Study of the Impact of Selective SMT High Schools:

Reflections on Learners Gifted and Motivated in Science and Mathematics

Rena F. Subotnik, American Psychological Association

Robert H. Tai, University of Virginia

John Almarode, James Madison University

Rationale: A central challenge for the National Research Council committee exploring *Highly Successful Schools or Programs for K-12 STEM Education* was to determine the attributes of success for different populations found within U.S. schools. Our charge was to focus on appropriate outcomes for learners gifted and motivated in science and mathematics, most particularly those who enrolled in selective secondary schools of science, mathematics and technology (SMT). Although policy makers tend to rely on standardized measures of achievement to rate student response to special interventions and programs, scholars studying high achievers have found that measuring program effectiveness with standardized tests is complicated by ceiling effects. As a result, our project ascribes success to completion of STEM related university majors or to the application of SMT content and skills to other productive career goals. The goal of our project, in sum, is to assess the value added by selective SMT schools to developing and maintaining the STEM pipeline and the application of STEM knowledge and skills to non-STEM pursuits through the university years.

Background**:** Selective science, mathematics and technology-focused high school schools offer the most intensive educational option for developing science talent at the secondary level. These environments typically bring together cohorts of highly able and motivated students with expert teachers, advanced curricula, technically sophisticated laboratory equipment and opportunities for apprenticeships with working scientists (Subotnik, Tai, Rickoff, & Almarode, 2010). Students who enroll in specialized SMT schools tend to have demonstrated over many years a capacity for advanced learning (Means, Confrey, House, Bhanot, 2008; Subotnik, Rayhack & Edmiston, 2007) and creative expression in STEM subjects. Their teachers are likely to hold terminal degrees in their domain of instruction, and expect their students to complete and generate high quality academic and creative work inside and outside of the classroom.

The most demanding specialized schools for learners gifted in mathematics and science were established in the Soviet bloc countries. In the late 1950s, distinguished Russian scientists advocated for educational opportunities to develop future generations of scientists (Donoghue, Karp, & Vogeli, 2000). In order to increase the geographical reach of the schools, several included boarding facilities. Admission was based on stringent criteria, including successful results in regional academic competitions. The faculty of these schools included pedagogically talented educators, and students had the opportunity to work with renowned professors at local universities as well. An example of one of these specialized institutions is the residential Kolmogorov School that enrolls 200 students per year from Russia, Belarus, and beyond (Chubarikov & Pyryt, 1993). Selection was and continues to be based on a record of success in regional Olympiads. Professors from the prestigious Moscow State University serve as the faculty, the coursework is heavy, and students are expected to conduct independent projects on topics of interest to them. The schools, which continue to exist in some form today, have graduates on the faculties of the most renowned institutions in Russia, as well as among the academic ranks of top Western universities (Grigorenko, & Clinkenbeard, 1994).

The U.S. created its first specialized technical high school – Stuyvesant High School – in New York City in 1904, followed by Brooklyn Technical High School in 1922. Although both originated as boys' vocational schools, they later transformed into powerhouses in science and engineering, and were joined by the Bronx High School of Science in 1938. The first state residential high school in the U.S., the North Carolina School of Science and Mathematics, was established in 1980 (Thomas & Williams (2010). In the mid-1980s, most likely in response to *A Nation At Risk* (Hanford, 1997; National Commission on Excellence in Education, 1983), public support led to the establishment of a number of other selective schools around the country designed to serve students talented and interested in SMT. Among them were additional residential schools (e.g., the Illinois Mathematics and Science Academy and the Arkansas School for Mathematics, Sciences and the Arts), and self-contained schools based on the New York City model (e.g., Thomas Jefferson High School for Science and Technology). New program models were developed including part time programs (e.g., the Central Virginia Governors School and the Kalamazoo Area Mathematics and Science Center), and schools-within-schools (e.g., Montgomery Blair Science, Mathematics, and Computer Science magnet and Liberal Arts and Sciences Academy).

Each school model is designed to provide advanced coursework, expert teachers, peers motivated and interested in SMT, and opportunities for independent research. However each model also has additional design features that potentially affect outcomes for their graduates. State residential schools serve students from all around the state, ensuring that every county has a chance at representation in the entering class. Self-contained schools are usually located in large metropolitan areas, serving an entire district or city's most talented students. Schools-within-schools are also typically located in urban areas, and were often founded to bring cohorts of academically talented students and additional resources to schools with fewer resources and few White and Asian students (Metz, 2003 discusses the influence of desegregation policies on magnet school development). The schools-within-schools model allows SMT students to participate in non-SMT classes with their schoolmates and for some non-SMT students in the school to take advanced courses designed for the SMT cohorts. A fourth category of selective SMT schools is the part time school model available in Virginia and Michigan, usually in poorly resourced or rural counties. These schools serve a geographical region, busing in students from a number of high schools to participate in advanced SMT coursework for part of the day. The rest of the day, students are enrolled in their home high school.

The policy climate: Recent public attention has been drawn to potential shortages of high level scientific workers and innovators (Augustine, 2007; National Research Council, 2006). For example, 59% of Chinese students and 66% of Japanese students major in STEM disciplines at university compared to under 30% of U.S. students (NRC 2005). According to Augustine, et al (2007), 38% of current PhDs in the U.S. STEM workforce are foreign born, and of those 45 years old and under, 52% are foreign born [and presumably educated as children and adolescents in their native country]. In order to address STEM pipeline problems, foreign nationals are serving at the doctoral and postdoctoral level of NIH through visa extensions and waivers for talented STEM professionals.

In the era of Sputnik, the National Defense Education Act (NDEA) responded to technological and military threats with provisions for identifying students in the public schools with "outstanding aptitudes and ability" and supported guidance and counseling programs for such students so that their talents might be successfully fostered (NDEA, 1958 Title V, Sec. 503a [1 and 2]. The threats today are different but no less critical including infectious disease, climate change, and water and food shortages, to name a few. Yet, U.S. students' interest in STEM careers drops precipitously during secondary school and during college. American schools are not generating sufficient numbers of students who are both willing and prepared to fill laboratories, institutes and the entrepreneurial community (Augustine, 2007).

The most likely "low hanging fruit" to fill this need is found among those attending selective SMT schools. And yet, in times of funding shortages, the education and research community tends to view this highly interested and achieving population of students as deserving the least attention because they will "make it on their own." In fact, recent data analysis from the Program for International Student Assessment (PISA) conducted by Hanushek, Peterson, and Woessmann (2010) and Fleischman, Hopstock, Pelczar, and Shelley, (2010) show that the U.S. is behind other advanced nations in producing strong elementary mathematics students and advanced adolescent science students. With regard to mathematics, 16 countries including Germany, Canada, Australia, the Czech Republic, Japan, New Zealand, Taiwan, and South Korea had at least twice the percentage of high achievers in mathematics as the U.S. Even when assessing only those U.S. students whose parents completed college, larger percentages of 16 countries' students perform at the advanced levels in mathematics, *regardless of the education level of their parents*. In the realm of mathematics, Finland, Japan and the Netherlands had twice the proportion of 15 year olds scoring at the highest levels on science literacy [defined as consistently identifying, explaining and applying scientific knowledge and knowledge about science in a variety of complex life situations]. Shanghai and Singapore had over three times the percentage of advanced fifteen year olds as the U.S. These outcomes can be explained in two ways: either U.S. students are inherently less able than students in other countries, or else they are not being sufficiently challenged to meet global standards.

Research in the behavioral sciences shows that all students need to acquire a growth mindset, that is, a view of intelligence that promotes developing one's capacities by accepting challenge and exerting effort (Dweck, 1986; 2006). Leaving advanced students to “make it on their own” reinforces a fixed mindset, or the belief in innate intelligence that need not benefit from development or guided practice (Ericsson, Krampe, & Tesch-Römer, 1993). Further, adolescents with interests and talents in mathematics and science are more likely to pursue STEM in post-secondary environments when provided with challenging curricula, expert instruction and peer stimulation (Bloom, 1985; Subotnik, Duschl & Selmon, 1993). Selective SMT schools have been designed to provide such experiences for high achieving students with expressed interest in science. The purpose of this research is to find out whether (1) SMT schools are successful in maintaining and enhancing young people’s commitment to STEM pursuits, as well as (2) the application of STEM content and skills to non-STEM pursuits. The analysis reported here focuses exclusively on purpose number one.

Research Questions: Principal goals of specialized schools are to provide high quality STEM education for academically talented students, and to prepare them for successful completion of university STEM programs and careers as accomplished STEM professionals. Yet, no existing studies provide rigorous analyses of the contributions that these schools make over and above regular schools (Subotnik, Tai, Rickoff, & Almarode, 2010). We have concentrated on two guiding research questions for this report:

- Research Question 1: Are graduates from specialized science, mathematics, and technology (SMT)-focused high schools likely to complete STEM majors?
- Research Question 2: What school models employed by specialized SMT high schools are most associated with completing STEM majors?

In the discussion of our research project and analysis, we examine particular characteristics of the high school experiences of students who attended these types of high schools.

Overview of the Study

The National Science Foundation supported *Study of the Impact of Specialized Public High Schools of Science, Mathematics, and Technology* was designed to be conducted in three phases. Phase 1 focused on the development and validation of a pilot survey instrument of high school experiences and personal objectives of graduates tested at one selective specialized high school as well as with a comparison group of students with identifiably similar abilities and interests in SMT, but who did not attend a specialized SMT school. The validated survey was subsequently used in Phase 2 of the study to collect data from a group of 8 specialized SMT high schools, two each from the four models described above: 1) residential, 2) comprehensive, 3) school within a school, and 4) half-day. The focus of Phase 2 is two-fold. First, we began the data collection for the study exploring the role played by school model. Second, we wanted to establish a survey solicitation protocol that we would employ with the graduates of a larger sampling of specialized high schools. Phase 3 of the study will involve employing the validated survey and solicitation protocols developed in Phases 1 and 2 with an additional 20 schools representing the four school models and a comparison group. The comparison group consists of participants who graduated from high school within the same timeframe as the selective school graduates, but did not attend specialized high schools. The comparison group participants scored highly on the SAT or ACT before age 13 and enrolled in summer science or mathematics courses at a major research university.

The study survey includes a variety of items designed to address the study research questions. The items were derived from relevant literature including selected instruments exploring attitudes, motivations, and career development of talented individuals in science. The pilot survey findings were used to cull the number of questions used in the final survey in order to shorten and focus the instrument.

The questionnaire items encompass a variety of categories including: demographics, high school characteristics; personal motivations for decisions related to schooling, science, and mathematics; retrospective evaluation of high school learning; high school curriculum, coursework, and teachers; high school research experiences; mentors and mentoring; social and interpersonal relationships in high school. The current analysis focuses on four central variables from the instrument enumerated below.

The survey was conducted using email solicitations. Contact information for the specialized high school alumni were obtained through a combination of school records and alumni association lists. A contact information verification service was contracted to determine the viability of email addresses prior to their inclusion into the survey data-base. An examination of the group demographics of responders with known demographics from schools indicated that the responders were representative with respect to the overall demographic backgrounds of schools.

Findings from the Analysis of Preliminary Data

Descriptive overview of the Preliminary Data Set

Table 1 shows the frequency distribution of survey responses across the four school models. The total number of respondents responding to the survey at the time of this analysis is n=1250. The largest subsample of respondents appears to be from comprehensive high schools with the smallest from residential and half-day schools. It is important to note, however, that the student bodies of the comprehensive schools are significantly larger than cohorts from the other schools. Despite the unbalanced proportion of responses, the number within each of the schools types is fairly robust. The gender distribution of the participants is also shown in Table 1.

Table 1: Distribution of survey respondents across 4 specialized school types and gender

	Frequency	Percentage
School Type		
Residential	192	15.4
Comprehensive	502	40.2
School in School	220	17.6
Half-day	336	26.9
Gender		
Females	657	51.2
Males	626	48.8
Total	1250	

The data in this preliminary sample have characteristics that allow for a reasonable examination of Research Questions 1 and 2. In addition, given the fairly robust representation within school types and the balance within the gender distribution, presentation of inferential analyses were a viable option.

Examination of Research Question 1: *Are graduates from specialized science, mathematics, and technology (SMT)-focused high schools likely to complete STEM majors?*

To address this question, we have used the nationally representative National Educational Longitudinal Study of 1988-2000 as a comparison group. The intervening decade between NELS and our data set limits the conclusions that may be drawn from this analysis, however, this comparison does offer a reasonable estimation of differences.

Table 2 offers two main comparisons: 1) Participants who entered SMT schools with already existing interest in STEM and who graduated from college with STEM degrees, and 2) participants who entered SMT schools primarily for reasons other than interest in STEM and who graduated from college with STEM degrees. The first comparison shows a nearly 20 percent difference in graduating with STEM-related college degree between those labeled *High Performers in Science and Mathematics (NELS)* (46.6%) and SMT school graduates (64.9%). It should be noted that STEM-related college degrees earned by US residents has declined steadily since 1966 according to data released by the National Science Foundation (2010).

With respect to students who entered selective SMT schools for reasons other than deep interest in SMT, it appears that specialized high schools do not change their direction. This outcome is not entirely surprising in light of prior work indicating the importance of establishing early STEM-interest (Tai, Liu, Maltese, & Fan, 2006).

Table 2: Comparison of Percentages of College Graduates Majoring in STEM-related areas who graduated from Specialized SMT high school graduates (age range 22-25 years) to the nationally representative data from NELS:1988-2000 (age range 25-26) of individuals who did not attend Specialized SMT high schools.

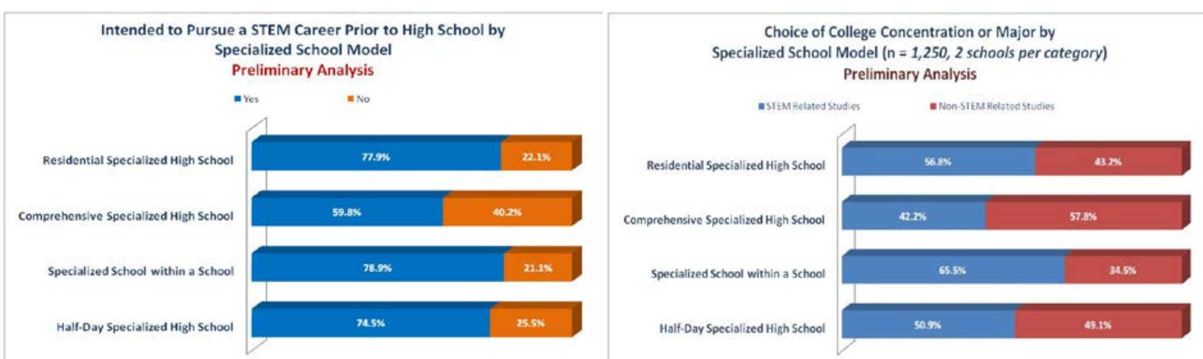
	Percentage
Initially STEM-Interested Students – Entering SMT HS	
National Educational Longitudinal Study of 1988-2000	
All Students	40.7
High Performers in Science and Mathematics	46.6
Specialized SMT High School Graduates	64.9
Initially Non-STEM- Interested Students – Entering SMT HS	
National Educational Longitudinal Study of 1988-2000	
All Students	21.9
High Performers in Science and Mathematics	34.0
Specialized SMT High School Graduates	27.5

A more rigorous examination of these variables will be available in Phase 3 when data from the comparison group will be entered into the analysis. Age peers who attended SMT-related summer programs offered through academic talent search programs for high school students housed at Research 1 universities are the academic and interest based peer group of high achievers attending specialized high schools. None of the summer enrichment program group in the study will have attended specialized high schools. A contrast of SMT participants with this comparison group offers an optimal opportunity to explore the value added by SMT schools.

Examination of Research Question 2: *What school models employed by specialized SMT high schools are most associated with completing STEM majors?*

Here we offer a preliminary comparison of outcomes across the four school models. This analysis includes 2 schools from each of the four models.

Figure 1: Comparison of percentages of Specialized SMT High School graduates who reported STEM-interest prior to entering High School (left panel) and Comparison of Percentages earning STEM-related college degrees 4-6 years after high school graduation (right panel).



Checking the Importance of Examining Multi-level Models

In the course of analyzing data clustered within clear groupings, as can be found in this data set, it is important to understand the portion of variance that occurs at the individual participant level and the portion that occurs at the school level. For this reason, we examined the intra-class correlation (ICC) for this data set and discovered that ICC = 0.036, or less than 4.0%

of the variance for the outcome variable of major completed for the baccalaureate degree. This result indicates that our analytical approach does not explicitly require variables on school level differences when examining completed college concentration as an outcome variable. As a result, the following analyses focus on variables at the level of individuals.

Inferential Analyses of Factors associated with Completion of STEM Majors

With the ICC finding in mind, we examine in the following analyses a series of factors related to high school experiences and how they might be associated with completion of STEM degrees by our survey respondents. For these analyses, we have separated college concentration into STEM-related and non-STEM concentration areas, creating a binary outcome variable, examining the association between high school experiences of specialized SMT high school graduates and STEM-related/Non-STEM college degree completion. We used binary logistic regression with the inclusion of background and demographic variables to act as controls for differences in gender, race/ethnicity, immigrant status, parental educational level, and primary language spoken at home.

The high school factors we examined include: 1) participation in authentic high school research experiences, 2) participation in internships or mentorships, 3) feelings of belonging in the academic setting, and 4) teacher efforts to make cross disciplinary connections in SMT courses. The results of these preliminary analyses are shown in Table 3. Each of the four factors is analyzed first as an individual predictor of completing a STEM-related college major as a binary outcome, and then subsequently in a model accounting for differences in background factors. These analyses are clear, and the odds ratios and their significance are unaffected by the inclusion of these backgrounds factors.

Table 3: Comparison of Odds Ratios across Binary Logistic Regression Models which examine the association of high school experiences and completion of STEM-related college concentration (n=1250, sample sizes vary slightly across each analysis)

High School Experiences	Odds Ratios							
Research Experience	1.77***	1.77***						
Internships or Mentorship			1.20***	1.20***				
Feelings of Belonging					1.22***	1.22***		
Cross Curriculum Connections							1.23**	1.23**
Background Factors								
Gender		Included		Included		Included		Included
Race/Ethnicity		Included		Included		Included		Included
Immigrant Status		Included		Included		Included		Included
Parental Education		Included		Included		Included		Included

*** $p < 0.001$, ** $p < 0.01$

The results of these analyses suggest that high school experiences that include *internships or mentorships* have a positive association with completion of a STEM-related concentration. As is the case with *feelings of belonging* and *making cross curriculum connections,* each of these three factors shows a clear but modest positive influence. However, *research experience* in high school reports an odds ratio of 1.77, a strong and significant positive association. This particular outcome indicates that the odds of an individual who reports having experienced conducting an original research project is nearly twice the odds of an individual who did not have this experience to report earning a degree with a STEM-related college concentration.

Examination of Gender through Split Data Sets

In a further examination of the preliminary data, we performed a gender split of the data set and analyzed responses from males and females separately. The relative size of the data sets (each greater than 400 respondents) allows for this approach. This approach allowed us to examine the factors analyzed previously while extracting gender and its potential interactions from the variable set. We have chosen to continue using binary logistic regression, which is robust for data sets of this size especially given the limited numbers of variables we have included as control measures.

We begin with a look at the distribution of males and females across each of the four school models (See Table 4). Among the selective SMT school graduates responding to our survey, it appears that the gender representation is more heavily female among *residential* and *comprehensive* schools, more heavily male in the *school-within-school* model, while split evenly among *half-day* respondents.

Table 4: Gender Breakdown across School Model Type

	Percentage	
School Type	Male	Female
Residential	42.6	57.4
Comprehensive	45.3	54.7
School in School	56.8	43.2
Half-day	50	50

Next we turn to a comparison of the odds ratios for binary logistic regression analyses examining *research experience*, *internships or mentorships*, *feelings of belonging*, and *cross curriculum connections*. Table 5 aggregates the results and presents some interesting outcomes. It appears that research experience is a strong predictor for both males and females. The odds ratio among female graduates of specialized SMT high schools is 2.00, indicating that among females the odds for those who reported having a high school research experience is two times the odds for these who did not that they will complete a STEM related major.

Participation in internships or mentorships shows a similar pattern of significance in the duel data set analyses, although with more modest odds ratios. Mentorships have been shown in the literature to prepare young scientists with some of the tacit knowledge and modeling they will need in order to be successful in their careers (Rosser & Lane, 2002; Zuckerman, 1977). With respect to *feelings of belonging* and *cross curriculum connections*, the results are somewhat mixed. Although *feelings of belonging* appears to be a significant factor for males, it does not appear to be a significant factor for females, countering the outcomes of research on this variable in the literature (Good, in press; Lee 2002). The outcome was the opposite with regard to *cross curricular connections*. Given the preliminary nature of this analysis it is difficult to draw conclusions. However, these outcomes suggest interesting areas for future focus. Should these findings prove to be robust, it would appear that gender differences may offer a lens on the types of experiences that are more strongly associated with STEM-related degree concentration.

Table 5: Gender Split Data Set Analyses across the four predictor variables examined previously

	Odds Ratios for Gender-Split Data Set Analyses							
High School Experiences	Males				Females			
Research Experience	1.57*				2.00***			
Internships or Mentorship		1.16*				1.23***		
Feelings of Belonging			1.31**				1.17 (ns)	
Cross Curriculum Connections				1.11 (ns)				1.35**
Background Factors								
Gender	Included	Included	Included	Included	Included	Included	Included	Included
Race/Ethnicity	Included	Included	Included	Included	Included	Included	Included	Included
Immigrant Status	Included	Included	Included	Included	Included	Included	Included	Included
Parental Education	Included	Included	Included	Included	Included	Included	Included	Included
Sample size (n)	492	502	479	502	547	556	528	556

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, (ns) not significant at 0.05 level

Comparisons Based on Participants' Parental Education Levels

In order to gain a deeper understanding of the background of selective SMT high school graduates, we examined the parental education level of the participants. Approximately 20% of selective school graduates in our survey have reported that neither parent completed a college degree.

Table 6: Parental Educational Levels of selective SMT high school graduates

Parental Education	Percentages
Some High School	3.0
High School	11.4
Some College	4.8
Baccalaureate Degree	19.1
Masters Degree	30.7
Doctoral Degree	31.0
Total	n = 1,217

However, survey participants whose parent(s) held a baccalaureate degree or higher were no more likely than survey participants whose parent(s) did not hold a baccalaureate degree to earn a STEM-related baccalaureate degree themselves. Notably, the variables we explored in the gender analysis described above, served as predictors for the participants with college educated parents, *but not for those with non-college educated parents*. In fact, students who had a least one parent earning a baccalaureate degree or higher and participated in or performed original scientific research in high school had 84% greater odds of earning a baccalaureate in a STEM-related concentration than peers with similarly educated parents who did not participate in a research study.

Among study participants whose parent(s) held a baccalaureate degree or higher and who participated in an internship or mentorship, reported feelings of belonging, or reported cross curricular connections in their SMT courses, we found they had 18%, 24%, and 27% greater odds, respectively, than other participants whose parents held similar degrees, but who did not report engaging in these activities.   However, among survey participants whose parents did not hold baccalaureate degrees, none of these experiences were found to be associated with greater odds of earning STEM-related baccalaureate degrees. This discrepancy will be explored more deeply in the analyses of our comprehensive data set, and could potentially lead to some important insights for schools on serving these subgroups of students.

Table 7: Parental Education among Specialized SMT high school graduates - Split Data Set Analyses across the four predictor variables examined previously

	Odds Ratios for Parental Education-Split Data Set Analyses							
	SpecSMT Grads Whose Parents Hold Baccalaureate Degrees or Higher				SpecSMT Grads Whose Parents Do Not Hold Baccalaureate Degrees			
High School Experiences								
Research Experience	1.84 ***				1.07 (ns)			
Internships or Mentorship		1.18**				1.16 (ns)		
Feelings of Belonging			1.24**				1.13 (ns)	
Cross Curriculum Connections				1.27 **				1.01 (ns)
Background Factors								
Gender	Included	Included	Included	Included	Included	Included	Included	Included
Race/Ethnicity	Included	Included	Included	Included	Included	Included	Included	Included
Immigrant Status	Included	Included	Included	Included	Included	Included	Included	Included

*** p < 0.001, ** p < 0.01, * p< 0.05, (ns) not significant at 0.05 level

The findings from the analysis of the preliminary data from the *Study of the Impact of Specialized Public High Schools of Science, Mathematics and Technology* suggest that particular high school curricular choices as well as demographic variables are associated with the completion of a college concentration in STEM-related fields. Most striking among these findings is the clear and strong association of high school research experiences with STEM-related college concentration choice.

Implications

Among our Nation's youth are those who have demonstrated a strong interest in STEM-related fields who are likely to play a critical role in further development of cutting edge science and technology. Evidence from biographical and longitudinal data, and from expert opinion suggests that adolescents with interests and talents in mathematics and science are more likely to pursue STEM in postsecondary environments when provided with challenging curricula, expert instruction, and peer stimulation. There are many mechanisms for generating these academically stimulating conditions. According to our research thus far, opportunities for conducting original research, a signature component of selective SMT schools, is a powerful tool for enhancing and maintaining interest in SMT disciplines, particularly for females.

Not every interested and academically talented young person can be accommodated by admission to a specialized school, as there are not enough to go around. With the completed research study, we hope to provide data and analyses to demonstrate the impact of these schools and concurrently identify those components of the schools that might be more widely implemented in other educational institutions. Questions regarding the impact and influence of selective STEM secondary schools abound. This study is intended to address these issues and bridge an important policy gap.

This material is based upon work supported by the National Science Foundation under Grant No. 0815421.

References

Augustine, N.R. (2007). *Is America falling off the flat earth?* Washington, DC: The National Academies Press.

Bloom, B. (1985). *Developing talent in young people*. New York: Ballantine Books.

Benbow, C. P., & Arjmand, O. (1990). Predictors of high academic achievement in mathematics and science by mathematically talented students: A longitudinal study. *Journal of Educational Psychology, 82,* 430-441.

Chubarikov, V. N., & Pyryt, M. (1993). Educating mathematically gifted pupils at the Komogorov School. *Gifted Education International, 9*, 110-130.

Donoghue, E. F., Karp, A., & Vogeli, B. R. (2000). Russian schools for the mathematically and scientifically talented: Can the vision survive unchanged? *Roeper Review, 22*, 121-123.

Dweck. C. S. (1986). Motivational processes affecting learning. *American Psychologist, 41,* 1040-1048. doi:10.1037/0003-066X.41.10.1040

Dweck, C. S. (2006). *Mindsets. The psychology of success.* New York, NY: Ballantine.

Ericsson, K A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100,* 363-406.

Fleischman, H. L., Hopstock, P. J., Pelczar, M. P., & Shelley, B.E. (2010). *Highlights from PISA 2009: Performance of U.S. 15-year-old students in reading, mathematics and science literacy in an international context* (NCES 2011-004). U.S. Department of Education National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Good, C. (in press). Sense of belonging, stereotypes, and achievement. In R. F. Subotnik, A. Robinson, C. M. Callahan, & P. Johnson (Eds.), *Malleable minds: Translating insights* *from psychology and neuroscience to gifted education*. Storrs, CT: National Center for Research on Giftedness and Talent.

Grigorenko, E. L., & Clinkenbeard, P. R. (1994). An inside view of gifted education in Russia. *Roeper Review, 16*, 167-171.

Hanford, S. (1997). *An examination of specialized schools as agents of educational change*. ERIC Document Reproduction Service 411 368. New York: Columbia University.

Hanushek, E.A., Peterson, P. E., & Woessmann, L. (2010). *U.S. math performance in global perspective: How well does each state do at producing high-achieving students?* Program Report No. 10-19, Program on Education Policy and Governance. Cambridge, MA: Harvard University Kennedy School.

Lee, J.D. (2002). More than ability: Gender and personal relationships influence science and technology involvement. *Sociology of Education, 75*, 349-373.

Lubinski, D., Benbow, C. P., Webb, R. M., & Bleske-Rechek, A. (2006). Tracking exceptional human capital over two decades. *Psychological Science 17,* 194-199.

Means, B., Confrey, J., House, A., Bhanot, R. (2008). *STEM high schools: Specialized science, technology, engineering, and mathematics secondary schools in the U.S*. Project Number P17858 submitted to the Bill & Melinda Gates Foundation. Washington DC: SRI International.

Metz, M.H. (2003). *Different by design: The contact and character of three magnet schools*. New York: Teachers College Press.

National Defense Education Act of 1958. PL 85-864.

National Educational Longitudinal Study of 1998 (2000).

National Research Council (2005). *Policy implications of international graduate students and postdoctoral scholars in the United States*. Board on Higher Education and the Workforce. Washington, DC: The National Academies Press.

National Research Council (2006). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technoloy. Washington, DC: National Academies Press.

National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital.* Washington, DC: National Science Foundation.

National Science Foundation Science and Engineering Indicators (2010). http://www.nsf.gov/statistics/seind10/

Olszewski-Kubilius, P. (2010). Special schools and other options for gifted STEM students. *Roeper Review, 32*, 61-70.

Pfeiffer, S.I., Overstreet, M., Park, A. (2010). The state of science and mathematics education in state-supported residential academies: A nationwide survey. *Roeper Review, 32*, 25-31.

Riegle-Crumb, c. & Barbara K. (2010). Questioning a white male advantage in STEM: Examining disparities in college major by gender, race/ethnicity. *Educational Researcher*, *39*, 656-654.

Rosser, S.V. & Lane, E.O. (2002). Key barriers for academic institutions seeking to retain female scientists and engineers: family-unfriendly policies, low numbers, stereotypes, and harassment. *Journal of Women and Minorities in Science and Engineering*, *8*, 163-191.

Stephens, R. (2010). Testimony to the House Science and Technology Committee Subcommittee on Research and Science Education. February 4, 2010. http://gop.science.house.gov/Media/hearings/research10/feb4/Stephens.pdf

Subotnik, R., Edmiston, A., & Rayhack, K. (2007). Developing national policies in STEM talent development: Obstacles and opportunities. In P. Csermely, et.al. (Eds.), *Science education: Models and networking of student research training under 21* (pp.28-38). Netherlands: IOS Press.

Subotnik, R., Orland, M., Rayhack, K., Schuck, J., Edmiston, A., Earle, J., Crowe, E., Johnson, P., Carroll, T., Berch, D., and Fuchs, D. Identifying and developing talent in science, technology, engineering, and mathematics (STEM): An agenda for research, policy, and practice. In L.V. Shavinina (Ed.) *International handbook on giftedness* (pp. 1313-1326).

Subotnik, R.F., Tai, R.H., Rickoff, R., & Almarode, J. (2010). Specialized public high schools of science, mathematics, and technology and the STEM pipeline: What do we know now and what will we know in 5 years. *Roeper Review, 32*, 7-16.

Thomas, J., & Williams, C. (2010). The history of specialized STEM schools and the formation and role of the NCSSSMST. *Roeper Review, 32*, 17-24.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning for early careers in science. *Science, 312*, 1143-1144.

Zuckerman, H. (1977). *Scientific elite: Nobel laureates in the United States*. New York, NY: Free Press.