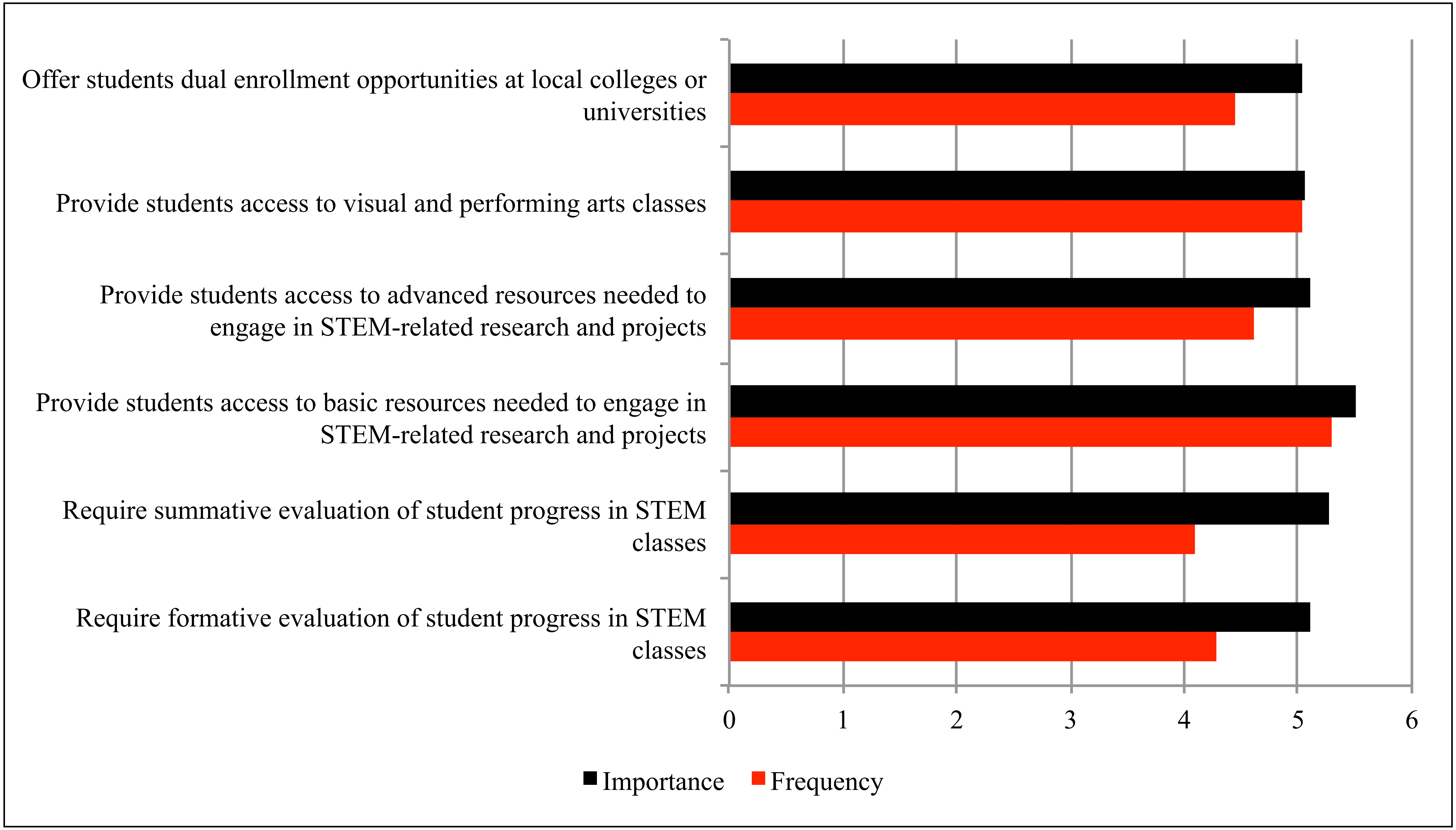


Figure 3.7. Administrators' mean importance and mean frequency ratings of Curricular and Instructional Practices items.

Providing access to enriched learning opportunities that develop students' intellectual and artistic abilities might support students' actualization of their gifts and talents. Dual enrollment opportunities provide an acceleration option for students, and arts classes can serve an academic or leisurely activity to support students' overall development. We acknowledge that issues such as economic disparities and geographic location of STEM schools across the U.S. influence access to opportunities and resources for students attending STEM programs. However, if administrators believe that engagement in STEM-related research projects and access to visual and performing arts classes should be an integral component of the curriculum, they should strive to provide these opportunities and resources on whatever level of service possible. To support enrichment endeavors, schools could consider creating an inventory list of individuals in the school or local community who might be interested in providing enrichment opportunities (e.g., Bagwell & Femc-Bagwell, 2012; Renzulli & Reis, 1997; Vega, 2012).

Evaluating Student Performance

Administrators believed it was *very important* or *essential* to gauge students' progress with formative and summative assessments as they pursued STEM-related research and projects. Assessing students' progress in STEM classes using standard (e.g., tests, reports, quizzes) and non-standard formats (e.g., projects, portfolios, demonstrations) can provide a holistic measure of students' achievement. These various formats can be used to summarize valuable performance feedback for administrators, teachers, students, and their families. Evaluation of student learning as an ongoing process has important implications for curricular and instructional planning and practice. For example, formative assessment can inform teachers on how to differentiate instruction and curriculum for students to promote continuous learning (e.g., Chappuis, S., & Chappuis, J., 2007/2008; Tomlinson, 2001; Wormeli, 2006).

Curricular and Instructional Practices Items of Interest: Overview of Results

Items that were not rated *very important* or *essential* (5 and above) for Curricular and Instructional Practices included:

- Require preassessment of student knowledge in STEM classes
- Require that the effectiveness of the specialized STEM program be internally assessed

- Require that the effectiveness of the specialized STEM program be externally evaluated
- Provide time for students to meet with research advisors
- Promote faculty-based research
- Provide students access to professional STEM journals
- Promote student involvement in national STEM competitions
- Promote student involvement in international STEM competitions
- Provide students opportunities to shadow professionals in STEM fields
- Provide students opportunities to complete internships in STEM fields

Though the above items were not rated as *very important* or *essential*, STEM administrators might consider the potential benefits of implementing and promoting these practices to develop learning communities that provide more comprehensive STEM experiences for students. While formative and summative assessment of students' knowledge in STEM classes was rated as *very important*, preassessment was not. Preassessment can be a strategy to maximize instructional time, whereby knowing students' current understandings and misconceptions, teachers can accordingly create learning experiences that will increase student outcomes.

Curricular and Instructional Practices Items of Interest: Implications for Practice

Evaluating STEM Programs

Internal and external evaluation of the specialized STEM programs schools are providing can guide future planning to develop effective learning communities—identifying which strategies and practices are effective and should continue, which should change, and which new ones should be considered for implementation. The administrators' recorded mean rating for external evaluation of the specialized STEM program was one of two items rated slightly below 4. Reasons for this rating may include lack of funding to conduct an external evaluation or reliance on other benchmarks such as results of accreditation reviews, performance on national or statewide assessments, or college acceptance rates.

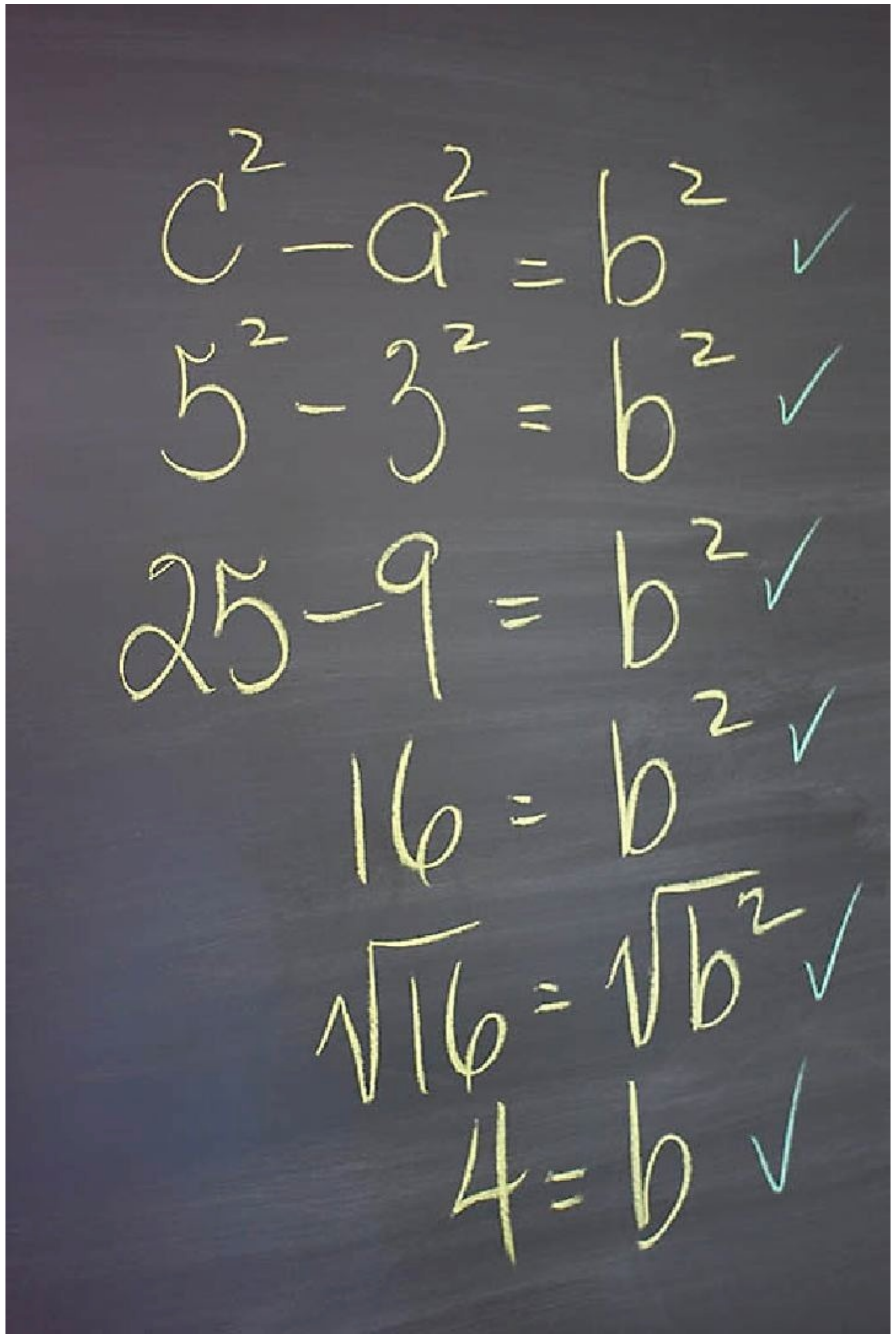
Access to Human and Material Resources

STEM schools might share a similar mission for nurturing students' talents in the STEM disciplines. To do this, they might consider implementing some of the practices that were not rated as *very important* or *essential*. For example, providing students with access to professional STEM journals and time to meet with research advisors might increase the probability that students will learn and apply research skills.

Student Competitions

Furthermore, promoting student involvement in national and international STEM competitions might be beneficial. The process of completing and presenting a project for real audiences can increase students' motivation, self-efficacy, and joy of research and creative productivity (Schneider, Krajcik, Marx, & Soloway, 2002). Learning alongside professionals in the STEM fields can expose students to potential college majors and careers, and equip them with not only the skills, but the emotional support to continue working toward their short and long-term academic goals.

Section IV: Policies and Procedures



Overview of Results

We asked STEM administrators to rate five items in the Policies and Procedures section for importance only. STEM administrators rated the following item as *very important* or *essential*: *Offer courses that integrate research skill development.* To promote student involvement in high quality STEM research projects, some schools provide single or multiple classes or courses to guide the development of research projects that might qualify for state or national competitions (e.g., Invention Convention, FIRST Robotics, Team America Rocketry Challenge, Google Science Fair, Siemens Competition, Intel Competition, or the DuPont Challenge: Science Essay Contest). Classes or formal courses allow students to gradually gain expertise in the design and development of research projects. Throughout the process, students work with their teachers or mentors with specific expertise and begin to experience what it is like to be practicing professionals at a junior level.

Policies and Procedures: Implications for Practice

Research skill development is a common learning goal listed in state and national standards. This standard is practical not only because research skills enable students to advance their knowledge beyond what is presented in the classroom, but can also prepare students for future research studies in college or their careers. To help students develop research skills, teachers in STEM disciplines can structure tasks with an integrated investigative component that requires students to identify and access resources to assist them with their research. The type of research methodology and skills taught should be dependent on the nature of the task and students' readiness levels; and further, should be developed within authentic contexts (Morrison, 2006; Vega, 2012).

Policies and Procedures Items of Interest: Overview of Results

The remaining items in the Policies and Procedures section were not rated *very important* or *essential* (5 and above), but *important* (at least 4):

- Hire teachers with an education degree concentration in a STEM discipline
- Hire teachers with alternative teaching certification
- Organize class schedules to allow for extended instructional time as needed
- Provide students with opportunities to obtain industry certificates

Commentary about teaching credentials, extending instructional time, and certificates for computer programs for implementation are presented.

Policies and Procedures Items of Interest: Implications for Practice

Teaching Credentials

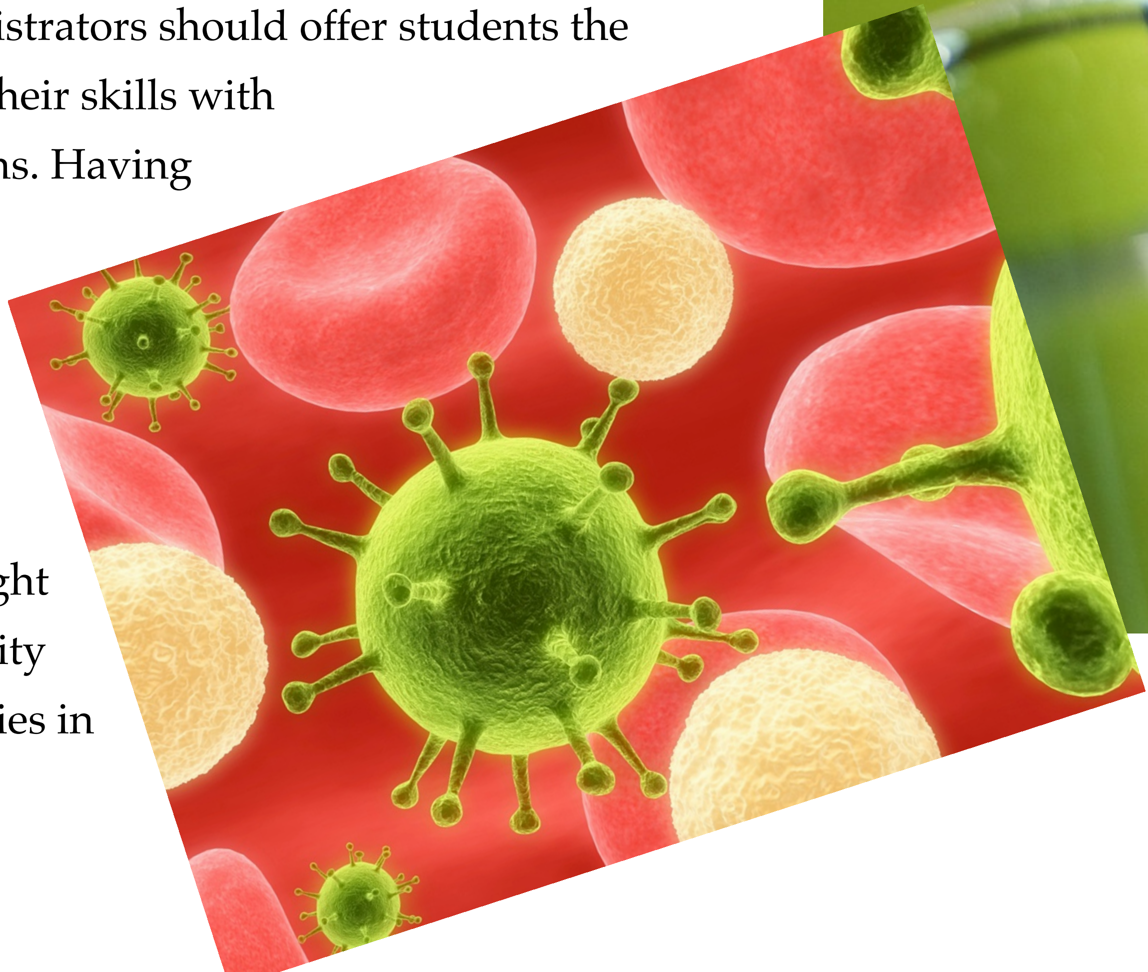
Administrators believed it was important to recruit faculty competent in teaching and learning practices. Teachers with degrees in education were preferred, such as those who had a specialization in a STEM discipline or who completed an alternative teaching program. Teachers candidates who have completed an education degree with a concentration in a STEM discipline may not only have an understanding of the pedagogy of teaching and learning, but also specific content knowledge in a STEM discipline. Therefore, they might be more suited for a teaching position at a STEM high school. Administrators may also consider teachers who have an alternative teaching certification as they may bring knowledge and skills acquired from other professions to benefit students in STEM high schools.

Extending Instructional Time

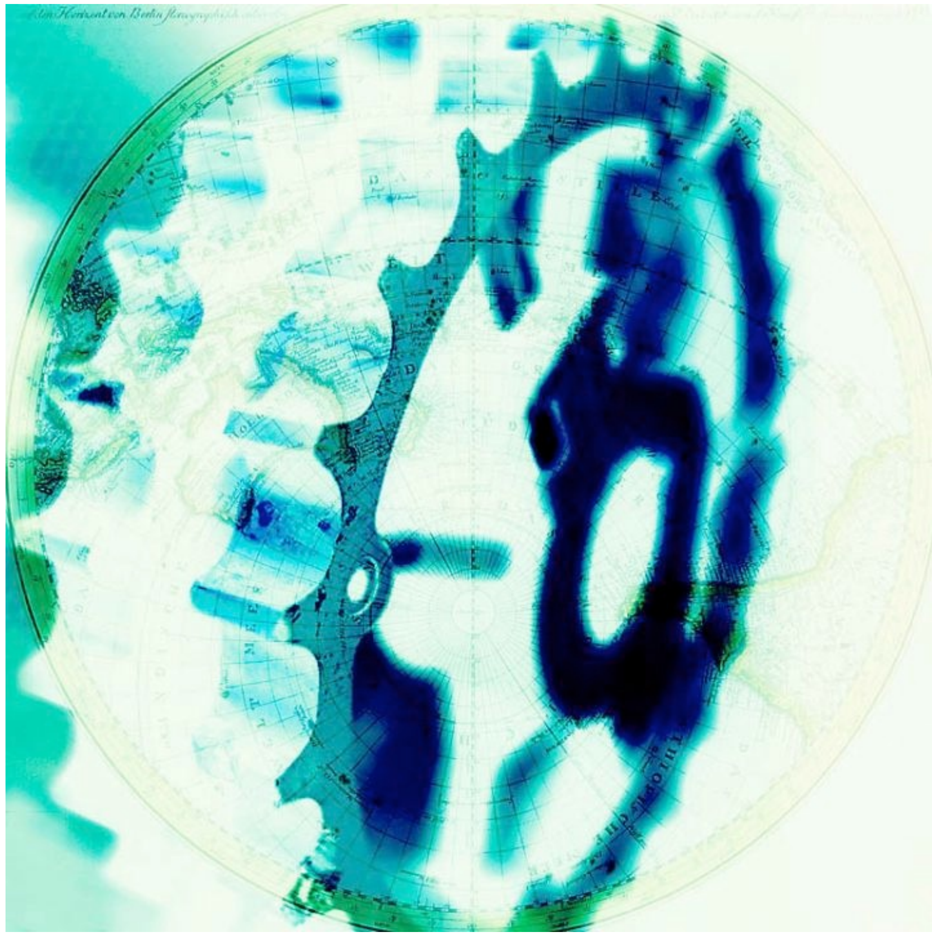
Administrators also recognized the importance of reorganizing class schedules to give students more time to work on classroom tasks with guidance from their teachers. Some students will require additional instructional support outside of class time. The purpose of extending instructional time might be to help students with class content and skills, to increase access to materials that are only available in class, or to collaborate with peers if they are unable to meet outside of school hours.

Certificates for Computer Programs

If possible, STEM administrators should offer students the opportunity to develop their skills with computer-based programs. Having computer software skills has the potential to increase the quality of work that students produce. Obtaining an industry certification might increase their marketability for future job opportunities in high school and after.



Section V: Description of Practices

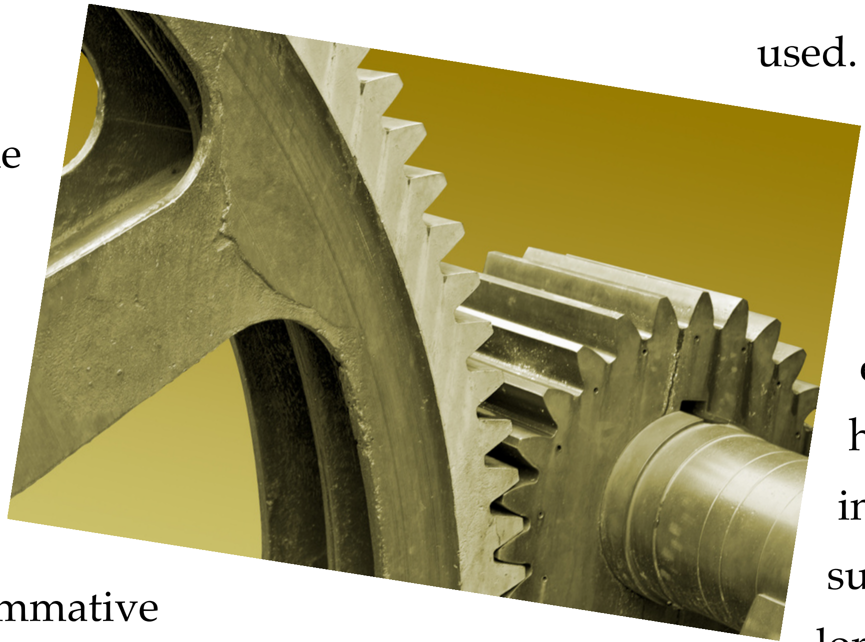


Overview of Results

STEM administrators responded to open-ended questions about developing the faculty at their schools and assessing the effectiveness of the STEM-focused services their schools provide. Administrators reported varying levels of teacher involvement with curriculum development. Some teachers chose to work on curriculum only during in-service sessions or occasional meetings, whereas other teachers sought to work with their colleagues on a weekly basis to develop curricula.

On the Policies and Procedures section of the administrator survey, two items were rated as important: *Hire teachers with an education degree concentration in a STEM Discipline and Hire teachers with alternative teaching certification.* With multiple university and college programs leading to teacher certification, alternative routes to certification, and specialized programs that permit college graduates to serve as teachers, options for securing highly qualified professionals are widely available. When hiring new teachers, many STEM administrators reported seeking candidates who were knowledgeable in their content area and who had earned an advanced degree in that area. Prior experience in the field was perceived highly desirable. Educational credentials and experience become important factors when projecting teacher effectiveness in their roles and responsibilities associated with STEM high schools.

Teacher effectiveness is often associated with student growth and development. As teachers are the main points of contact with students on a daily basis, their involvement with the curricula and the opportunities they create to engage students in learning opportunities have an ultimate impact on educational goals and objectives. Assessing the educational impact can be accomplished through formative and summative assessments.



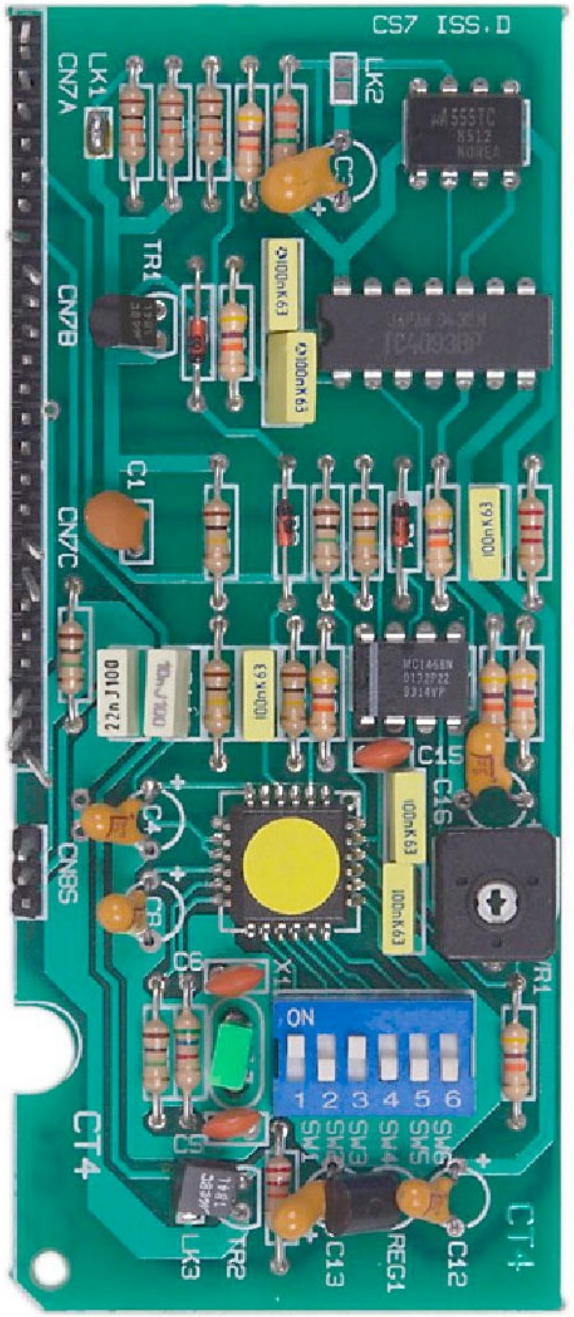
Administrators rated the importance and frequency of items related to formative and summative assessments on the close-end items under the survey section on Curricular and Instructional Practices, and they elaborated on their practices in their responses to an open-ended question. Typically, they relied on results on standardized tests such as the PSAT, SAT, ACT, and AP exams to assess the effectiveness of their curricula. Additionally, anecdotal and performance-based data from classroom and extra-curricular learning experiences were used to measure the overall effectiveness of their STEM programs.

Implications of Administrators' Description of Practices

Curricula can be adopted, adapted, or developed. Schools may make their curricular selections based on the their goals or objectives and the academic needs of their students. For some advanced courses, college texts and related resources are used. For other courses, teachers may choose to develop their own units and related activities.

These practices may be viewed as starting points for the comprehensive evaluation of the effectiveness of curricula and programs at STEM high schools. Other available data sources (e.g., informal and formal teacher evaluation data, parent surveys, community surveys, student surveys, longitudinal surveys, and student products) may guide revisions to current policies and procedures and curricular and instructional strategies and practices, and the development of new ones. In addition, the items from the STEM High School Administrator Survey may be used to determine the extent to which other educational options may be considered for implementation or adoption by administrators and teachers.

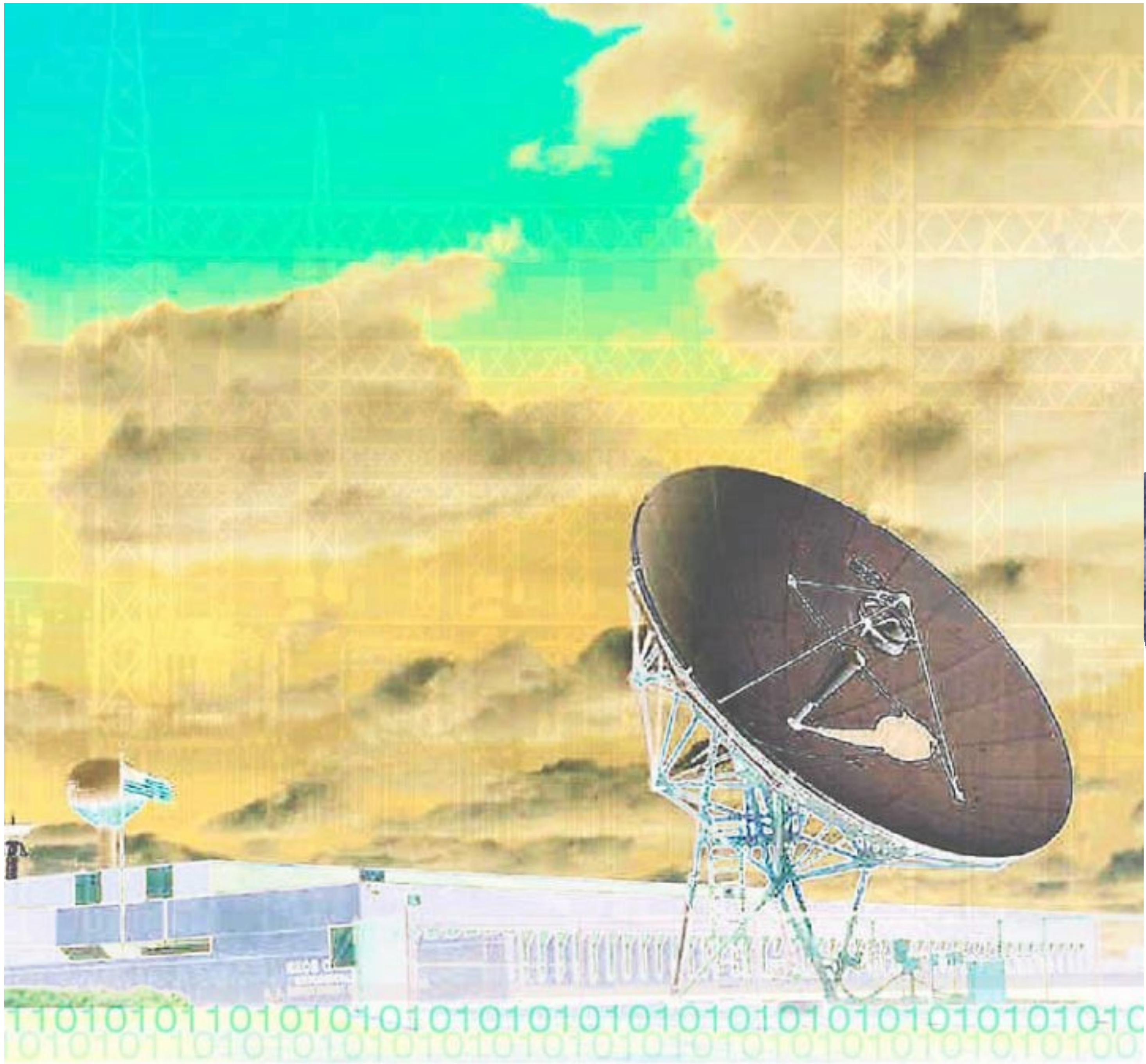
Summary



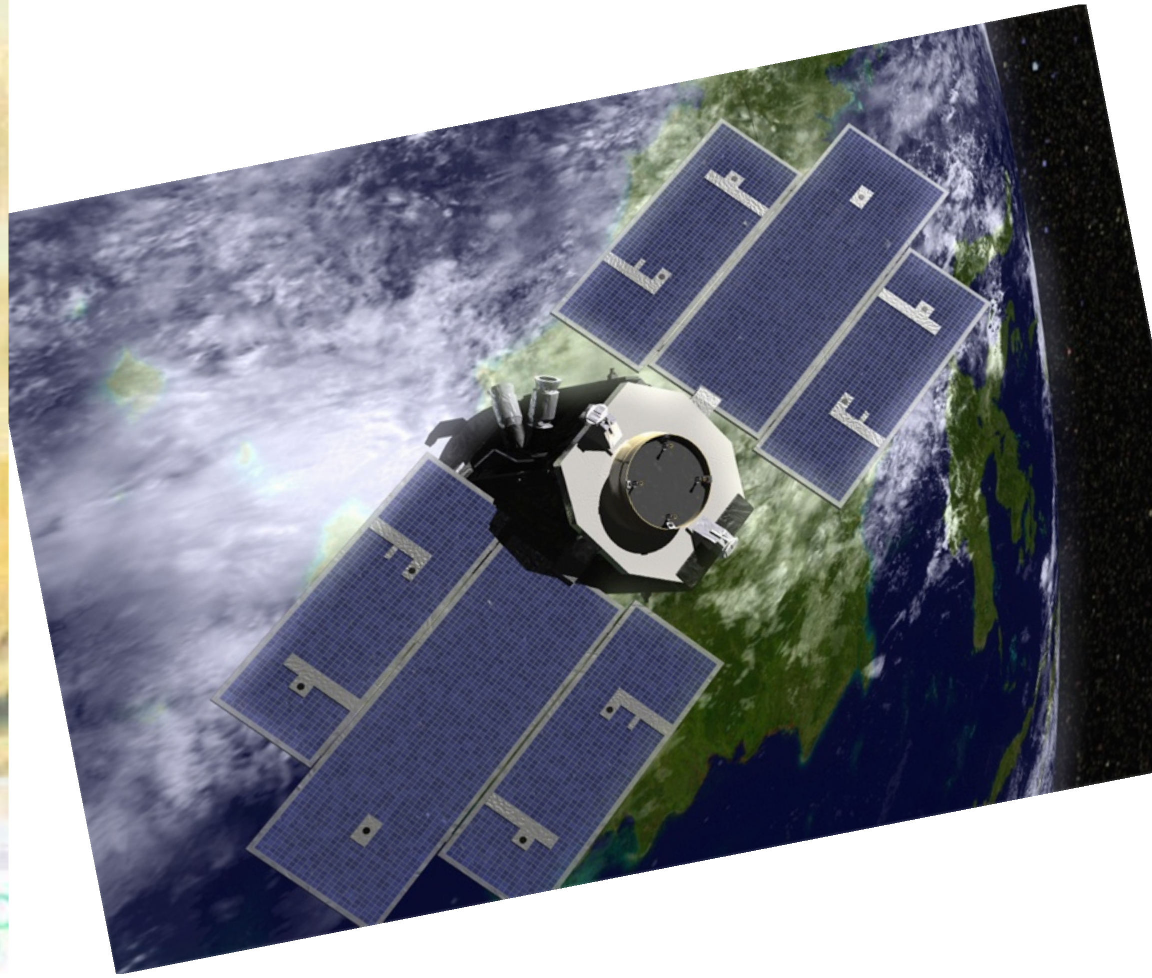
Currently, there is substantial interest in STEM high schools across the country. Television ads, books, newspaper articles, and journals quote scholars, practitioners, and the general public about the importance of science, technology, engineering, and mathematics. However, until now there have been few reports from people who are actually implementing STEM high schools. This section of the report presented a summary of data from 205 high school administrators from 31 states indicating the importance of specific items related to Professional Culture, Curricular and Instructional Practices, and Policies and Procedures. Administrators also described their practices relative to faculty's role in developing STEM goals and curricula, commented on teacher credentials to be considered in the hiring process, and addressed assessment techniques to determine the effectiveness of their STEM curricula and STEM programs.

All of the resulting data were highly skewed in terms of importance of each item. Therefore, we selected to share data from ratings of *very important* or *essential* and offered commentary on the various practices that may be considered as educators plan new STEM high schools or update current practices and policies. We also commented on items of interest that were rated *important* for reflection and discussion by educators and policymakers.

We recognize that these data from administrators are just a brief snapshot of what is actually occurring inside of STEM high schools today. Over 200 administrators completed the surveys; however, there are over 900 STEM schools that we identified across the country. Therefore, we consider the administrative data as a beginning of many conversations about pertinent practices and policies that may really define STEM schools of excellence in the future.



Next, we will present the teachers' perceptions. Once again, data from the importance scale will be profiled. However, the corresponding data from the frequency scale may also generate conversations among educators.



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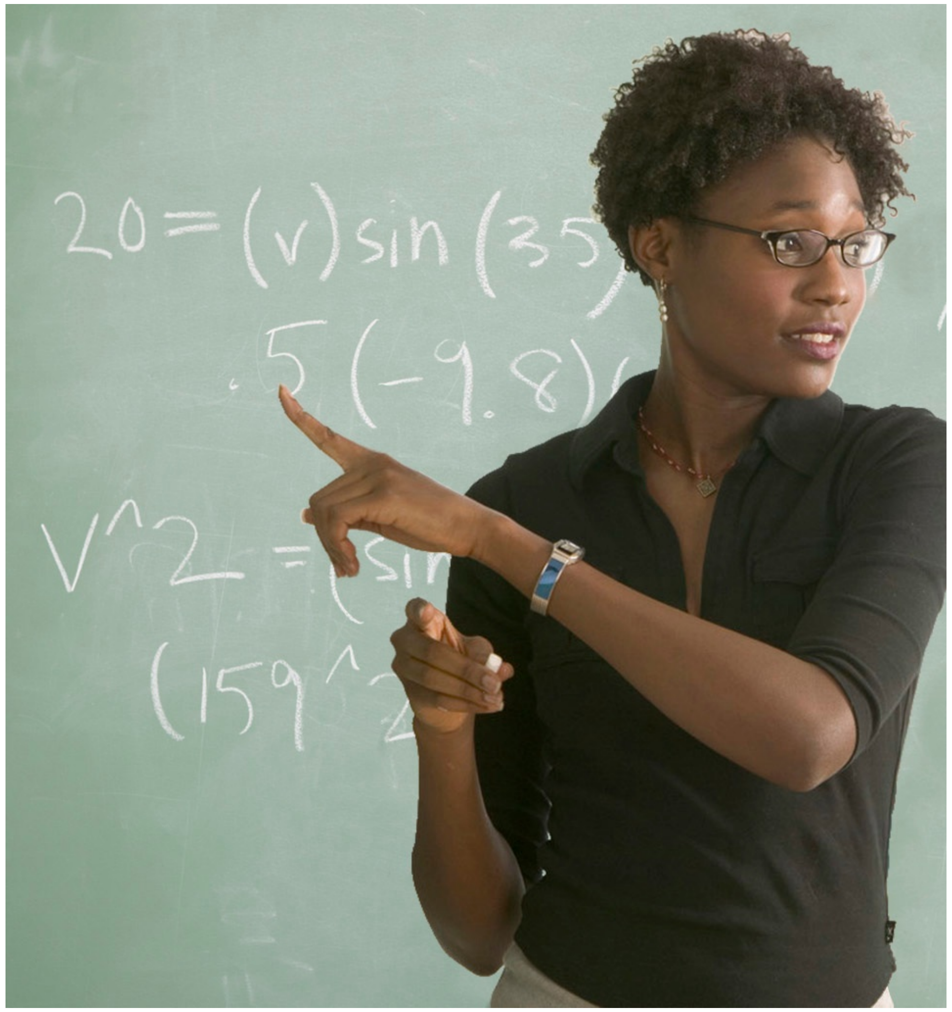
Chapter 4

STEM High School Teacher Survey

STEM High Schools: Teachers' Survey Results



We followed the same procedures described earlier on the development of the STEM Administrators' survey to create and disseminate a national survey of teachers' curricular and instructional strategies used in high schools classified as STEM or STEM-focused high schools. The goal of the study was to report on the state of STEM high schools and to offer commentary on sound educational practices that emerged from a review of literature and onsite observations, interviews, and focus groups. These practices may guide others who are interested in developing STEM high schools or who would like to reflect on their current approaches to educating high school students.

Geographic Distribution of Respondents

Figure 4.1 displays the geographic distribution of the 777 teacher respondents from 35 states and the District of Columbia. Teachers from Florida, Texas, and California returned over 50 surveys per state, which most likely reflects the number of current STEM schools in operation. Several teachers from Connecticut, New York, Virginia, North Carolina, Georgia, and Michigan completed the surveys as well. The perceptions on the current curricular and instructional practices from the STEM High School Survey represent a wide variety of respondents currently involved in schools with STEM-focused missions.

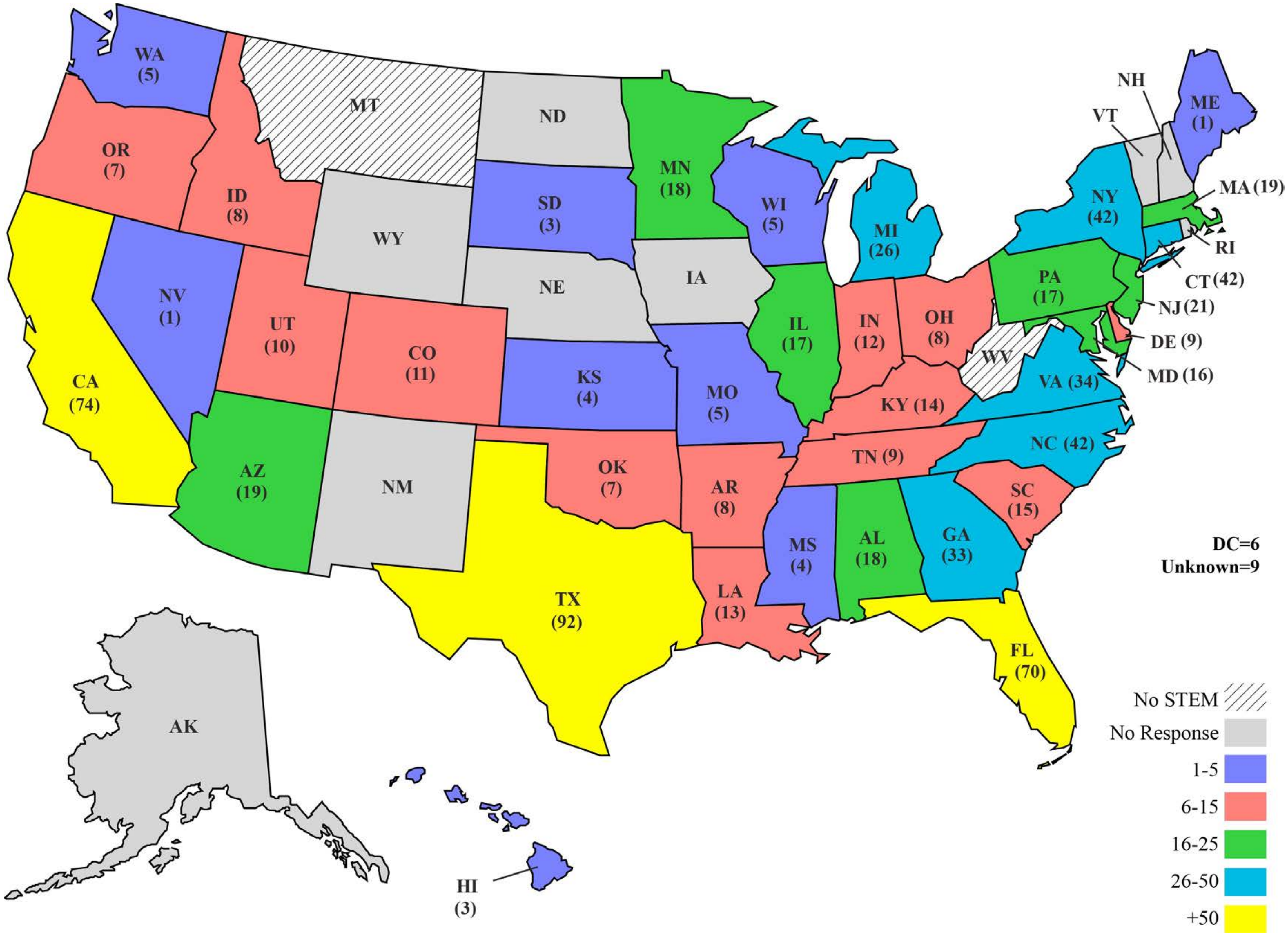
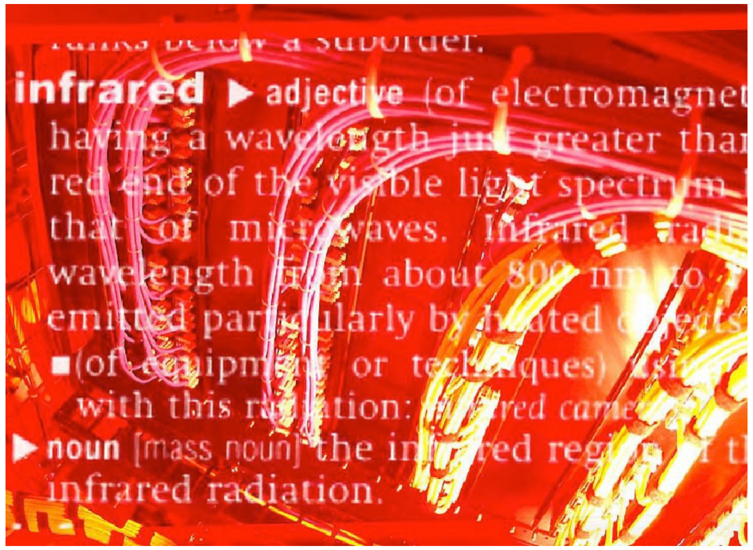


Figure 4.1. Geographic distribution of teacher respondents (*n*=777).

Format of the STEM High School Teacher Survey



The high school teacher survey consisted of 41 close-ended items subdivided into four sections: School Climate (9 items), Curricular Approaches (17 items), Instructional Strategies (11 items), and Learning Environment (4 items). The rating scales were similar to the administrator survey—the Importance Scale measured the degree to which STEM high school teachers perceived the strategies or practices were important, and the Frequency Scale measured the degree to which teachers perceived the strategies or practices were implemented. Data were available from 777 teachers. Table 4.1 presents the rating scale format.

Table 4.1

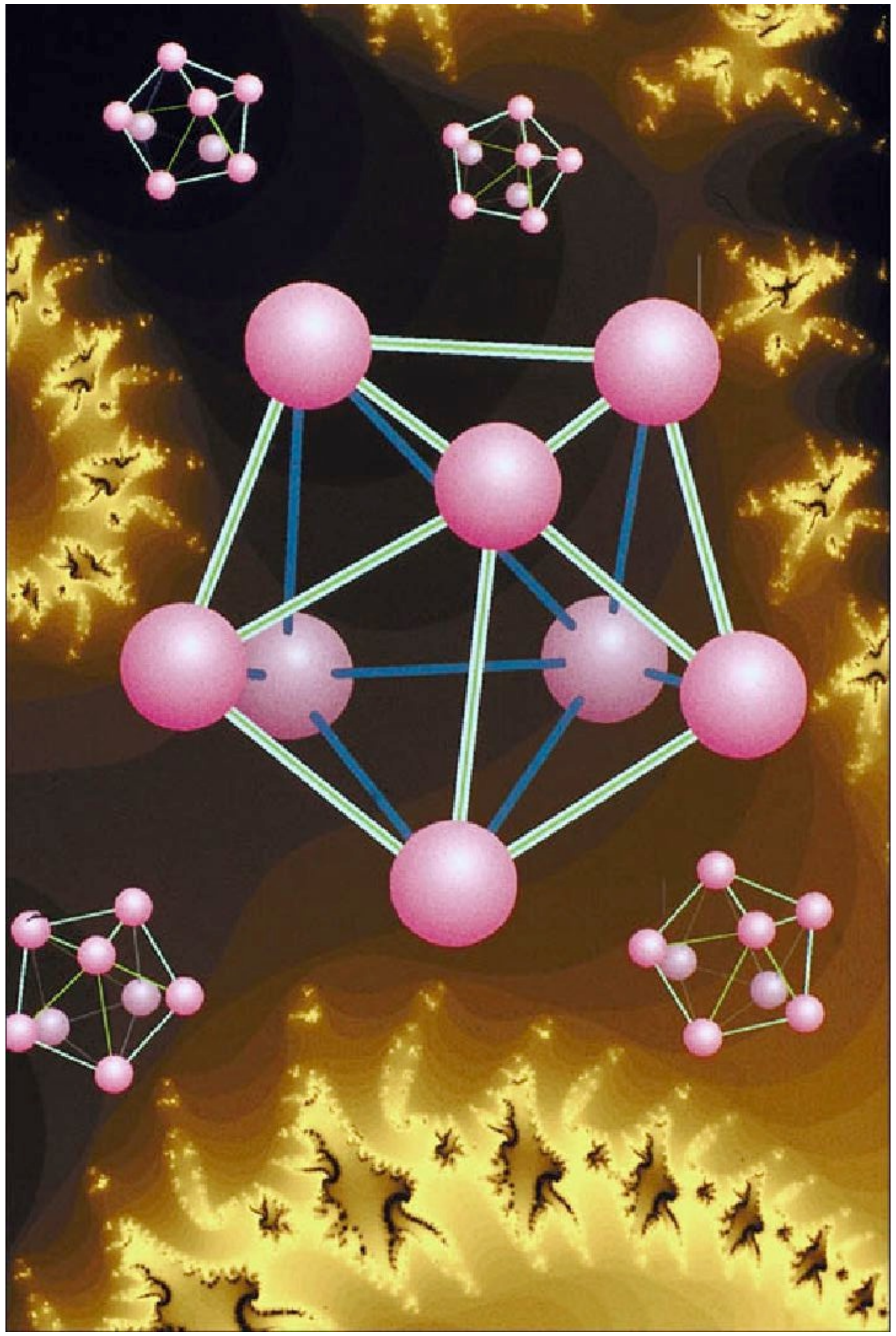
Importance and Frequency Scales for Teacher Survey

Importance Scale	Frequency Scale
(1) Unimportant	(1) Never
(2) Not very important	(2) Once or twice a year
(3) Moderately important	(3) Once or twice a grading period
(4) Important	(4) Once or twice a month
(5) Very important	(5) At least once a week
(6) Essential	(6) Every day
(N/A) Not applicable	(N/A) Not Applicable

Results of the STEM High School Teacher Survey

The results of the four sections of the STEM High School Teacher Survey with means equal to or greater than 5 are presented: School Climate, Curricular Approaches, Instructional Strategies, and Learning Environment. The teachers would have selected *very important* or *essential* as their response choice on the Importance Scale. Items that met this criterion are displayed in the tables with their corresponding ratings on the frequency scale. The frequency of the teachers' mean ratings is also displayed graphically for the reader's information only. It should be noted that although survey items received high ratings, the frequency ratings varied by design or by necessity due to specificity of strategies or practices. Foreman et al. (2013) report additional specifics of the teacher survey results.

Section I: School Climate



Overview of Results

On average, STEM teachers rated 5 of the 17 survey items in the School Climate section of the survey as *very important* or *essential* (see Figure 4.2). These items reflected responsiveness to students' academic and affective needs. Interested stakeholders might consider how implementing certain curricular approaches at their STEM school can facilitate students' optimal performance by building their self-concept and promoting responsibility. Implications of the findings are provided in the areas of application of student knowledge, positive reinforcement from adults in school community, offering students guidance and counseling, providing support for student readiness, and maintaining a professional environment.

School Climate: Implications for Practice

Positive Application of Student Knowledge

Teachers' ratings indicated that encouraging students to use their knowledge in positive ways was *very important* or *essential*. Creating learning experiences that will support successful current and future academic pursuits is important, as is helping students discover and realize their abilities. As their

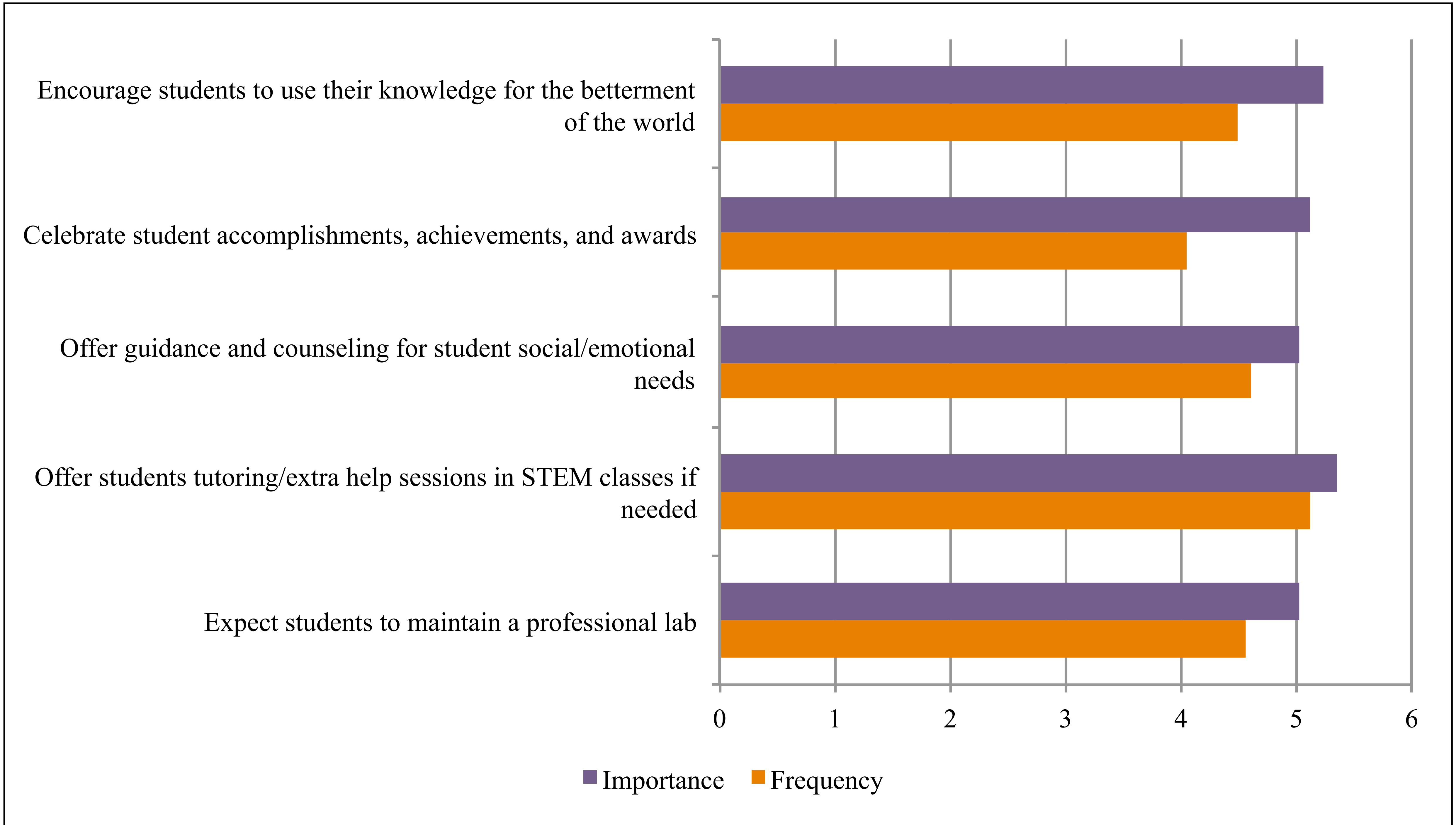


Figure 4.2. Teachers' mean importance and mean frequency ratings of School Climate items.

gifts and talents are realized, teachers can encourage students to apply their knowledge in positive ways such as improving the quality of life for others in the world (National Science Board, 2010) or pursuing personally meaningful careers or vocations.

Positive Reinforcement From Adults in School Community

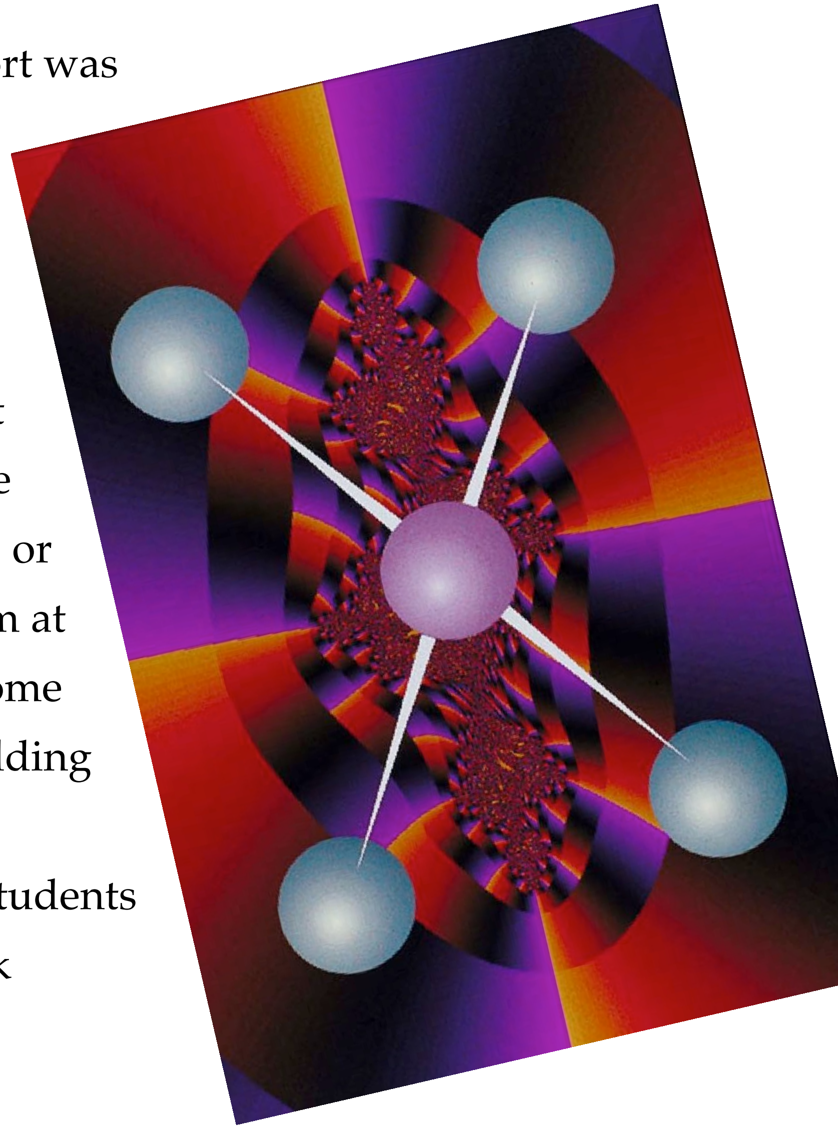
The teachers also perceived recognizing and celebrating students' accomplishments, achievements, and awards on average as *very important* or *essential*. Encouragement may be received in the form of positive reinforcement from teachers when students have achieved success that is personal or that has been recognized publicly. Celebrating students' accomplishments, achievements, and awards can increase self-efficacy and motivation, which can lead to future achievements. The act of recognizing students' work may create a sense of caring and belongingness.

Offering Students Guidance and Counseling

Teachers believed it was also *very important* or *essential* to attend to students' social-emotional needs by offering guidance and counseling services. Not all schools have guidance and counseling services for students; and, if services are available, the services might not be sufficient for some students. Educators have the responsibility to nurture students' social and emotional development in whatever capacity they are able. If formal services are unavailable, the school personnel should do their best to guide students and their families to outside resources. Guidance and counseling can have a positive indirect effect on students' academic performance and overall well being.

Providing Support for Students' Readiness

Offering academic support was rated highly by the teachers. STEM high school students may have varied readiness levels in different content areas, even if students are grouped by ability across or within classes. To perform at their highest potential, some students will need scaffolding beyond what is provided during classroom time. Students or their families may seek tutoring and assistance



independently, but if possible, teachers should provide the necessary academic support. And, if teachers are unable to offer extra support, they should try to seek academic support that will, at least, help their students achieve personal success in their classes, and at most, actualize their abilities to their highest potential.

Maintaining a Professional Environment

Promoting STEM talent development through high expectations was evident in other practices rated as *very important* or *essential* such as maintaining a professional lab. High school students attending STEM-focused programs may or may not enter college majors or careers in the STEM disciplines. Regardless, they should learn how to maintain a professional lab. Tasks completed in a lab setting require great attention to precision, sanitation, and safety. Engaging in these acts creates a sense of responsibility for respecting one's work environment, which may transfer to the respect for their work; and is reflective of a practicing STEM professional's duties.

School Climate Items of Interest: Overview of Results

Though 4 of the 9 items for the School Climate section were not rated *very important* or *essential* (5 and above), they were still rated *important* (4 and above but less than 5):

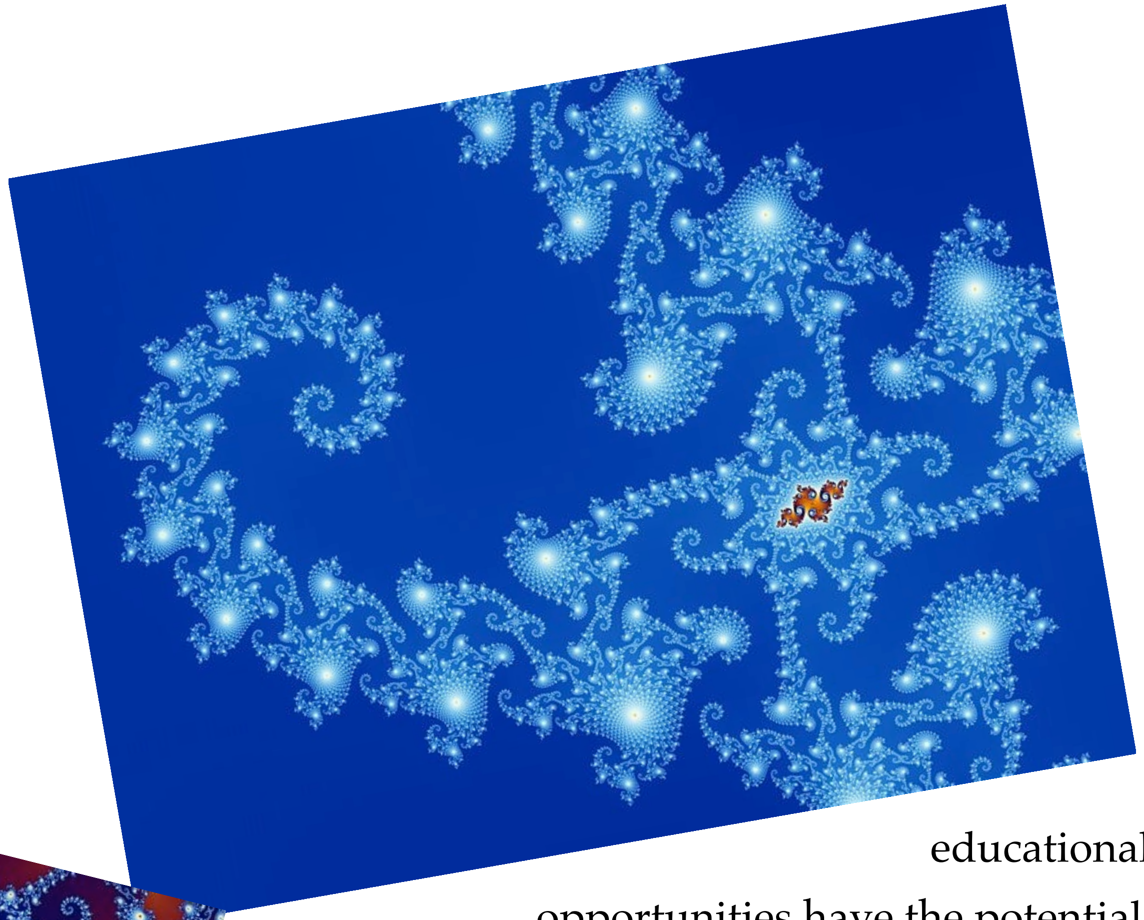
- Work to enhance and promote the reputation of excellence at your school
- Collaborate in STEM curriculum development
- Arrange collaborative projects for students with working professionals
- Offer students opportunities to meet with STEM professionals of various backgrounds

This set of items from the teacher survey has the potential to contribute to the development of an effective STEM high school. Therefore, we suggest that teachers strive to implement the above practices.

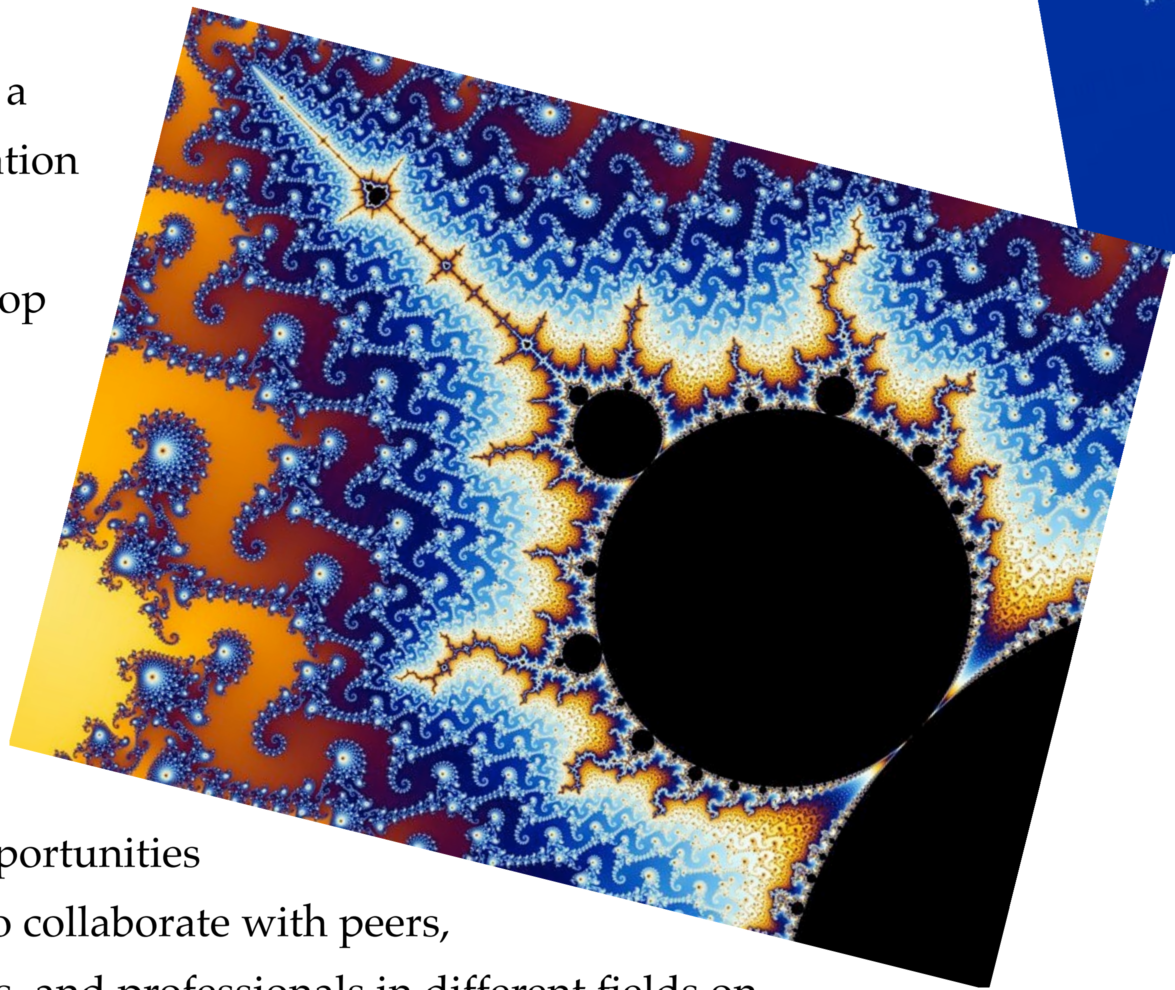
School Climate Items of Interest: Implications for Practice

Enhancing Reputation of School

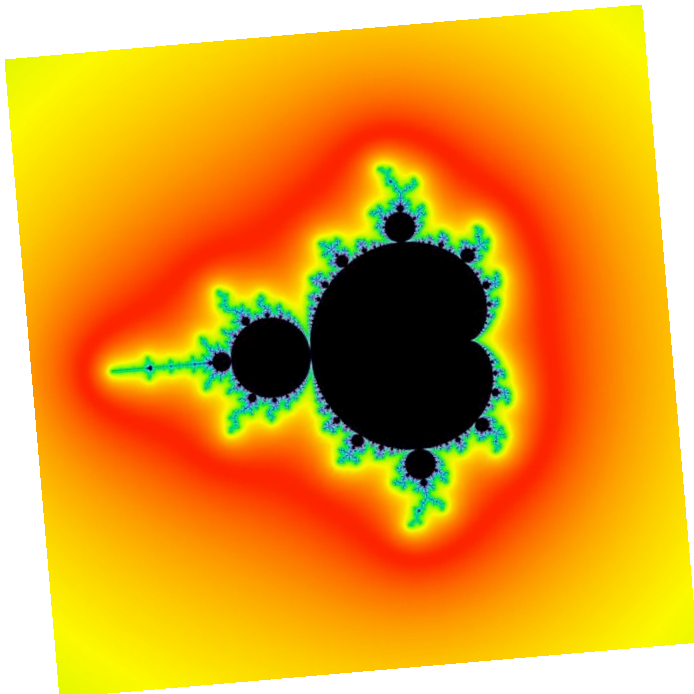
On average, STEM high school teachers did not perceive it was *very important*, but *important*, to enhance and promote the reputation of excellence at their schools. Making efforts to do so might attract more students and families to attend their school or draw attention for funding or investment in its development. Teachers can help develop the schools' reputation by inviting parents and community members to tour the school, observe in classrooms, attend presentations and performances, and participate in events. Collaborating with community organizations on a project and publicizing the outcomes of can help create a positive image in the community. Discussing schools' accomplishments and other positive features with others outside of the school can also serve to enhance the school's reputation.



Encouraging Collaboration



Teachers can foster a culture of collaboration by working with colleagues to develop STEM curriculum. School faculty members with varied experiences in the STEM fields can share their expertise, and help coordinate opportunities for their students to collaborate with peers, STEM professionals, and professionals in different fields on short-term and long-term tasks and projects. These enriched educational opportunities have the potential to influence students in meaningful ways, and may be perceived as a form of career guidance.



Section II: Curricular Approaches

Overview of Results

On average, STEM teachers rated 7 of the 17 items in the Curricular Approaches section of the survey as *very important* or *essential* (see Figure 4.3). Interested stakeholders might consider how implementing these curricular approaches at their STEM school can support students' learning and preparation for future college experiences. We offer commentary on teaching research and academic writing skills, creating authentic learning experiences, and modifying curriculum for students' readiness.

Curricular Approaches: Implications for Practice

Teaching Research and Academic Writing Skills

Teachers rated research and academic writing skills *very important* or *essential*. Given that research skills should be taught in primary school and middle school, beginning high school students should be able to demonstrate at least proficient levels of performance (Cotton, 1991). During the high school years, it is imperative that teachers in different courses teach the necessary skills to prepare students to engage in research in any discipline, then and in college. Teaching research skills through didactic teaching methods can be informative

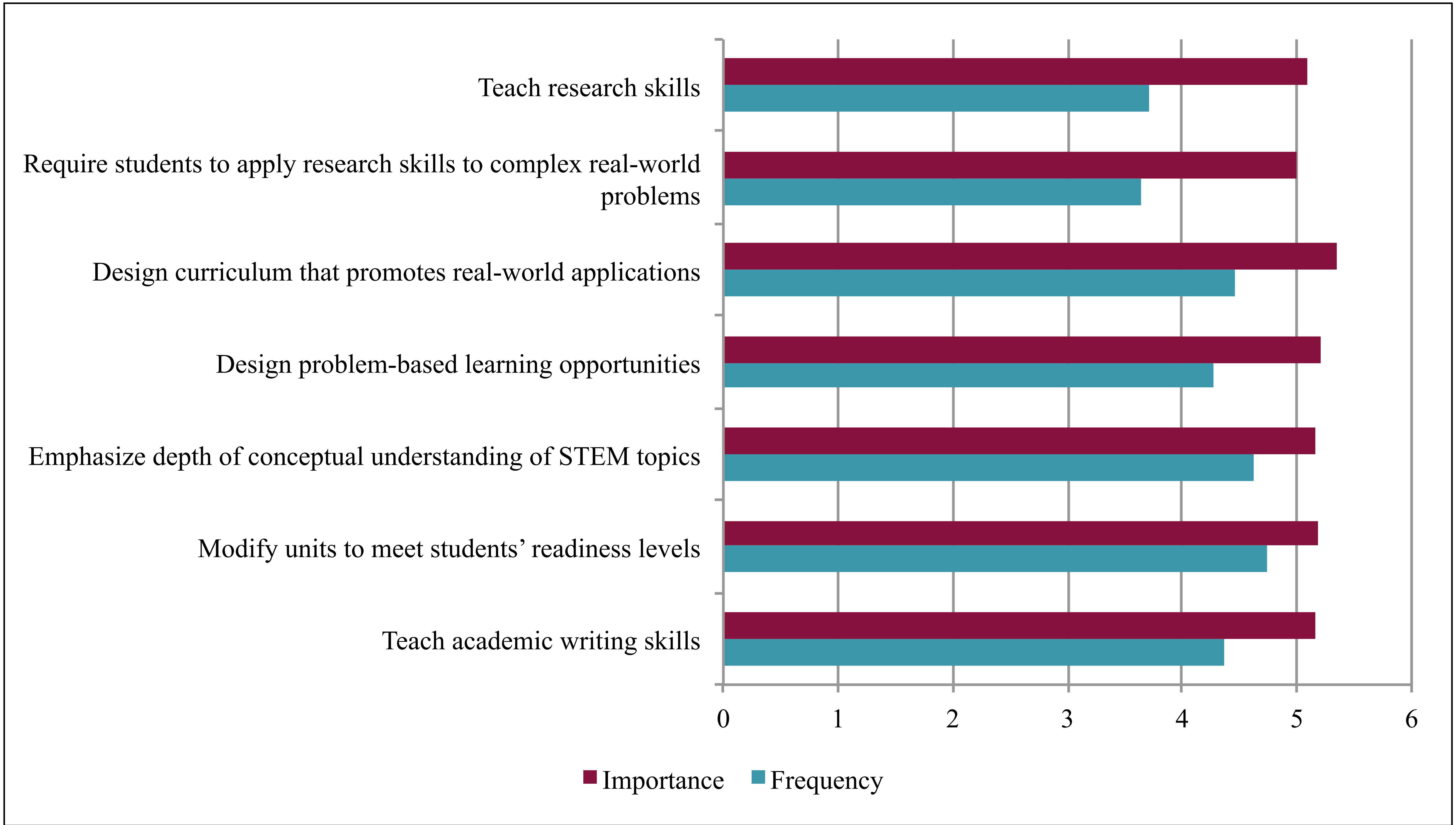


Figure 4.3. Teachers' mean importance and mean frequency ratings of Curricular Approaches items.

and serve as introduction to learning specific skills, but should also be supplemented with application of those skills in real-world scenarios where students solve complex problems.

As significant, if not more significant, as teaching research skills, is the teaching of academic writing skills. As stated in the Common Core State Standards, it is expected that all teachers teach academic writing skills (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Communicating understanding of academic content through writing is a skill that students need for successful experiences in high school and in all fields studied in higher education. For students interested in pursuing STEM majors, it is particularly important for teachers to teach students how to prepare scientific lab reports and findings from research for presentation for targeted audiences. Special attention must be devoted to supporting students who are English-language learners, who will require additional scaffolding with vocabulary and grammar.

Creating Authentic Learning Experiences

STEM high school teachers perceived it was *very important* or *essential* to engage students in practical and problem-based learning experiences. Most important was designing curricular experiences that would promote such engagement.

STEM high school teachers can teach research skills and writing skills simultaneously by designing curricular experiences that require students to apply knowledge and skills to complete real-world and problem-based tasks. Students' involvement in authentic tasks can help them acquire 21st century skills (cf. Learning and Innovation Skills; Information, Media, and Technology Skills), which are beneficial across disciplines; and, learning within real-world contexts can create meaningful and engaging learning experiences that might lead to students' increased motivation. Furthermore, as teachers create these authentic experiences, they need to remain mindful of students' current knowledge and abilities. To assess for readiness, they might first give students a diagnostic assessment and then guide students to higher levels of understanding and levels of performance beyond what they were previously able to accomplish. Differentiating for students by creating or modifying curricula to meet students' readiness, interests, and learning styles can also contribute to a satisfying learning experience for students where they are working at their optimal potential.

Modifying Curriculum for Students' Readiness

Other practices viewed as *very important* or *essential* included creating differentiated learning opportunities by modifying curriculum to match students' readiness levels. Modifying curriculum to meet students' readiness levels and learning profiles is a practice that STEM high school teachers can implement to promote engaging and appropriately challenging learning experiences. Diagnostic assessment might guide teachers in compacting the curriculum so that students are not repeating content and skills, and awareness of students' interests might inform further modifications.

Moreover, as teachers introduce students to concepts in STEM and non-STEM disciplines, depth of understanding should be emphasized over breadth. Conceptual knowledge will support students in understanding the "big picture," instead of disparate facts (Vega, 2012). Emphasizing the significance of learning about STEM topics in depth is a way of teaching students what it means to develop expertise in an area.

Curricular Approaches Items of Interest: Overview of Results

n of the 17 items were not rated *very important* or *essential* (5 and above) for the Curricular Approaches section. Of the 10, 9 were rated as *important* (4 and above but less than 5) and 1 was rated as *moderately important* (3 and above but less than 4): *Modify preexisting challenging and advanced STEM units of study.*

- Adopt preexisting challenging and advanced STEM units of study without making modifications
- Modify preexisting challenging and advanced STEM units of study
- Create challenging and advanced STEM units of study
- Model making connections across and within STEM disciplines
- Integrate controversial and/or timely STEM topics into class content
- Encourage students to select STEM research topics
- Provide an opportunity for students to design and complete self-selected research project(s)
- Encourage students to present products to authentic audiences
- Provide explicit lessons to teach students to take notes effectively

- Provide direct instruction to students on time management skills

Curricular Approaches Items of Interest: Implications for Practice

Tailoring Curricular Units for Students

Acknowledging the uniqueness of the individual, we recognize that students' needs vary depending on their readiness levels, interests, and learning styles. The demographics of the student population and available resources are other factors that will inform teachers' decisions in creating curricular opportunities for students. Teacher autonomy for carrying out this responsibility will vary, considering different school districts and schools will have different guidelines and expectations with regards to curriculum. For example, some schools may require teachers to use specific curriculum, while others encourage teachers to modify and create their own. Other schools might offer teachers complete autonomy in selecting the curriculum.

As the results of the Teacher Survey indicate the importance of challenging curricula, current and future, STEM high school teachers should commit to adopting, adapting, or creating challenging curricular experiences that will meet their students' needs. An important initial step would be to review what challenging STEM curriculum exists. Teachers may determine that their curriculum is well suited for their current population requiring minor modifications to the existing curricula. Next, teachers should decide how the curricula might be implemented with their students. Does it need to be changed so that it provides more differentiated learning opportunities for their students? Does it need to be adapted to incorporate more of the state standards? Does the rigor of the curriculum need to be enhanced?

Teachers should capitalize on own their strengths and abilities when deciding how they will modify preexisting curricula. For example, some teachers may have a developed base of content knowledge for a specific topic, they might add to the depth of content presented in the curricula. Some teachers may decide that they need to, or prefer to, create new curriculum to provide students with increased challenge, depth, and creative opportunities. Other teachers may be comfortable modifying curricula to allow for integrative arts and social justice experiences. Teachers should also exercise their knowledge, skills, and creativity to create unique curricula that will facilitate quality and memorable learning experience for their students (Members of the 2005 Rising Above the Gathering Storm Committee (2010).

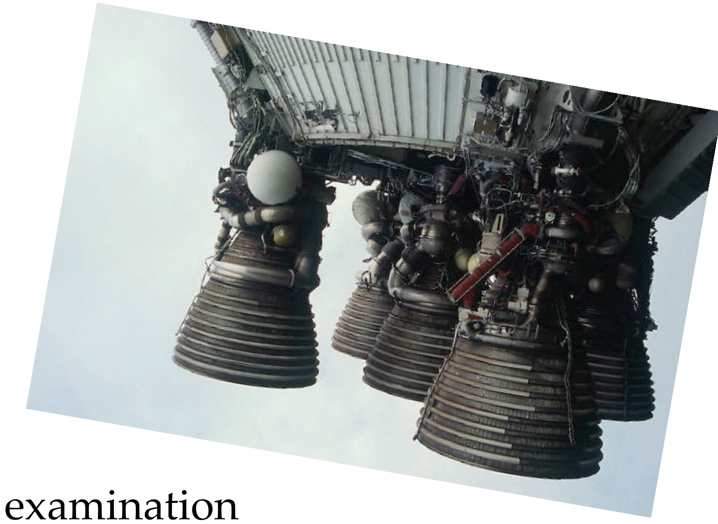
Teaching Skills for Success

Both implicit and explicit knowledge is integral to student success such as thinking skills that support interdisciplinary thinking and executive functioning. Creating curriculum that is interdisciplinary in nature can support students in making connections as it fosters creative and innovative thought, and deepens understanding of content (Cotton, 1991). Teachers should also model how to make connections across and within STEM disciplines. Developing executive functioning skills will also support students' optimal academic performance. Teachers should provide students with direct instruction for developing effective organizational skills, note-taking skills, and time-management skills within the context of a curricular unit. This knowledge will serve them in their high school and college years when their responsibilities and demands on time increase.

Providing Opportunities to Pursue Independent Projects

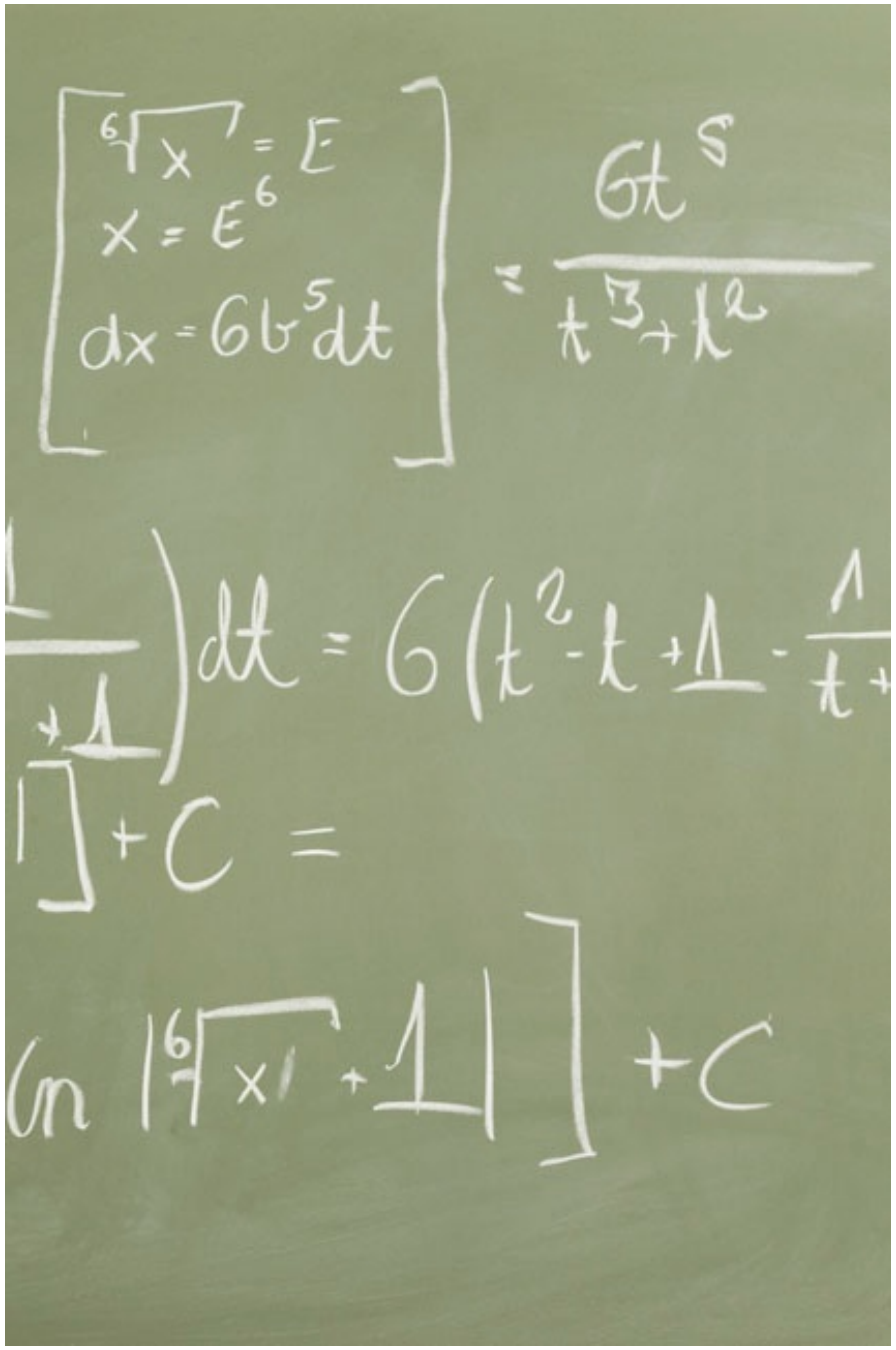
Implementing a philosophy of differentiation includes creating spaces for students to pursue special topics of interest. When students engage in tasks that they are interested in and that offer choice, motivation and learning outcomes are likely to increase. Teachers rated self-selected research opportunities for students as *important*; therefore, others may consider creating curricular options for students to engage in self-selected STEM projects (Schneider, Krajcik, Marx, & Soloway, 2002). Providing opportunities may not be enough to inspire or motivate students; encouragement on the part of adults might be necessary. Additionally, we suggest that projects include a presentation component in which students share their work with selected audiences. This is an important part of the project experience as students reflect on the research and product-development process and realize how their work has the potential to influence others.

Studying Controversial and/or Current Events



Teachers may consider creating curricular opportunities where students examine controversial and / or current events in the STEM disciplines. Their critical examination will not only provide a justification for studying specific topics and learning specific skills to address these issues now and in the future, but also help them realize the importance of examining how past events came to bear upon current ones. Teachers can integrate these experiences into class content or schedule separate tasks or separate time for discussion.

Section III: Instructional Strategies



Overview of Results

Overall, STEM teachers believed it was *very important* or *essential* to implement instructional strategies to support students' learning, rating 10 of the 11 items in the Instructional Strategies section as *very important* or *essential* (see Figure 4.4). The most important practice was to encourage student questioning. Other items that STEM teachers rated as very important included those that integrated questioning techniques to promote creative and higher level thinking, student collaboration, and reflection.

STEM high school teachers reported characteristics of an environment that could be described as dynamic and engaging. Moving beyond an instructional style where the right answer is the most valued, it appeared that STEM teachers promoted a culture of inquiry with hands-on learning approaches and justification of thinking—emphasizing the development of skills, behaviors, and habits of mind needed to be successful in collegiate and professional STEM careers.

Implementing these curricular approaches at STEM schools might help students develop skills, attitudes, and habits of mind that will prepare them for successful STEM endeavors in college and after. We offer commentary on

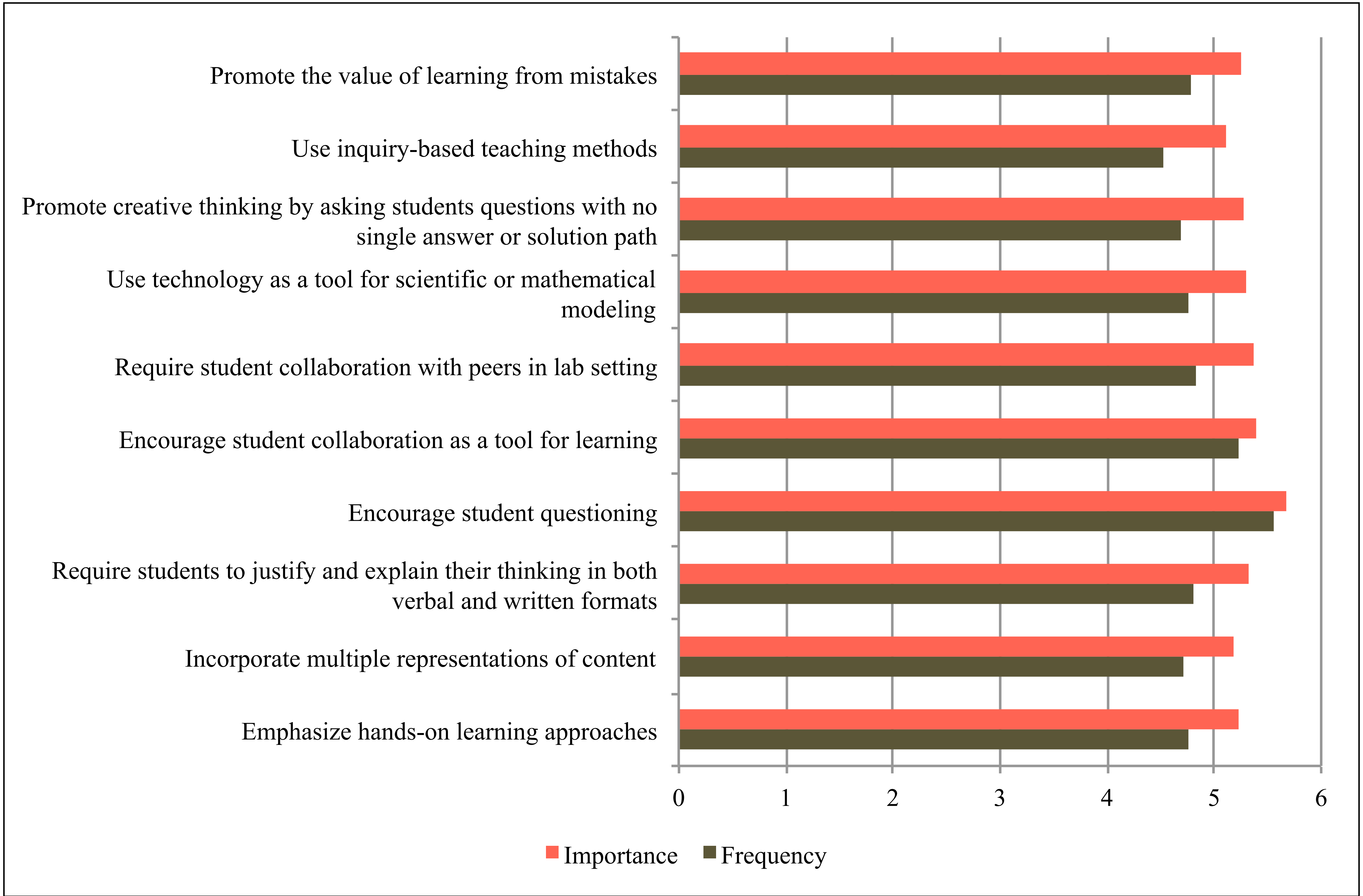


Figure 4.4. Teachers' mean importance and mean frequency ratings of Instructional Strategies items.

items related to Instructional Strategies teachers rated as *very important* or *essential*.

Instructional Strategies: Implications for Practice

Promoting Scientific Thinking

To effectively teach content, it might be beneficial for teachers to reflect on the personal characteristics they wish to develop in STEM high school students. What attitudes and habits of mind will promote scientific, innovative, and creative thinking? Curricula can support such thinking, as can the instructional strategies used to teach the curricula. Inquiry-based teaching methods that teach content within the context of problems and scenarios can help students develop the skills needed for approaching and engaging in work like practicing STEM professionals.

Teachers can also develop students' scientific thinking skills by applying questioning techniques, such as creating questions for students to respond to and encouraging them to develop their own questions. Posing questions that challenge students' thinking is often recommended to add depth and complexity to topics of investigation and stimulate curiosity and innovative thought. Developing questioning skills are important, as they are needed for generating and testing hypotheses when conducting research (Anderson & Krathwohl, 2001). Learning how to craft good questions might lead to research that solves presently unmet problems in different fields (Gall & Rhody, 1987).

Though teachers should teach questioning skills implicitly in their daily interactions with students, they should also teach questioning explicitly in ways such as modeling during think-alouds and by direct instruction. Furthermore, posing questions that have multiple answers and varied solution paths can promote the originality and flexibility needed for creative thinking. Ultimately, implementing questioning techniques should deepen students' understanding, stimulate curiosity and generation of new ideas, and lead to solutions.

Finally, students will need to develop not only scientific thinking skills, but also attitudes that will support their engagement with high-level STEM content over time. Teachers rated learning from mistakes as *very important* or *essential*. In this reflection process, students assess a situation, identify what worked and what did not work, and plan for what they might do next time. The aim is that students will be more knowledgeable, motivated, and confident about how they may approach a similar situation in the future.

One way to communicate the significance of learning from mistakes is to offer biographical examples of individuals or organizations that erred or seemingly failed in the process of an eventual success, discovery, or invention. Further, teachers may discuss the personal attributes that these people shared and the positive aspects of the experience. Resilience is one such characteristic that may be identified, and in some instances, students might find that accidental discoveries were made. Learning from others who have found personal success yet encountered misfortune or experienced feelings of failure might encourage students to persevere.

Encouraging Student Collaboration

Collaboration was also rated highly on the Teacher Survey. As required in school and in work environments in various fields, students must learn to complete tasks that require independent and collaborative work. Working effectively with other people requires skills and attitudes that must be learned and practiced, such as listening, patience, respect, providing feedback, and commitment to the group's goals. Teachers should teach the value of collaboration as a tool for learning. Prompting students to reflect on the benefits of collaboration might guide them in realizing how collaboration is a strategy for learning, which might entail clarification of misunderstandings and the creation or development of new ideas and knowledge.

Teachers must create opportunities for students to collaborate in different disciplines and for different purposes, such as in lab settings to work on scientific research. These experiences will help prepare them for the collaborative experiences they are sure to encounter in college and in their future careers in STEM.

Supporting Advanced Thinking

Teachers at all levels should engage students in tasks that require higher levels of cognitive functioning, such as requiring students to justify and explain their thinking in verbal and written formats. Doing so not only supports students in advancing their thinking and communication skills, but also conveys the value of the process that led to results and product. Furthermore, some students will have more advanced verbal abilities as demonstrated by their oral and written communication, whereas other students may possess increased proficiency in one modality, or struggle with both. We acknowledge the challenge of teaching verbal skills in non-STEM disciplines, as the emphasis is on developing STEM content knowledge and skills. However, STEM high school teachers must maintain the expectation for students to practice justifying and explaining in both verbal and written formats regardless of their level of proficiency or preference. The potential for improvement is infinite. Having developed abilities in both forms will be of benefit in their future college and career experiences.

Creating Student Engagement

On average, teachers rated representing content in multiple ways as *very important* or *essential*. Teachers who are committed to differentiating for their students strive to address students' diverse learning needs, which include their learning preferences. Students will have different inclinations for the way in which they learn new content. For example, some students might identify as an audio/visual learner, others as a verbal learner, interpersonal learner, kinesthetic learner, and so on, when referring to Gardner's (1983) theory of multiple intelligences. Incorporating multiple representations of content has the potential to increase the likelihood that students will meet the stated learning objectives, expand their schemas, and develop a richer understanding of the content. Providing examples from different sources demonstrates to students how they can learn about a topic by accessing multiple sources. Though implicit, teachers should discuss this learning strategy explicitly.

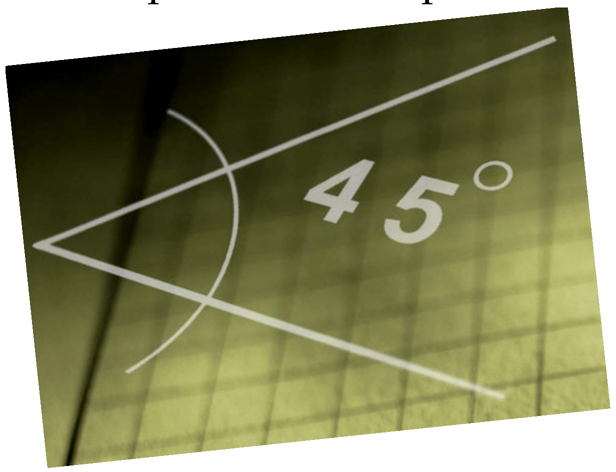
Similarly, providing representations of content in diverse formats and delivering the content using diverse instructional strategies can increase student engagement and learning outcomes.

The benefits of students' use of technology to complete academic tasks are various and should be incorporated into the curriculum at all grade levels if possible. All high school teachers should endeavor to create learning experiences that allow students to use technology with the prospect of increasing their learning outcomes and enhancing the quality of their work.

Instructional Strategies Item of Interest: Overview of Results

One of the 10 items was not rated *very important* or *essential* (5 and above) for Instructional Strategies, though it was still rated as *important* (4 and above but less than 5).

- Incorporate students' prior STEM experiences into instruction



Instructional Strategies Item of Interest: Implications for Practice

Building on Students' Prior Experiences

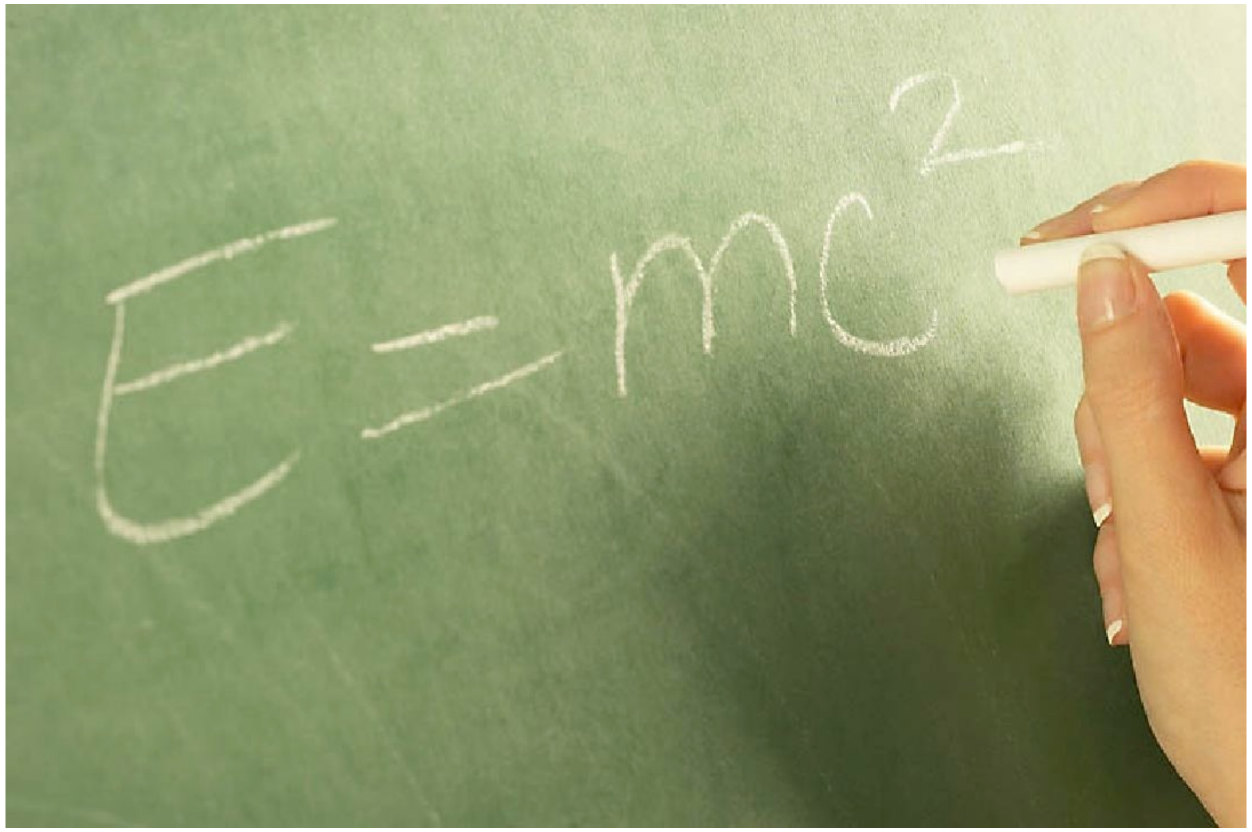
STEM high school teachers can incorporate students' prior STEM experiences into instruction by acquiring a diagnostic measure of students' proficiency with content and skills that they plan to teach. Knowing what students know and what they would like to know can help guide teachers' curricular and instructional planning.

Some ready-made curricula include pre-assessments. If unavailable, we encourage teachers to create their own diagnostic assessments, in forms such as the following:

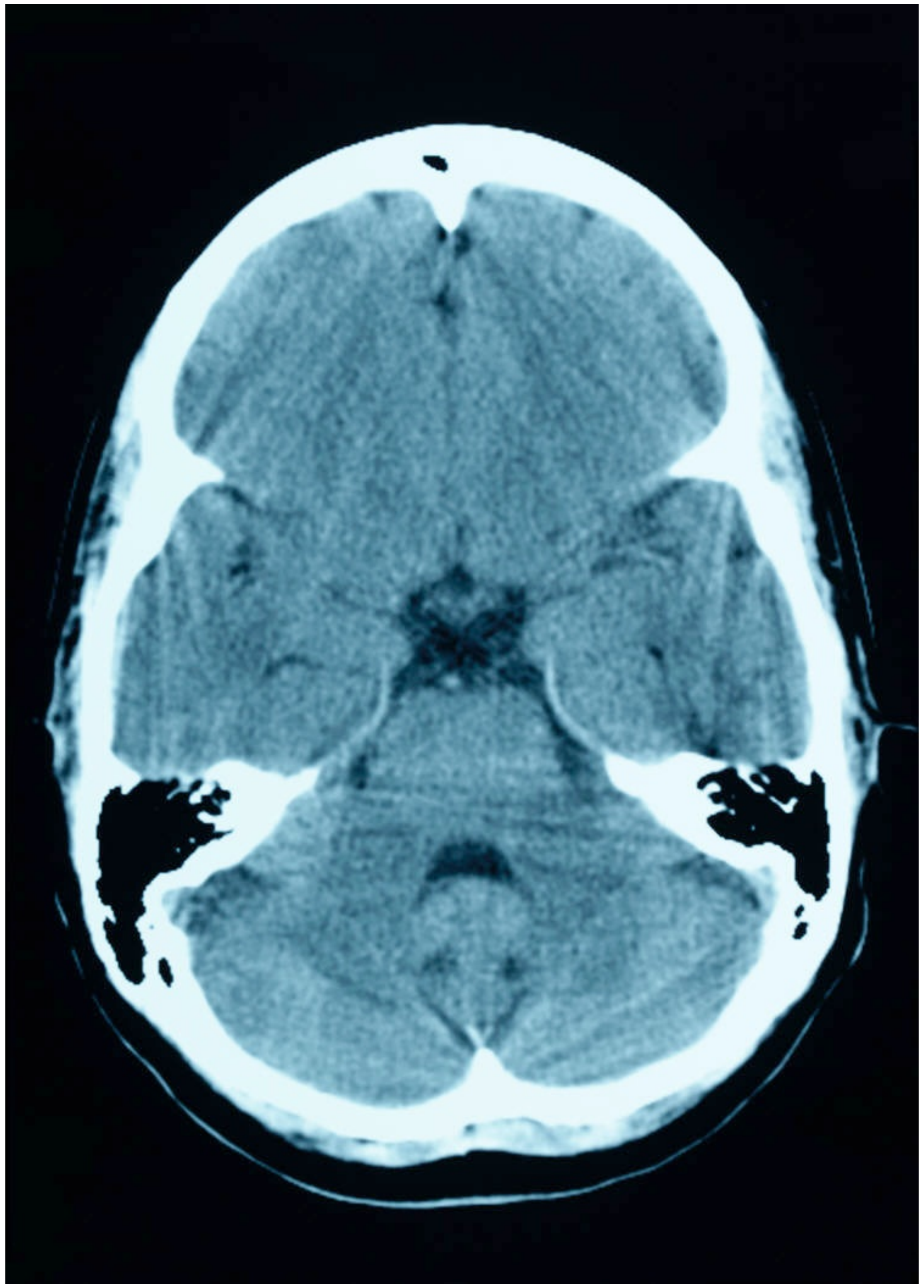
- K-W-H chart. Students write what they know about the content or skills that will be taught, what they want to know, and how they might learn them.

- Students compose a paragraph about their prior experiences with the STEM topic under investigation. How and when did they learn the content and skills? What were the most important things they learned? What more do they want to know or need to practice? What did they like about the learning experience? What would they suggest for teachers as they teach?

We have discussed instructional strategies that may lead to the development or transformation of an effective STEM high school. The relationship between instructional strategies and curricular approaches is bound in the classroom teaching and learning context, whereby the instructional strategies are the vehicles in which to transport curricular approaches. As we have considered the ways in which students learn and practice content and skills, we must also consider the environment in which the learning takes place. Accordingly, the next section is reserved for discussion of practices STEM high school teachers can implement to create an effective learning environment.



Section IV: Learning Environment



Overview of Results

Teachers were asked to rate the importance of the Learning Environment items only; therefore, therefore Figure 4.5 does not depict frequency ratings. Overall, STEM teachers perceived it was *very important* or *essential* to implement practices that would enhance the effectiveness of the learning environment, rating 2 of the 4 items in the Learning Environment section as *very important* or *essential*. Of the practices listed, the most important was *Promote a common vision of excellence for the school* followed by *Provide direct instruction to students on how to support their learning by asking for help from peers and teachers*. Creating and maintaining a learning environment of excellence at STEM high schools requires involvement from several members of the education community.

Learning Environment: Implications for Practice

Creating Learning Environments of Excellence

Teachers reported sharing a common vision for promoting excellence at their STEM high schools. School vision and mission statements may serve as a navigation tool for school faculty. As all members set their sights on the final

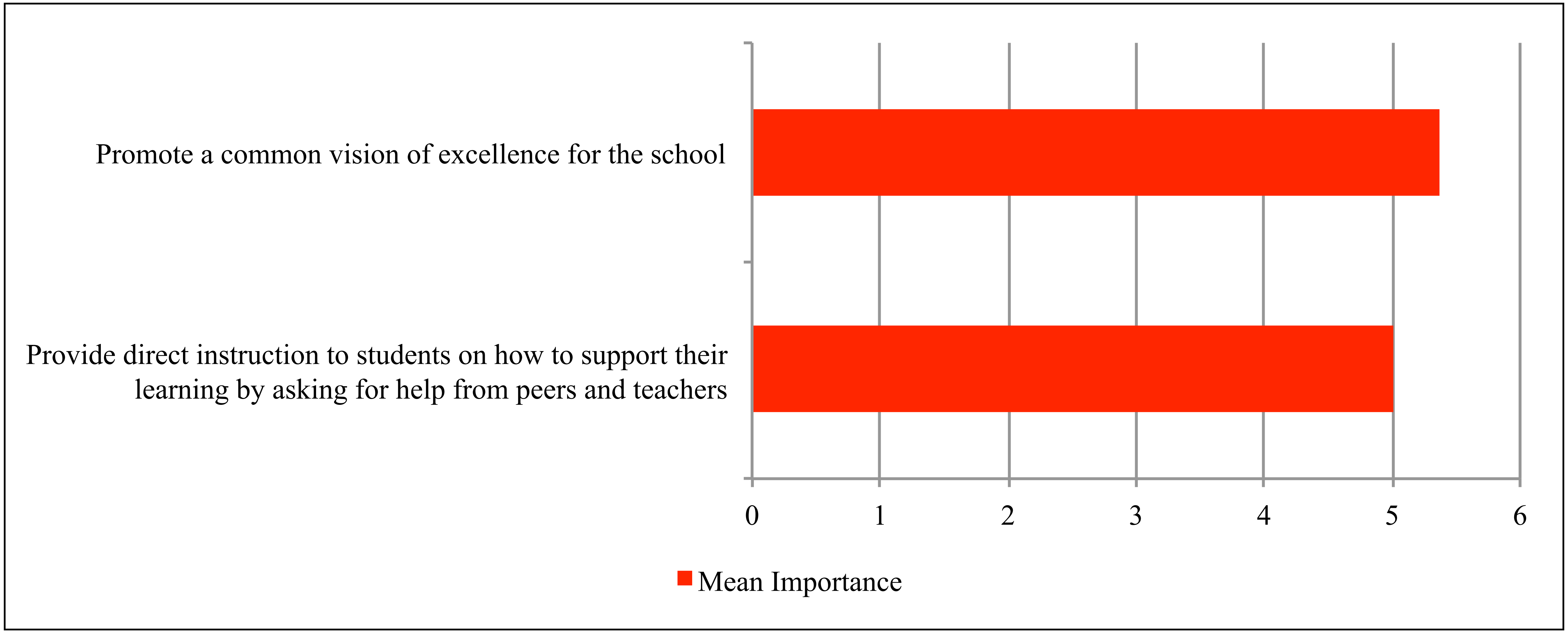


Figure 4.5. Teachers' mean importance rating of Learning Environment items.

destination, they continuously collaborate to support each other in remaining on course in their respective journeys, though mindful that all teachers may not travel the same path (Gabriel & Farmer, 2009). STEM administrators should consider integrating discussion of the schools' common vision for a learning environment of excellence periodically throughout the school year to remind the faculty about their unified purpose and motivate them to continue on their journeys.

We suggest that schools without vision and/or mission statements aim to create them as they can inspire and guide teachers in their efforts to serve their students and school community. Administrators may do this collaboratively with their faculty to encourage a democratic environment where teachers feel respected and that they have a voice. If administrators choose to forgo establishing a vision and/or mission for their STEM high school, we encourage teachers to create their own as a faculty, or by grade level, discipline, or content area.

STEM high school teachers also reported advocating for a classroom and school community that imbued excellence. It appeared that they acknowledged a learning environment where all classroom community members served as resources for learning and recognized the value of teaching students to ask others for assistance with their academic tasks, with the primary intention of scaffolding students' learning. Indeed, teachers should explain the importance of working independently, but discuss the matter in a way that communicates the benefit of asking peers and teachers to assist if needed; help from others can support their learning. Teachers' implementation of this practice can be perceived as a demonstration of caring for students' academic development, anticipating that they will further develop their knowledge and skills by accessing information from others.

Encouraging students to seek academic support from classroom community members may also be viewed as having concern for students' social-emotional needs as students find comfort in knowing that other people are readily available to help them. Creating an environment that embraces collaborative learning may alleviate some feelings of anxiety about completing tasks that students otherwise could not complete without assistance from their peers and teachers. Moreover, as students experience the learning benefits resulting from requesting help from their classroom community members, they might be more apt to seek assistance in the future. Promoting excellence in a collaborative learning context has the potential to increase students' chances for personal academic success.

Learning Environment Items of Interest: Overview of Results

Two of the 4 items for Learning Environment were not rated *very important* or *essential* (5 and above), but were still rated as *important* (4 and above but less than 5).

- Promote STEM careers over other career options
- Require written or oral articulation of long term career plans beyond undergraduate education

Learning Environment Items of Interest: Implications for Practice

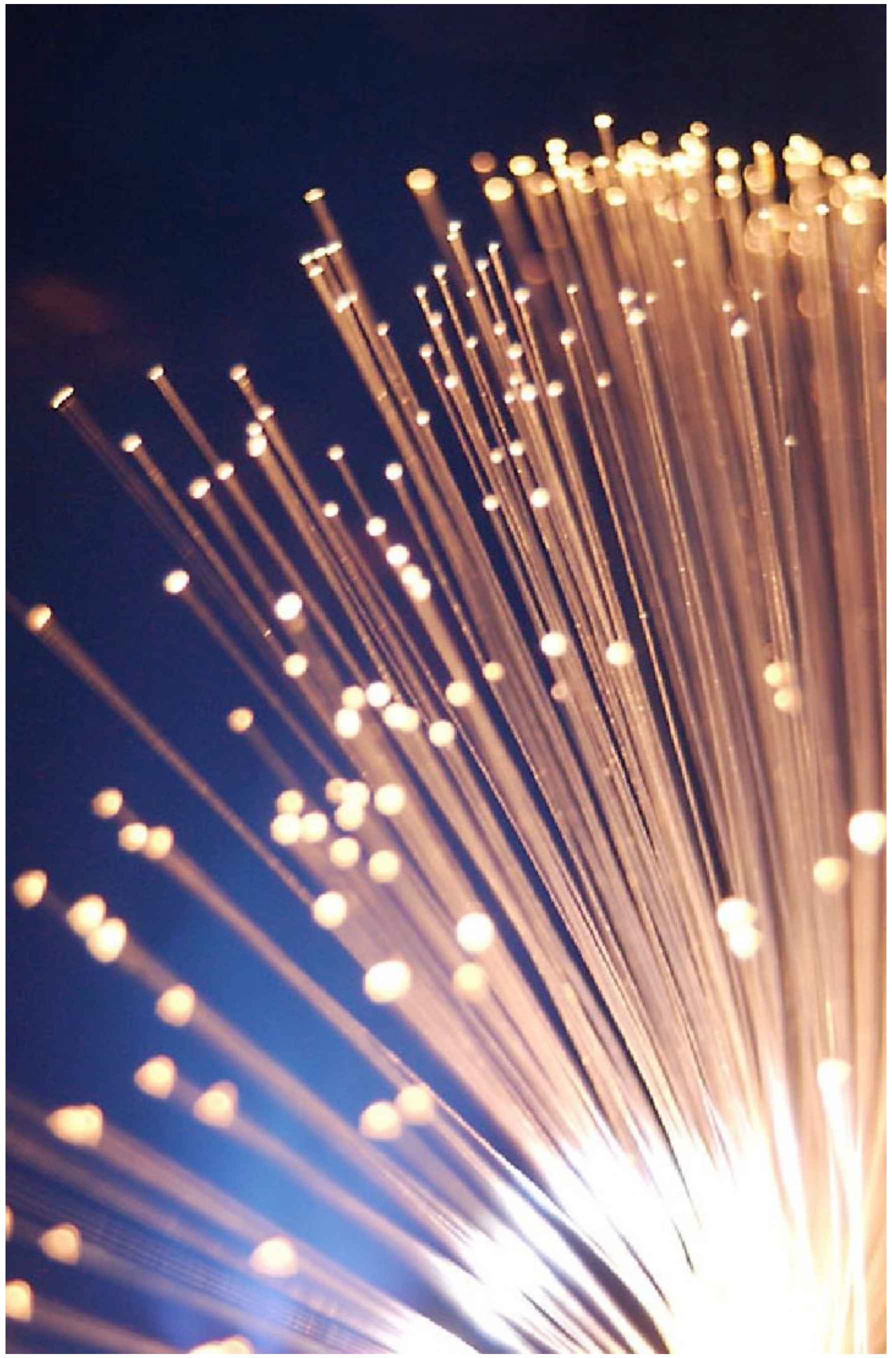
As teachers rated promoting STEM careers as important, those starting new STEM high schools or improving existing ones, should consider infusing academic opportunities that will encourage students to pursue STEM careers. Some students attend STEM high schools because of their interest in STEM, knowing that it will be their emphasis during their college and/or career years.

Encouragement to pursue STEM careers may be provided to varying extents. Creating opportunities for students to learn about STEM careers from practicing professionals might be one way of introducing students to potential STEM careers. Teachers could invite STEM professionals to discuss their job duties, and roles and responsibilities, or arrange mentorships and internships with practicing STEM professionals, which might offer students career guidance and encouragement. The hope is to inspire students to choose paths of interest that will lead them to careers in STEM fields.

To help students in the career planning process, teachers can prompt students to articulate their career goals and reflect on what they must do to attain them. Teachers can ask students what fields appeal to them. What careers do they envision themselves working in after college? What must they do to prepare for entering such a career? Who will help them? Thinking about their long-term career plans is a beginning; still, requiring students to articulate their plans orally and in writing can help students chart a more tangible course for success.

The goal-setting task may be beneficial for students, as well as other individuals who may support them on their journey. For students, goal setting can support self-regulation as they begin to identify and practice the thinking, attitudes, and behaviors needed to enter fields and careers of interest. For teachers, parents, and other stakeholders, learning about students' career interests can guide them in seeking and creating experiences to support students in their respective journeys.

Summary



The survey responses obtained from the 777 STEM teachers from 35 states and the District of Columbia provided insights to the practices currently implemented in STEM high schools across the U.S. We organized the survey items into four sections with importance and frequency scales. The results informed us of STEM high school teachers' perceived importance of implementing practices relating to school climate, curricular approaches, instructional strategies, and learning environment.

We created graphs to display the results of the practices rated by STEM teachers as *very important* or *essential*, to which we provided commentary on the significance of implementing the practices in STEM high schools. We also provided commentary for items that were not rated *very important* and *essential* since we believe that all items in the teacher survey are practices that can support the development of effective STEM-focused high schools and programs.

The implications we have presented have the potential to inform educators and policymakers about effective practices in STEM high schools related to school climate, curricular approaches, instructional strategies, and learning environment. Interested stakeholders may review the results from the teacher survey and our corresponding commentary, and consider how they may implement the suggested practices in their STEM high schools accordingly.

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Chapter 5

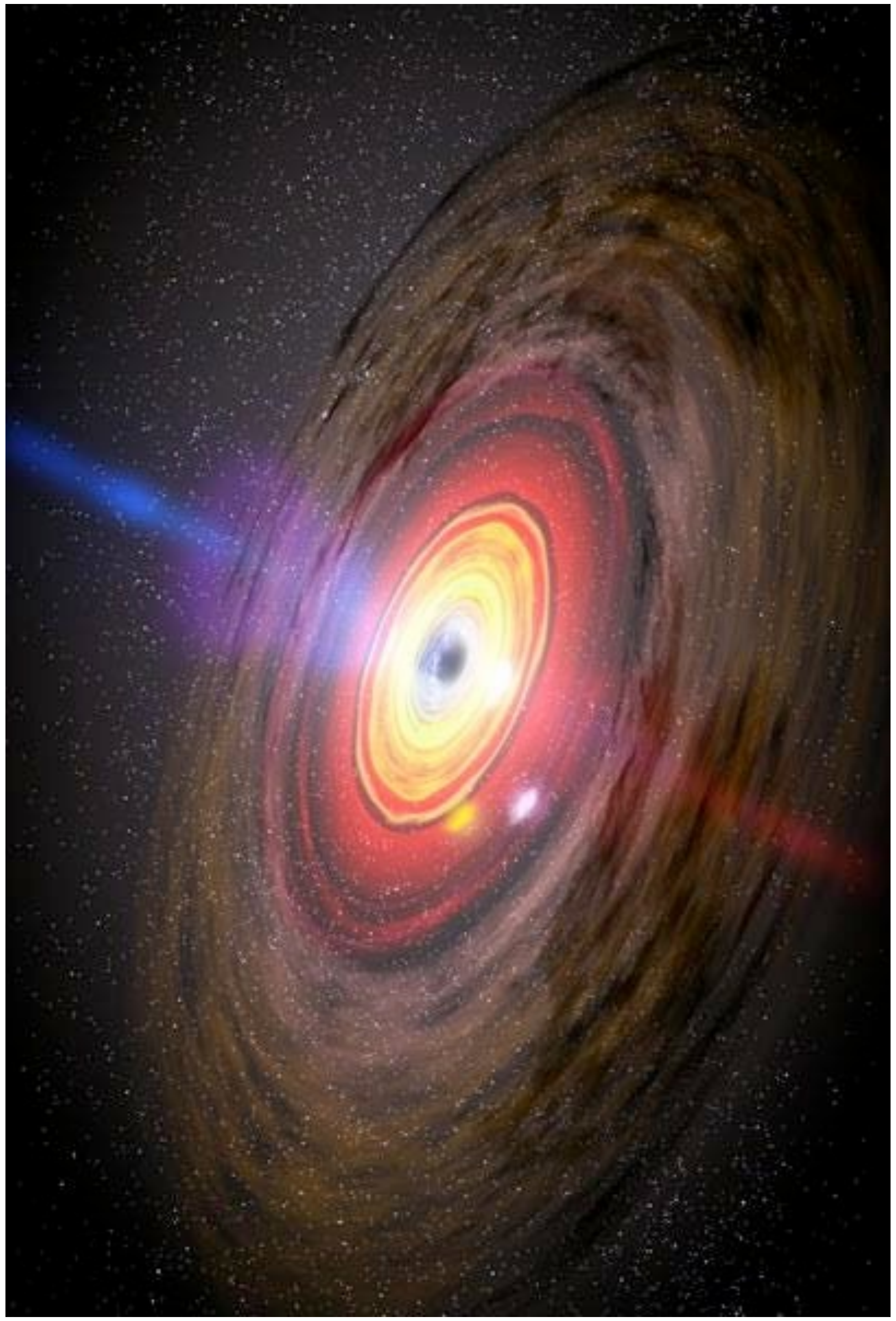
STEM High Schools: Administrator, Teacher, and Student Perceptions

STEM High Schools: Administrator, Teacher, and Student Perceptions

The results of the administrator and teacher surveys provided a "big-picture" view of the state of STEM high schools across the United States. To further our understanding of the instructional and curricular practices implemented by teachers in these schools, the research team visited STEM high schools of varying designs. One reason was to observe these practices in STEM schools of various organizational types (e.g., residential, half-day, magnet, charter, school-within-a-school). We were also able to hear directly from several stakeholders including administrators, teachers, and students about what they considered the important instructional and curricular features of the STEM schools.

Administrators and teachers at the STEM high schools developed these skills through a variety of methods, and the overall curriculum often focused on making a connection to the real world. In addition, the STEM high schools maintained a climate focused on creating a community of learners. Finally, students were supported both intellectually and personally. These findings will be explored below with practical suggestions for implementation.

Section I: Curricular and Instructional Practices



Teachers at the STEM high schools created learning environments that encouraged the transfer of knowledge by making real-world and interdisciplinary connections, focusing on process skills, asking higher level questions, and incorporating technology.

Independent Real-world Problem Solving

An instructional practice frequently observed in the STEM high schools included the use of real-world connections in various contexts. For instance, in math classes, students examined real-world statistics and asked questions, such as: How do statistics affect the courtroom? What are the chances of survival when diagnosed with breast cancer? What are the chances of survival when wearing a seat belt?

Teachers as well as students also made real-world connections. Some students referenced movies they had seen such as Michael Moore's health care film, *Sicko*, the "Long Island Sound" as an example of a geography concept, or "Wall Street" as a connection to understanding the financial world. Additionally, in one school, the students had to complete a project with a real-world problem emphasis. A teacher explained:

> [W]e now have a capstone course, so kids can either do a science project or a science research [study], or they can come up with a problem in engineering—a problem that needs to be solved, and go off and do the work to solve it. (Teacher Focus Group)

Further, STEM high school teachers across these sites promoted independent learning as an instructional practice. This was pointed out during a teacher focus group: "We want them in as much as possible to be developing the ideas themselves rather than simply just being told what other people had done" (Teacher Focus Group). Independent learning was infused into project-based learning because as one teacher explained ". . . what it allows us to do is let the students discover, let the students learn in the most opportune fashion for that student while we guide them over the rough spots (Teacher Focus Group).

In addition to independent learning, students were also required to present their research findings for an authentic audience: "We're not there to shove information, but we're there to teach them how to use that information to convey it to an audience, . . . and then that translates in research also" (Teacher Focus Group). Students appreciated the real-world audience presentations and they enjoyed seeing other students' research projects.

> [A]t the end of the year, . . . we have [a] research symposium. It allows people who have done research to present their material and . . . people from the community and people from families come in. It's kind of interesting to see what achievement they've accomplished. (Student Focus Group)

Problem Solving and Questioning

Flexibility and creativity in approaching real world problem solving was emphasized as an instructional practice at the STEM high schools. Teachers wanted students to

> . . . get out of the mindset of follow this one style of solving problems that maybe you were presented in middle school. Let's have discussions and why you would want to approach it April's way, but then Alphonso's way might be better in this scenario . . . . (Teacher Focus Group)

Using questioning strategies teachers promoted critical analysis during class discussions while problem solving in various subject areas. Students learned to refrain from accepting answers that were not vetted by others or supported by relevant evidence. Teachers modeled questioning techniques for students by "teaching them to ask good questions, and then throwing out conundrums . . . ." (Teacher Focus Group).

Several of the schools we visited developed research programs geared to engage students in the practices of researchers. Embedded in these programs were opportunities for students to develop their own questions to explore through independent research projects. One student shared the following experience:

> And now that we have developed our means of analysis, we've just been set free on our own to formulate our own questions and if our results turn out well then our teacher is going to try to use our research and use it to submit to . . . someone who is conducting research on antioxidants cause she knows that this person who is looking for usable data so this is actually a real-life thing that's going on in our AP Chemistry class. (Student Focus Group)

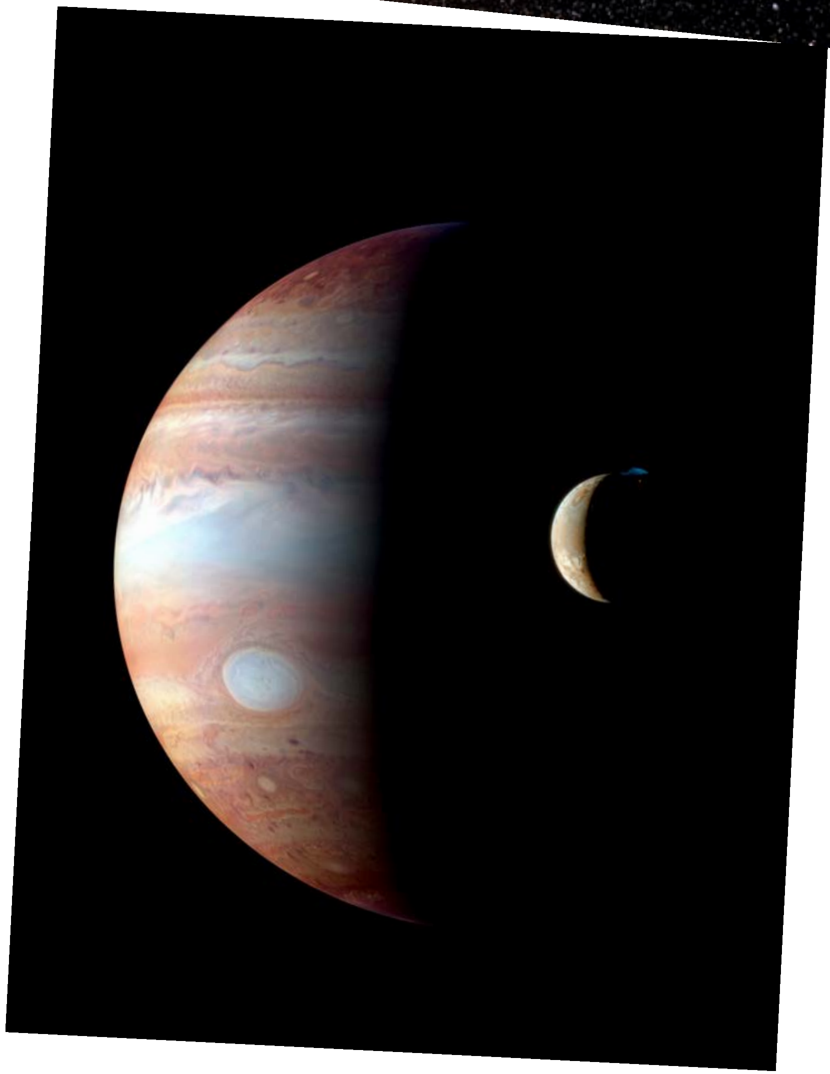
Implications

Several important implications for future or developing STEM high schools were gleaned from the site visits. These included a strong emphasis on research programs designed to promote student engagement and practices of authentic researchers. In addition to involving students in conducting their own original research, some schools created a series of classes to teach research skills. The following suggestions are based upon the site visits to the STEM high schools:

- Provide students time to develop and conduct their research with support from teachers and or mentors.
- Embed research opportunities into subject specific courses such as mathematics or science.
- Promote capstone projects to serve as a concrete goal for students to share their research accomplishments.
- Analyze the methods and practices of professionals to ensure that students have access to the statistical and technological advances to pursue their own research.
- Connect students with professionals who are completing similar research.

Furthermore, if the mission of your school is to support students as independent researchers then you may consider the following suggestions:

- Create a schoolwide plan of action for research, with time dedicated to help students develop research skills.
- Teach students statistics skills to facilitate the analysis of their data.
- Support students in locating a real-world audience to share and display findings, including people from the industries/disciplines that connect with the research topics.
- Connect students with professionals who are conducting research in a mentoring context or student-apprentice relationship.



Section II: Academic Rigor of STEM High Schools

Infusing challenging experiences across the disciplines and offering rigorous courses were greatly appreciated by the students we interviewed at the STEM high schools. Teachers and administrators also had very high expectations for performance in these courses, which students also appreciated.

A Desire for Challenging Course Work

In the majority of the STEM high schools that we visited, many course offerings for students were perceived as academically rigorous, including AP level and honors courses, as well as highly specialized classes that might not typically be offered in traditional high schools. Students expressed an interest in attending these STEM high schools due to the challenging courses, as one student explained, ". . . developmental biology, climate change biology, immunology . . . all these classes that [are] unconventional . . . I just wanted the chance to actually branch out from the standard AP bio and go into these other disciplines" (Student Focus Group).

The students who met with us also discussed the rarity of being challenged in other educational settings. This was a reason for attending a STEM high school. A student shared, ". . . [T]he level of academic caliber that the school offers is really unparalleled" (Student Focus Group). Another high school student commented,

> I chose [this school] because when I was in middle school I was doing really good, getting straight A's and I felt like I wanted to challenge myself more and my friend talked to me about [this school] and so I'll try it out. And then when I got here I felt like it was good for me to try to do more than what I was already doing. (Student Focus Group)

Students across all the schools also communicated a strong appreciation for the opportunity to be challenged to prepare for college and work experiences. They expressed a desire to be challenged and to try new things. ". . . I was always the kid . . . [who] sat in the back of the class doing nothing . . . . I thought [it would be good] coming here where there were more advanced classes" (Student Focus Group). Students put forth more effort as a result of being challenged. As one student explained:

> But for me challenging, like every year there is always that one hard-harder class, but that is the class that I would put more effort into and that I would . . . gradually put more interest into that course because it was a little bit more challenging than the others. (Student Focus Group)

In addition to these challenging courses, STEM high schools were purposeful in creating an academic environment to help students accomplish high-levels of work as well as to develop their own ideas. The courses were not necessarily viewed as isolated experiences, but rather an interdisciplinary approach to the curriculum was promoted. "It's the whole aspect of being a program and not a collection of classes that are isolated . . . here we try to make that connection for them that everything you learn has a purpose and is all connected" (Teacher Focus Group).

High Expectations

Coupled with an academically rigorous offering of STEM focused courses, administrators and teachers both held high-expectations for students to perform equally high-level, professional work. There was a sense that all students would strive to meet these high expectations. Teach to the "top of the class, and then the other students have to rise up versus teaching in the middle" (Teacher Focus Group). Another teacher shared that

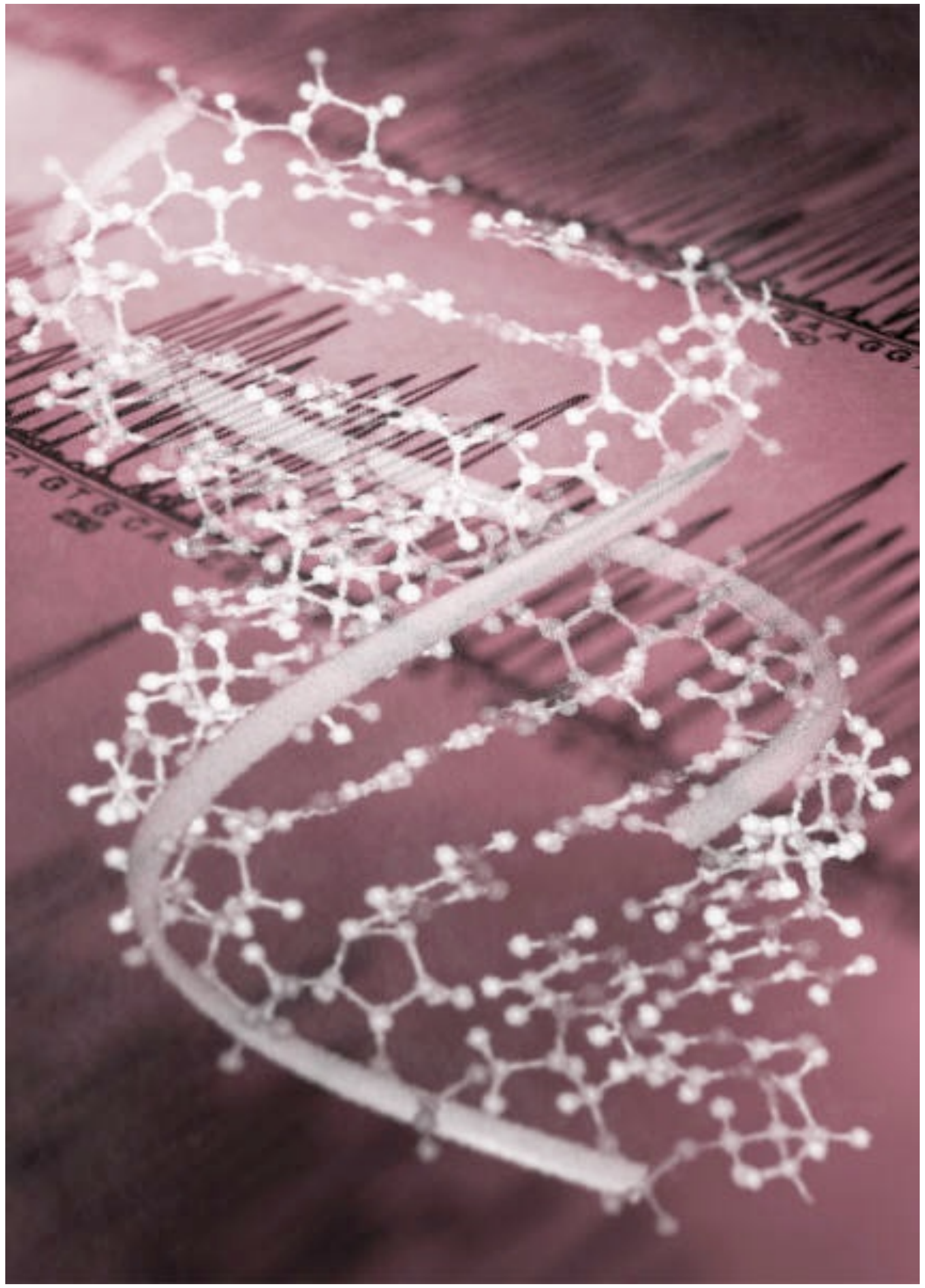
. . . standards are high and that they rise to reach that level and I think that's beneficial. A lot of students, you know, come in and they say, 'I can't do this.' You know, then you sit down and you work with them, and you know, you're not going to accept anything less, so I think that helps as well in challenging students. (Teacher Focus Group).

Implications

If your school's goal is to increase the challenge of the courses then you may want to

- Add challenging courses to your curriculum, capitalizing on teachers' expertise and interest.
- Help students understand how professionals in a connected field work and have similar expectations for the students.
- Connect coursework from various disciplines to help students develop a body of knowledge.
- Think about your highest achieving students and how to challenge them, and then consider how to help the other students perform at that level, too.
- Consider which resources you need to support student STEM development, including but not limited to physical resources (e.g., building structure and layout, computer and science labs) and human resources (e.g., community partnerships with local businesses, colleges, and universities).

Section III: Support for Student Success



Creating a collaborative and supportive school climate for both teachers and students was considered vital to stakeholders in the schools we visited. Administrators, teachers, and students explained the general feeling of the STEM high school as academically challenging and focused on students' needs. This combination helped to create an environment where students were engaged in an academically rigorous environment for the first time in their educational careers.

Awareness of Student Academic Needs

The challenging nature of the schools made it necessary to provide students with academic support. Some students mentioned learning study skills and strategies for the first time while attending the STEM high schools. They also mentioned that they would ask teachers for help during class, after school in tutoring, and even called teachers at home when there were homework questions. One student explained, "I think this school sees that you improve throughout the year and the teacher thinks you could do better than that class so they put you in AP honors" (Student Focus Group). A teacher explained how students' readiness levels informed class schedules, if "he's ready for Algebra I, well maybe we'll give him Geometry also because he doesn't need the basic math skills, or the kid that's had Algebra I already, and we'll give him Algebra II and Geometry" (Teacher Focus Group).

Fostering a Safe School Community

Beyond attending to students' readiness levels, the teachers talked about their desire to help students reach their potential. The first step in helping students was developing a school community or "family." An administrator explained, ". . . we always refer to our school as a family and we look out for one another and this is our house and we maintain it . . ." (Administrator Focus Group). This sense of community was also fostered among the students. "So, they just feel, you know, a sense of belonging here. The kids are very accepting of one another, too . . . . It's a very safe environment here" (Teacher Focus Group).

These school environments were also thought to be sites where it is okay to be smart, to ask questions, and to discuss interesting concepts and ideas. There was a perception among teachers and students that other schools do not support students' identity as smart. One teacher expressed, "And I think there's a culture where it's okay to be smart, and I think sometimes in the other schools the kids don't feel like that . . . ." (Teacher Focus Group). Students were also safe to express their own identities, as one teacher pointed out, "They have the freedom to be who they really are here in a sort of a warm, family welcoming environment" (Teacher Focus Group).

Formal and Informal Support Systems

As the curriculum and course offerings across most of the sites we visited were challenging, and for some students this was their first experience with such rigorous expectations, students appreciated having an adult to provide assistance when needed.

Each school provided additional help for students. Formally, schools instituted tutoring sessions, and advisory periods. One site utilized late busses to allow students to stay afterschool for tutoring, while teachers at another site had office hours and Saturday study sessions. Other formal support systems such as advisory periods were developed to provide students with help to navigate their high school careers and prepare for college. As noted by an administrator, the advisory sessions

> . . . acclimate [students to learn] how to survive high school—what kinds of things you [need] to know. Then, sophomore year you'll go a little more into more study skills, the cap[stone] preparation; junior year there's a

> focus on PSATs and applications for college; and senior year, the college application process. (Administrator Interview)

Informally, students commented they felt support from both teachers and other students. A student shared, “One thing that’s like helped me out a lot is the support I get from teachers because when I need help with a subject I could always come after school and get like help with whatever I need help with” (Student Focus Group). Students also expressed a comfort with approaching teachers when they needed support,

> I don’t feel any hesitation to just go and sit in any of my teachers’ offices and be like ‘Okay, this is what is really going on and this is, I don’t understand any of this problem and the people on my hall don’t understand how to explain this problem to me.’ And you’re always going to find someone here who wants to get down to your level. (Student Focus Group)

In addition to relying on teachers for assistance, students also supported each other. “I have my team member, which having two brains on a problem is better than just having one, and that is basically how I tackle a problem” (Student Focus Group).

Implications

Some suggestions to foster a collaborative and supportive school environment include the following:

- Ensure that teachers are highly skilled in their content areas.
- Provide formal and informal opportunities for students to discuss interesting ideas and abstract concepts
- Provide students with access to both teacher and peer support. Communicate to students early in the school year when and where teachers are available for additional assistance.
- Consider whether this assistance would require teachers to have adequate pay / scheduling to allow for tutoring sessions with students.
- Determine what travel resources would be available for students who typically take a bus home after school.
- Consider alternatives for students who might need financial support for individual tutoring programs, such as after school programs.

Summary

Our on-site analysis of the curricular and instructional strategies across selected STEM high schools in the United States revealed important and relevant implications for developers of future STEM high schools and for those who are seeking to improve current practices.

Students, teachers, and administrators in these schools appeared to express a deep appreciation for a collaborative and supportive school environment where students were challenged with a rigorous curriculum and instructional strategies. Students in the STEM schools, regardless of school structure, appreciated the diverse course offerings compared to those offered by their home schools. There was a strong and central focus on real-world applications of the content and skills, problem-based learning, and challenging questioning strategies within the STEM curriculum. In addition, teachers provided students with opportunities to conduct independent and relevant research projects with opportunities to share their results with real-world audiences. The perspectives offered here may help to guide future developments in new or existing STEM high schools to promote and support our talented youth.

Chapter 6

Conclusions and Future Directions: What Is Known and Unknown About STEM High Schools

Conclusions and Future Directions

A considerable amount of research and journalism related to STEM high schools exists to guide educators and policymaker as they design or redesign schools. We presented additional data from The National Research Center on the Gifted and Talented STEM High Schools' Database, national surveys of administrator and teachers, as well as perceptions of administrators, teachers, and students collected through onsite observations, focus groups, and interviews. These multiple data sources provided further insights into how STEM schools were organized and how administrators and teachers viewed the importance and frequency of curricular and instructional strategies and practices.

Collecting data on STEM high schools presented some obstacles. Some schools operate with a mission statement that clearly signifies their philosophical and programmatic approaches to engaging students in an environment that emphasizes STEM; however, there is no reference to STEM in their school's name. Other schools may be self-declared STEM schools confirmed by their schools' names. The naming may result from efforts to distinguish career-focused high schools in local communities, to attract students with obvious or emergent interests in the disciplines, or to expose students to dynamic fields of study that may encourage them to pursue future career and professional opportunities in science, technology, engineering, and mathematics. We used multiple sources to find references to existing STEM high schools to create The National Research Center on the Gifted and Talented STEM High Schools' Database, which allowed us to reveal several important facts:

- The number of STEM schools in existence has been typically referred to as 100, as stated in reports from the President's Council of Advisors on Science and Technology (2010) and the National Research Council (2011). However, our initial searches resulted in locating 949 STEM high schools. The number of schools was later reduced to 916, as some schools closed; other schools confirmed that they were not STEM-focused yet.
- The proliferation of STEM high schools was quite evident from 2000-2009 with 313 designations as STEM.
- Magnet and charter schools comprised the majority of STEM high schools in the database.
- The majority of STEM high schools (58%) were in suburban communities, followed by urban communities (26%).
- Almost all of the STEM high schools were classified as day schools (94%).
- Eighty percent of the STEM high schools were inclusive as students were eligible to attend without admissions criteria.

A subgroup of administrators who chose to respond to the STEM High School Administrator Survey offered some similar or different demographic information:

- STEM high schools served urban (38%) and suburban (31.2%) student populations.
- STEM-focused comprehensive high schools (25.8%), magnet high schools (19.5%), and charter schools (16.5%) predominated the school types.
- Administrators selected multiple types of admissions criteria: grades/report cards/transcripts (45.4%); no selection criteria (40%); and teacher recommendations (31.7%).

The STEM High School Teacher Survey data we highlighted were based on teachers' mean ratings equal to or greater than 5. Table 6.1 offers a closer look at mean importance ratings of specific ratings by setting a higher criterion of ≥5.25. This collection of items reflects an active and engaging learning environment promoting critical, creative, and research skills within curricula that emphasize real-world applications of students' knowledge and skills. However, the frequency (*once or twice a month* [4] or *at least once a week* [5]) with which the opportunities were implemented in classrooms varied by item. It is important to note that some of the variations in mean frequency were due to the specific item content. For example, teachers may not *Design curriculum that promotes real-world applications once a week* or *every day* nor *Use technology as a tool for scientific or mathematical model* at the highest levels of frequency. In contrast, *Encourage student questioning* occurred almost *every day*.

To some extent, this set of items is reminiscent of several 21st Century Skills (Partnership for 21st Century Learning, 2011) featuring Learning and Innovation Skills:

- Creativity and Innovation
    - View failure as an opportunity to learn
    - Understand that creativity and innovation is a long-term, cyclical process of small successes and

Table 6.1

STEM High School Teacher Survey Response Summary

Item	Mean Importance *(SD)*	Mean Frequency *(SD)*
5. Offer students tutoring/extra help in STEM classes if needed	5.34 *(0.90)*	5.11 *(1.14)*
18. Design curriculum that promotes real-world applications	5.34 *(0.88)*	4.46 *(1.35)*
29. Require students to justify and explain their thinking in both verbal and written formats	5.32 *(0.83)*	4.81 *(1.12)*
30.Encourage student questioning	5.67 *(0.64)*	5.56 *(0.87)*
31. Encourage student collaboration as a tool for learning	5.39 *(0.82)*	5.22 *(0.92)*
32. Require student collaboration with peers in lab setting	5.38 *(0.85)*	4.83 *(1.12)*
33. Use technology as a tool for scientific or mathematical modeling	5.29 *(0.90)*	4.75 *(1.19)*
35. Promote creative thinking by asking students questions with no single answer or solution path	5.28 *(0.87)*	4.68 *(1.20)*
37. Promote the value of learning from mistakes	5.26 *(0.94)*	4.78 *(1.17)*

frequent mistakes (Partnership for 21st Century Learning, n.d._a, para. 2)

- Critical Thinking and Problem Solving
  - Effectively analyze and evaluate evidence, arguments, claims and beliefs
  - Analyze and evaluate major alternative points of view
  - Identify and ask significant questions that clarify various points of view and lead to better solutions (Partnership for 21st Century Learning, n.d._b, paras. 2 & 3)
- Communication and Collaboration
  - Demonstrate ability to work effectively and respectfully with diverse teams
  - Assume shared responsibility for collaborative work, and value the individual contributions made by each team member. (Partnership for 21st Century Learning, n.d._c, para. 2)

Additionally, the National Academies of Science (2012) delineated eight practices considered essential for learning science and engineering in grades K-12. Although these practices were linked to specific STEM disciplines, they, too, reflect creativity and innovation, critical thinking and problem solving, and communication and collaboration, which are important for multiple disciplines typically offered in schools.

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (p. 42)

These foundational skills and practices should occur in all classrooms as students engage in challenging curricula that will provoke their learning and allow them to pursue content, concepts, and principles at the highest levels of the disciplines. If current and future generations of students, and their teachers, want to nurture problem seekers and problem solvers to successfully confront 21st century issues, then one area of education that needs immediate attention is STEM education.

The National Research Council (2011) described three goals for U.S. STEM education that will ultimately enhance the growth and development of our technology-dominated world that is increasingly reliant on a scientifically literate public to address social, educational, scientific, environmental, business, and technological issues:

- ★ Goal 1: Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.
- ★ Goal 2: Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.
- ★ Goal 3: Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines. (pp. 4-5)

As schools are the main partners in these efforts to educate and to inspire current and future students, it is important contemplate the potential contributions of STEM schools. Lynch, Behrend, Burton, and Means (2013) proposed 10 critical components for "creating opportunity structures for students' success in STEM" (p. 5):

1. STEM-focused curriculum
2. Reform instructional strategies and project-based learning
3. Integrated, innovative technology use
4. Blended formal/informal learning beyond the typical school day, week, or year
5. Real-world STEM partnerships
6. Early college-level coursework
7. Well-prepared STEM teaching staff

8. Inclusive STEM mission

9. Administrative structure

10. Supports for underrepresented students. (pp. 5-7)

Bruce-Davis, Gubbins, Gilson, Villanueva, and Foreman (2013) and Bruce-Davis et al. (2013) completed qualitative analyses of observational, focus group, and interview data from administrators, teachers, and students that mirror these 10 components for "creating opportunity structures" (Lynch et al., 2013) in STEM magnet, charter, residential, and comprehensive high schools. Foreman et al. (2013) provided further confirmation of these components that Lynch et al. will use to conduct an empirical research study of inclusive STEM schools. Findings from their research will inform educators and researchers about the effectiveness of STEM high schools.

Now that The National Research Center on the Gifted and Talented study of STEM high schools provided some evidence of where the STEM high schools exist, the nature of their policies and procedures, and the degree of importance and frequency of specific curricular approaches and instructional strategies, it is time to consider factors that might characterize STEM schools of excellence. It is definitely not enough to just adopt the acronym and assume that expectations and outcomes for students and their teachers will result in high quality STEM schools. Observable and measurable goals and objectives must be created and codified that lead to specific outcomes if we want to

- ★ promote students' career aspirations to enter STEM pipeline as future scientists, technology specialists, engineers, and mathematicians;
- ★ provide multiple research opportunities for students to engage in solving real-world problems;
- ★ encourage students' pursuit of technological advances; and
- ★ develop a highly educated citizenry with the goal of learning throughout the lifespan.

Determining the observable and measurable goals and concomitant objectives for STEM high schools will require strategic planning among educators, policymakers, and community members. Thoughtful deliberations must ensue to fully implement strategies and practices that characterize STEM high schools of excellence. What types of schools will be created, and where? How will educators design their professional culture, policies and procedures, school climate, admissions criteria, curricular approaches, instructional strategies, and learning environment?

Information from The National Research Center on the Gifted and Talented STEM high school data may offer guidance for the strategic planning and prompt discussions about the importance of STEM education to our society's well being. The establishment of STEM high schools has been a response to economic and educational needs for more than 100 years; therefore, it is reasonable to assume a focus on STEM education will remain a national priority for years to come. We encourage the STEM education community to acknowledge "the needed focus on excellent STEM instruction that will inspire and excite those who might pursue STEM careers is crucial for *all* learners" (National Science Board, 2010, p. 6). Our data provide an initial blueprint for educators and policymakers to conduct an informal assessment of current practices and procedures and to respond to the clarion call for 200 STEM high schools that will become centers of excellence to increase the intellectual capital ready to embrace and resolve known and unknown problems and issues for the betterment of the nation and its citizenry.

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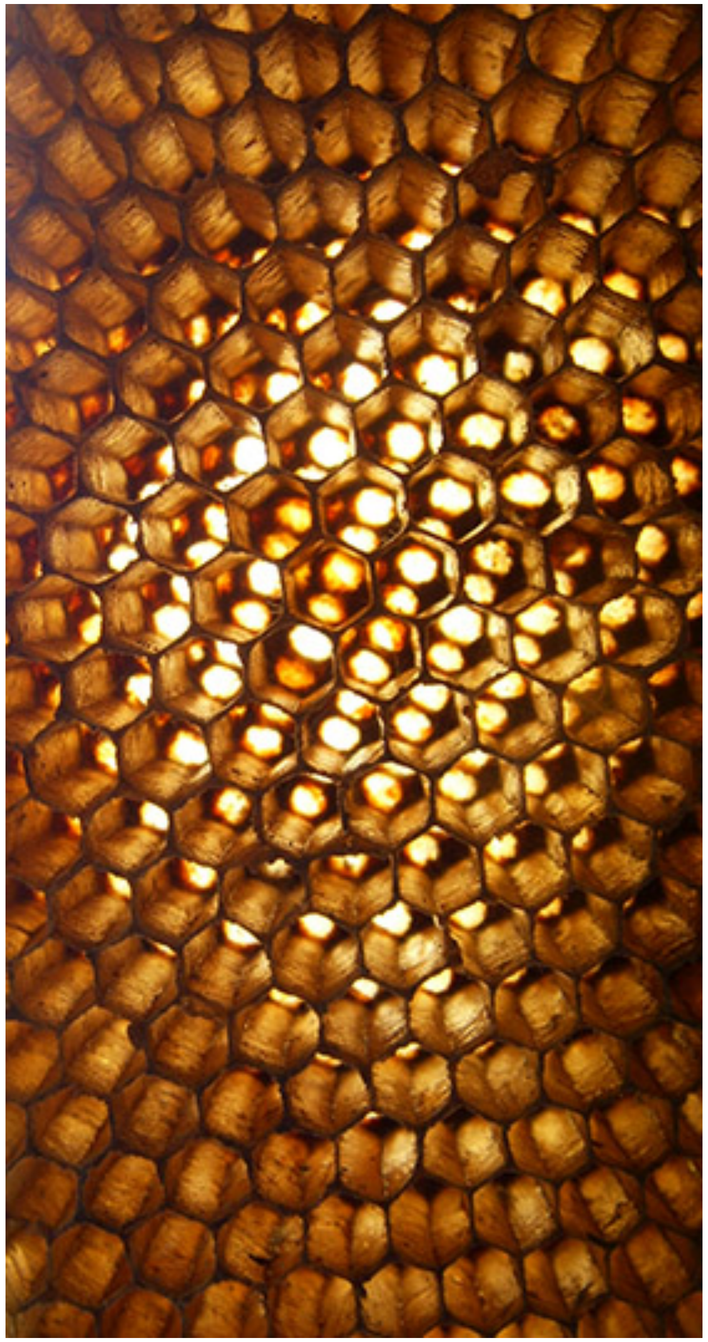
Chapter 7

STEM High Schools' Interactive Matrix

- STEM High Schools' Interactive Matrix

STEM High Schools' Interactive Matrix



The National Research Center on the Gifted and Talented created the STEM High Schools' Interactive Matrix to document the types and number of STEM high schools in the United States. Prior reports indicated that approximately 100 STEM high schools were in existence. As of December 2012, we identified 894 schools through multiple data sources. Information from schools' websites was used to classify schools as specialized, magnet, charter, Governor's, or Other. Schools were then subdivided into day, residential, or partial-day programs. We also delineated schools based on their admissions criteria. If schools listed specific admissions criteria such as test scores or grades, they were classified as "exclusive." If schools had open admissions policies, they were classified as "inclusive." The screen shot of the STEM High Schools' Interactive Matrix provides the frequencies of schools by the classifications.

The STEM High Schools' Interactive Matrix (4th ed.) is available on a CD from The National Research Center on the Gifted and Talented on a cost-recovery basis. Please visit http://www.gifted.uconn.edu/nrcgt for order information. The matrix allows you to access a list of schools by type and category as shown in the next screen shot for one of the pages of the Charter Day Inclusive Schools. You may select a school and learn more about the year of establishment, grade levels, size of student population, type of community,

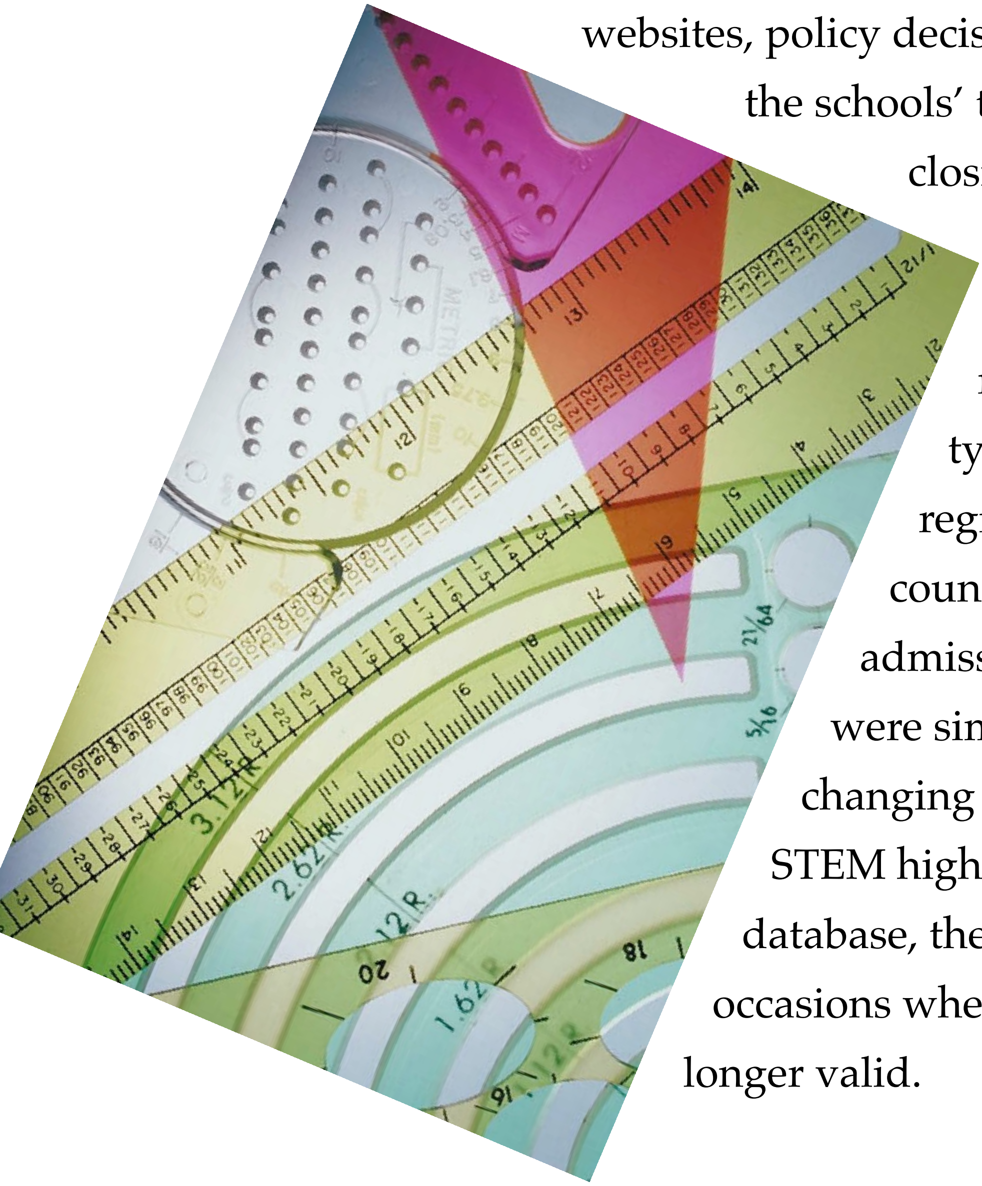
STEM High Schools' Interactive Matrix

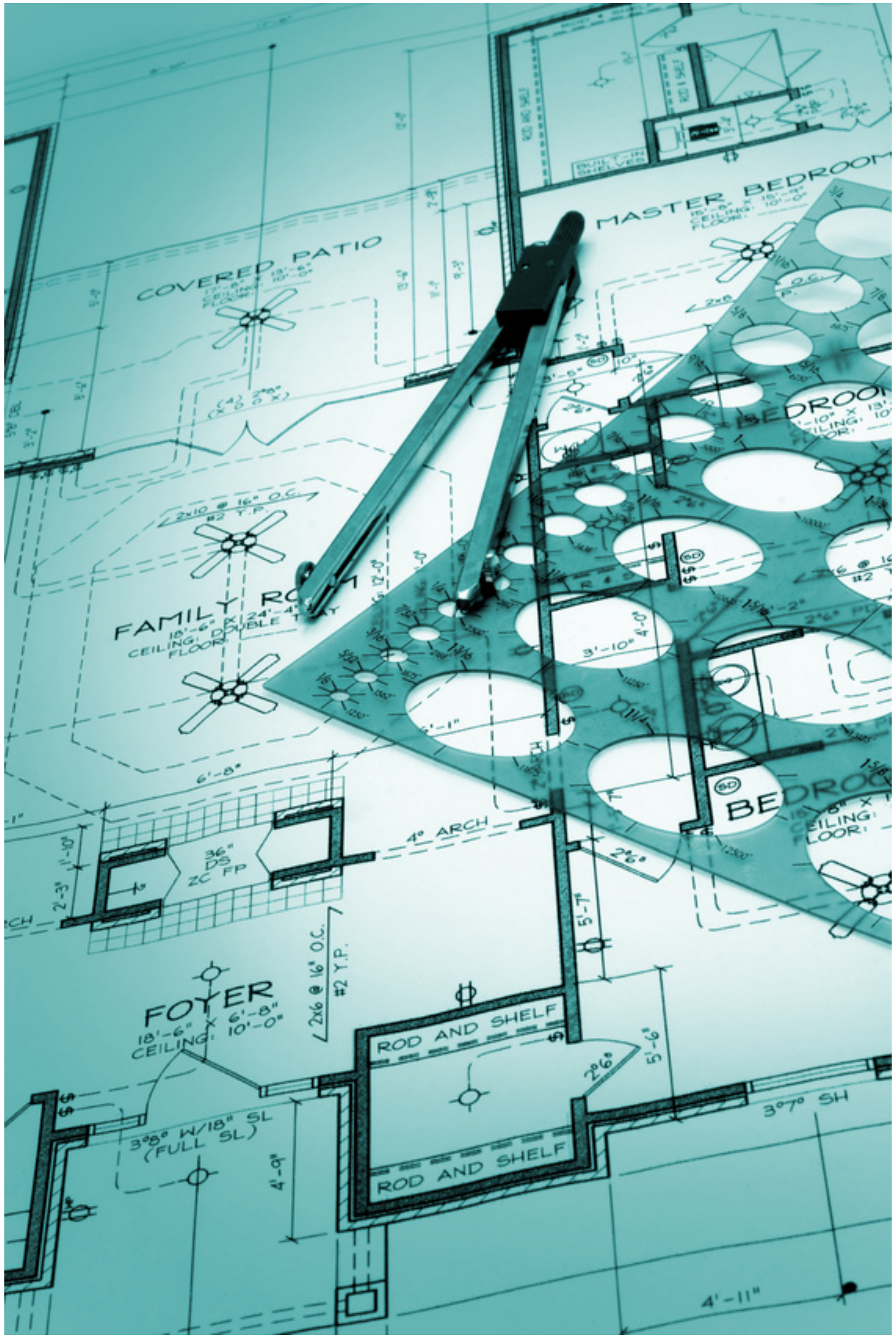
	Specialized		Magnet		Charter		Governor's		Other	
	Exc.	Inc.	Exc.	Inc.	Exc.	Inc.	Exc.	Inc.	Exc.	Inc.
Day	33	127	61	94	15	155	5	5	29	326
Residential	1	X	1	X	X	X	8	X	2	3
Partial-day Program	X	5	9	2	X	4	5	2	4	1

Notes: Click on a button to go to the list of schools in that specific category. If there are no schools listed for any category, there is an X and the button is inactive.

and tuition, if applicable, as illustrated in the screen shots below.

Note. The number of schools represented in the STEM High Schools Interactive Matrix (*N*=894) is slightly lower than the 916 schools in The National Research Center on the Gifted and Talented STEM High Schools' Database described in Chapter II due to changes in availability of websites, policy decisions related to the schools' themes, or closing of schools. However, the patterns of representation by type of school, region of the country, and admissions criteria were similar. Given the changing status of the STEM high schools in the database, there may be occasions when the links are no longer valid.





Charter Day Inclusive Schools *(cont'd)*

- Harmony School of Innovation (Dallas, TX)
- Harmony School of Innovation (El Paso, TX)
- Harmony Science Academy (Beaumont, TX)
- Harmony Science Academy (Brownsville, TX)
- Harmony Science Academy (Bryan, TX)
- Harmony Science Academy (Dallas, TX)
- Harmony Science Academy (El Paso, TX)
- Harmony Science Academy (Euless, TX)
- Harmony Science Academy (Fort Worth, TX)
- Harmony Science Academy (Grand Prairie, TX)
- Harmony Science Academy (Laredo, TX)
- Harmony Science Academy (Lubbock, TX)
- Harmony Science Academy (North Austin, TX)
- Harmony Science Academy (San Antonio, TX)
- Harmony Science Academy (Waco, TX)
- High Tech High Chula Vista (Chula Vista, CA)
- High Tech High International (San Diego, CA)
- High Tech High Media Arts (San Diego, CA)
- High Tech High North County (San Marcos, CA)
- High Tech Los Angeles Charter High School (Van Nuys, CA)
- Highland Tech High School (Anchorage, AK)
- Hmong College Prep Academy (St. Paul, MN)
- Horizon Science Academy (Cincinnati, OH)

List Continues

School Information

School Name	High Tech High Chula Vista
Year School Established	2003
School Website	www.hightechhigh.org/schools/HTHCV
Grade Level (Begins)	9
Grade Level (Ends)	12
Student Population	460
Community	Suburban
Tuition	Free

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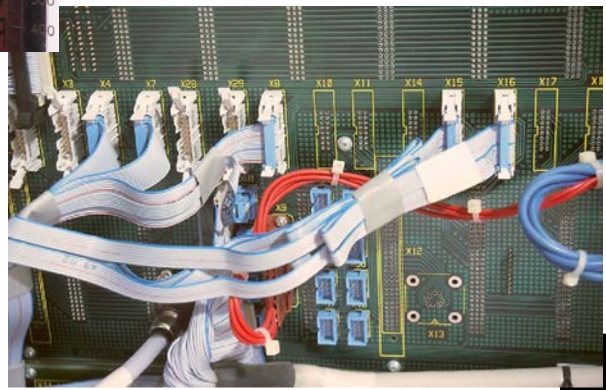
S



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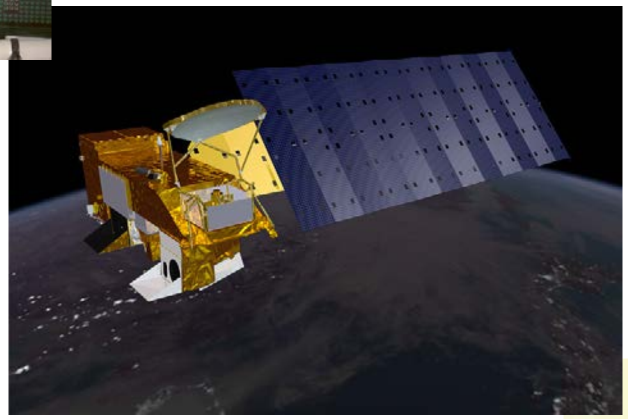

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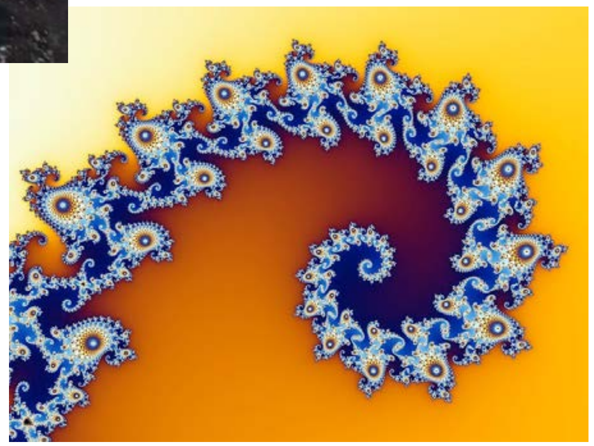

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STEM

Science, Technology, Engineering, and Math

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