Developing National Policies in STEM Talent Development: Obstacles and Opportunities

Rena. F. SUBOTNIK[1], Ashley M. EDMISTON and Kristin M. RAYHACK
Center for Psychology in Schools and Education, American Psychological Association, Washington, D.C., U.S.A.

Abstract. The goal of this chapter is to analyze the current U.S. approach to serving adolescents who are talented and interested in science, technology, engineering and mathematics (STEM). The first section of this chapter reviews the status of national government investments in STEM and contrasts it with private and local funding. The second section addresses key problems we view as obstacles to meeting national goals. Next we describe policy proposals that might be implemented in the future. We close by posing a challenge to our colleagues, the response to which could assist us in restoring the appeal of STEM careers for our talented youth, and perhaps offer insights into the obstacles and opportunities that exist in our colleagues' own nations.

Keywords. Policy, adolescence, talent development, obstacles, opportunities, STEM.

Introduction

Since the 1970s, federal efforts to promote programs that target talent in STEM without regard to student background have been dismissed as elitist and have had little political traction. More recently, however, both public and private sectors in the U.S. recognize that if the U.S. wants to keep its edge in technological and scientific endeavors we must engage, encourage and develop the talents of adolescents with interests in STEM. A 2006 report [1], "Rising Above the Gathering Storm," produced by the U.S. National Academies of Sciences, makes four relevant recommendations: (1) increase America's talent pool by improving kindergarten through grade 12 STEM education; (2) strengthen the federal commitment to long-term basic research; (3) develop and retain the best students; and (4) ensure that the United States is the premier place for innovation by modernizing the patent system and realigning tax policies to encourage private investment in research and development. The report reinforces the role that education plays in supporting U.S. STEM initiatives.

[1] Rena F. Subotnik: Center for Psychology in Schools and Education Director , 750 First Street, NE, Washington, D.C, 20002.; E-mail: rsubotnik@apa.org.

1. Current Mechanisms for Supporting Adolescents Talented in STEM

1.1 Federal Commitments.

Graduate level talent development in STEM is widely supported by the U.S. government. Selection to programs is rigorous, top students usually have access to outstanding mentors and equipment, and federal funding is generous. At the university level funding is available as well, and is channeled into preventing attrition from STEM majors.

At the pre-university level, federal programs target improved STEM "literacy," -- understanding STEM subjects well enough to help students become informed citizens. Only three small federal programs are directed at rewarding or providing services for students with special interests and abilities in STEM subjects. The Academic Competitiveness Grants program offers university scholarships to economically disadvantaged students who take rigorous STEM courses in secondary school. The Advanced Placement Incentive Program grants, pay for examination fees associated with rigorous, elective secondary courses. And a third, the Javits Grants program, provides support for experimental curricula designed to challenge under-represented groups in STEM (i.e. African Americans, Hispanic Americans, Native Americans, and females).

1.2 State and Private Initiatives.

In addition to federal initiatives, there are four models of state or privately funded programs that are designed to identify and develop STEM talent[1]:

- Special schools – secondary schools emphasizing STEM subjects;
- Apprenticeship/laboratory programs – after school or summer programs focused on providing hands-on opportunities to work in an authentic STEM context such as a laboratory, hospital, or museum;
- Competitions – STEM national contests for middle and high school age students;
- and Summer and after-school courses – for middle and high school students.

In preparation for this chapter, we reviewed websites from over 100 programs. We pursued this approach because no comprehensive list exists on the web or in print that includes all programs available for STEM interested or talented youth. Since not every program has the capacity or will to develop a truly informative website, we had to limit our review to those programs with websites. The programs with websites underwent the following analyses:

- Programs with information about selection requirements on their websites compared with those that did not.
- Programs with selection requirements that were in any way STEM related compared with those that posted only non-STEM related criteria
- Programs with selection requirements that posted criteria requiring demonstrated interest in STEM compared to those that posted only non-STEM related criteria.

- Programs with information about desirable outcomes for program participants on their websites compared with those that did not.
- Programs with desirable outcomes that were in any way STEM related compared with those that posted only non-STEM related outcomes.
- Programs that posted whether women and/or minorities were targeted for selection.
- Whether programs had geographical boundaries defining whom they could serve.

We made the assumption that a program's posted selection criteria reflected how the program operationalized a definition of STEM talent. We also made the assumption that the outcomes that programs posted were those that they hoped their participants would achieve.

1.21 Special Schools

We reviewed the websites of 78 Special STEM schools. Only 61 had information we were seeking relating to selection criteria and desirable outcomes for their participants. The statistics we report for selection criteria were based on the 56 schools that posted any type of criteria at all. A fascinating outcome of our search was to discover that 44 of the programs ask for standardized tests (including both mathematics and verbal) scores or locally designed tests, but 34 post STEM related criteria such as: science or mathematics teacher recommendations, STEM course completion requirements and pre-requisites, grades in STEM classes, essays, descriptions of experience; or interviews. Only 17 require a stated interest in mathematics and science as a criterion for admission, getting at the notion that being proficient at something does not necessarily imply that you are interested in it.

Program outcomes are not clearly defined in STEM related terms either. Out of the 61 special schools, 39 list desirable outcomes for their graduates on their websites, however 24 of the 39 post outcomes that are specifically SM related, and a smaller subset tell us anything about whether their alumni pursue STEM related majors or careers.

1.22 Apprenticeships/Laboratory Experiences

Apprenticeship/laboratory programs provide introductions by mentors into professional networks and associated values, according to two studies of elite science talent development [2], [3]. Fifty percent of the apprenticeship and laboratory programs require both verbal and mathematics standardized test scores for participation and all require some expression of STEM interest for admission. Many of the programs, especially those that have been in existence for many years, boast that their alumni perform well in competitions and go on to university majors and careers in STEM.

1.23 Competitions

Competitions, in general, aim to promote STEM fields and make them accessible to a wide variety of students.

For that purpose, pre-requisites are minimal and are based on the assumption that if someone wants to spend the time on competing, they must be interested in the subject. The prizes and scholarships they provide can be very useful in making such interest into a reality. In particular, the prestigious Intel Science Talent Search, sometimes referred to as the 'junior Nobel Prize,' notes six decades of excellence on their website. Alumni of this program hold more than 100 of the world's most coveted science and mathematics honors, including six Nobel Prizes, three National Medals of Science, 2 Lasker awards, 10 MacArthur Foundation Fellowships and two Fields Medals. (www.intel.com/education/sts)

1.24 Summer and After School Courses

Adolescents who are not satisfied with the quantity or quality of their schools' STEM curriculum have the opportunity to take summer and after school courses at various universities. We examined 19 providers of enrichment courses that offer talented students classes that are challenging and stimulating. According to our survey, 17 of the providers have admissions criteria, 11 of which include SM related criteria. Sixty-three percent of these programs do require some type of testing for entry. Again, selection criteria emphasize general knowledge and abilities, rather than targeting STEM specific knowledge, abilities, and interest.

2. Obstacles to a Productive National Policy for Developing STEM Talent

A large amount of money is spent on programs in ways that are intuitively appealing and certainly benefit in some way those who partake of them. With few exceptions such as the Intel Science Talent Search and MathCounts, however, we are faced with a paucity of empirical evidence that these programs are effective. That is to say, we do not know from the current state of the literature on STEM talented development whether those who are selected and participate in the programs are the "right ones" – those who may be future innovators in STEM.

2.1 No Consensus Exists Thus Far on Definitions of STEM Talent

Although there are many preconceived notions of what defines talent, most end up in the category of "I know it when I see it," or equate it with high test scores. Some programs use standardized achievement or locally designed tests as gauges of STEM talent, others utilize teacher recommendations, course completion requirements and pre-requisites, grades, papers, essays, or interviews to demonstrate superiority over other candidates. Notably, the SAT-M is the only test that has shown to have any predictive validity with regard to performance in STEM related fields [4]. Since there is no consensus on talent definitions, programs have no established standards by which to identify talented individuals, making it difficult to initiate policy directed at fostering qualities that remain undefined. Therefore, these schools are potentially wasting their resources on adolescents who lack interest and may never choose to further pursue the STEM disciplines after high school.

If more admission criteria were geared towards interest, STEM students who are motivated to be high achievers, may have more of an impact than on those purely involved because of misconceived notions of talent.

2.2 No Consensus on Desirable Outcomes for Participants of STEM Programs.

Although there is no agreement on what it is that predicts the fulfillment of STEM talent, one would think that the policy and education community would agree on what they hope such efforts will lead to. We were surprised to find that only 34 out of the total 117 programs we reviewed did allude to any STEM related outcomes at all. Competitions such as Math Counts and Intel Science Talent Search are the only mechanisms that claim to encourage STEM university majors and career pursuits and offer documentation to support their claims.

2.3 What Evidence Do We Have About the Effectiveness o f These Programs?

A small number of longitudinal studies support the claims of individual programs. For the most part, however, there is little funding available to follow participants over time, and only anecdotal evidence bolster the contention that STEM programs are effective in aiding adolescents' career trajectories.

2.4 Accessibility of STEM Programs Is Uneven

Aside from federal initiatives to promote study of STEM topics, there are the four previously mentioned locally or privately funded programs: special schools, apprenticeship/laboratory programs, competitions, and summer and after-school courses. Only 27 out of 50 states offer school programs ranging from STEM centers, magnet schools, governor schools, to exam schools. A select few of these states have five or more school STEM programs which appear in descending order: Michigan (10), Virginia (9), Georgia (8), New Jersey (8), New York (7), and Maryland (5). Other states of equivalent population offer no such opportunities. Although laboratory/apprenticeship, competitions and out of school course type programs recruit students from the entire country, participants do vary by region.

Another accessibility problem is due to the scope and sequence of STEM curriculum in U.S. schools. In the U.S., deep science instruction is introduced late in a student's career compared to other countries in Europe and Asia. In contrast, schools in other advanced nations, science is taught more regularly and is integrated as part of the curriculum thought primary school. Further the content of the curriculum in various states is not very rigorous. In Kansas, a debate has raged for years about whether or not to teach evolution. By not teaching principles of evolution, students miss out on biological concepts essential to a comprehensive science education. In addition, students who do not complete a "gatekeeper" algebra course in grade 8 have a difficult time completing all the other STEM courses they need in order to enter STEM majors in university [5]. During the middle school years, when interests are extremely malleable and key decisions are made based on interest, very few STEM related programs for middle school students reinforce deep existing interests that prepare individuals for careers in these fields.

To highlight the relative lack of available resources for adolescents, the National Association for Gifted Children (www.nagc.org) states that only 9 states allow middle school students to take high school courses and no states allow them to take college courses. More opportunity at this crucial time may influence more children to pursue the STEM route.

2.6 Teacher Qualification and Preparation

Another obstacle operating within the schools is the number of teachers who hold majors or certification in STEM subjects. Only 39% of U.S. students have a qualified chemistry teacher, 33% have a certified physics teacher, and 68% of secondary school students had a qualified mathematics teacher [6]. Through major legislative initiatives such as the law entitled, No Child Left Behind, states are required to ensure that teachers are "highly qualified." However, some states have established very low standards for what is considered "highly qualified" and students in those classrooms pay the price. Without adequate teacher preparation, it is impossible to improve the numbers of students who may take an interest in STEM subjects.

2.7 Low Status of STEM Careers

Too few U.S. students are entering STEM majors and careers. Only 30% of U.S. college students major in STEM disciplines compared to 59% of the students in China and 66% in Japan. Further, more than 50% of doctoral level staff and 58% of the post-doctoral fellows at the National Institutes of Health are foreign nationals. For STEM occupations, 38% of doctorate level employees are foreign born, up from 24% in 1990 [7]. As visas become more challenging to acquire and research facilities improve abroad, clearly that reliance on non-U.S. scientists can not be sustained.

3. Policy Proposals

3.1 Think Creatively About Talent Identification

One resource for STEM talent lies in underrepresented groups such as minorities and females. Six special schools focus special attention to underrepresented students. In addition, the Science Outreach at Rockefeller University and the University of Connecticut Mentor Connection, both apprenticeship/laboratory programs, specifically recruit females and minorities. Programs such as these are important because twice as many boys as girls demonstrate an interest in science, engineering, and technology by the eighth grade. Even when girls perform just as well as boys do, they lose interest in the STEM disciplines [8]. Specialized curriculum and opportunities may therefore enhance STEM interest and performance for these groups.

Another way to capitalize on potential interest in underrepresented groups is to experiment with selection criteria. Two special schools of particular interest are the New Orleans Charter Science and Mathematics High School in Louisiana and the Academy for Math, Engineering, and Science in Utah, both of which employ open admissions policies. If students select such a school over another one, will they perform as well as those who are selected based on tests?

Without such experiments, we will not be able to answer this question and gain further insights into components of STEM talent.

3.2 Coming to Consensus on Desirable Outcomes for Participants of STEM Programs

In order to demonstrate the effectiveness of the programs we reviewed, standard outcome criteria must be established. We propose that the following STEM related outcomes could provide a solid foundation for establishing standardized outcome criteria:

- enrollment in post secondary STEM programs,
- graduate satisfaction regarding preparation for STEM majors,
- achievement of graduates in STEM majors and/or careers,
- organizational and individual staff recognition for STEM related activities and accomplishments,
- and awards and honors won by graduates in STEM related contexts[2].

With such criteria in place, comparative studies can be conducted on effectiveness of various practices designed to foster STEM talent development.

3.3 Collecting Evidence About Effectiveness

Recent developments in the research design and statistical analysis allow us to test questions such as, (1) “Does this program work?” as well as (2) “Why does it work?” and (3) “Does it work better for some students than others?” Mixed methods designs combine the rigor of randomized controlled trials with qualitative methods such as interviews and focus groups. Multiple cohort longitudinal studies also give us tremendous insights into prediction and opportunities to analyze obstacles to talent development. These designs usually require cooperation across scientists and institutions because of costs and complexity. Such cooperation can lead to greater incentives to increase the number of demonstration sites and disseminate the outcomes widely.

3.4 Make STEM Opportunities More Accessible Across All Regions

Some states invest much more in adolescent STEM talent development than other states. This disparity poses the question, are there human capital payoffs for states that invest in adolescent STEM talent? If there are human capital payoffs, then what are the best predictors in terms of identification criteria to achieve these payoffs? Based on the notion that participation leads to achievement [9], the answers to these questions may prove as an inspiration to states that lack these types of programs and subsequently generate increased STEM interest in the U.S.

3.5 Improve STEM Teacher Education

During primary education students have the most favorable attitude toward science and teachers [10].

Though it may be difficult to identify talent in elementary school, teachers play a key role in retention of STEM interests throughout the secondary and post secondary school phases. Among the factors in determining retention in STEM subjects is the presence of a positive role model [11]. Given that teachers spend up to 50% of a child's waking hours with them during the school year, the potential influence they can assert on attitudes and perceptions is enormous.

It is imperative that teachers are thoroughly trained not only in their subject area, but also in how to deal with different populations of students in the same class, including those who have been identified as gifted. A teacher is a valuable resource who can encourage students and educate parents about the programs that have been discussed in this chapter.

3.6 Engendering More Interest Among U.S. Students

Although sport and music have long used coaches to maintain the stamina and focus needed to stay on task during difficult times, academic arenas have not embraced this notion. We propose that teachers and mentors adopt the role of academic coach during their work with gifted adolescents. We know that a young person may be expert with regard to knowledge and skills, but without motivation to overcome setbacks and patience to pursue difficult projects, this expertise will not be applied productively. Although we often assume that these qualities of persistence and resilience are innate, they can in fact be taught [12], [13]. According to research on talent development the role of psychosocial dimensions of talent development become increasingly important over time [14].

SM participation among U.S. youth has stagnated since the Sputnik era. When the government felt threatened in its science and technology race with the Soviet Union upon its successful launch of the Sputnik satellite in 1957, millions of dollars were invested in STEM talent development. Conducting a campaign to restore Sputnik era level luster and prestige to STEM careers would prove informative and useful. Attempts to answer the following questions could prevent further decreases in STEM involvement: Why are fewer students interested in pursuing STEM related careers compared to the Sputnik era? Is it possible that attitudes toward and stereotypes about those involved in STEM may deter otherwise qualified adolescents from becoming interested in the sciences and mathematics?

More perplexing, other countries in the world award a significantly higher proportion of degrees in STEM than the U.S. [15] and appear to hold STEM careers in higher regard. We would like to understand what cultural components lead to such differences in career development and possible different perceptions of status that lead to these outcomes.

Implications for Talent Identification and Program Goals

- The U.S. needs consensus on what we are looking for with regard to STEM talent (e.g. should we require excellent grades in pre-requisite STEM courses at school?).

- We will not have consensus until we agree on what program outcomes we are seeking (e.g. should most program alumni complete STEM majors at university?).
- We will not have consensus until we find out whether the talent identification mechanisms that are currently in place are predictive of those agreed upon desirable outcomes (e.g. do high scores on pre-requisite courses in school predict completion of STEM majors at university?).

- We need to understand the cultural factors that lead our colleagues in other parts of the world to continue to value STEM careers in ways that our youth do not.

- We hope that this analysis is useful for our colleagues as they assess their own nations' support for STEM talent development.

Endnotes

1. Outside the U.S. SM clubs, circles, and palaces are enjoyed by many talented students. This model is growing in influence, although there presence is more difficult to document as the other models.
2. These criteria are modified versions of those posted by the Marine Academy of Technology and Environmental Studies.

References

[1] Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, National Academy of Sciences, National Academy of Engineering, Institute of Medicine; Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. National Academies Press, Washington D.C., 2006.
[2] R.F. Subotnik, R.A. Duschl, and E.H. Selmon, Retention and Attrition of Science Talent: A Longitudinal Study of Westinghouse Science Talent Search Winners, *International Journal of Science Education* **15** (1993) 61-72.
[3] H. Zuckerman, Scientific Elite: Nobel Laureates in the United States. Transaction Publishers, New Brunswick, NJ, 1996

[4] C.P. Benbow, D. Lubinski, and H.E. Sanjani, Our Future Leaders in Science. Who Are They? Can We Identify Them Early? In: N. Colangelo & S.G. Assouline (eds.), *Talent Development III*. Great Potential Press, Scottsdale, AZ, 1999, pp. 59-70.

[5] R. Atanda. Do Gatekeeper Courses Expand Education Outcomes? Education Statistics Quarterly, 1. 1999.
[6] National Commission on Educational Statistics. Out of Field Teaching in Middle and High School Grades, 2003.
[7] Committee on Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States, Board on Higher Education and the Workforce, National Research Council. Policy Implications of International Graduate Students and Post Doctoral Scholars in the United States. Washington DC, National Academies. 2005.
[8] Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development, Land of plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology. National Science Foundation, Washington, D.C., 2000.
[9] C. Sorge, H. Newsom, and J. Hagerty, Fun is Not Enough: Attitudes of Hispanic Middle School Students Toward Science and Scientists, *Hispanic Journal of Behavioral Science* **22** (2000) 332-345.

[10] B.L. Barrington and B. Hendricks, Attitudes Toward Science and Science Knowledge of Intellectually Gifted and Average Students in the Third, Seventh and Eleventh Grades, *Journal of Research in Science Teaching* **25** (1988) 679-687.
[11] T. Koballa, Persuading girls to take elective physical science courses in high school: Who are the credible communicators? *Journal of Research in Science Teaching* **25** (1988) 465-478.
[12] J.C. Cogan, R.J. Sternberg, and R.F. Subotnik, Integrating the Other Three Rs into the School Curriculum: A Model For Improving Achievement. In: R.J. Sternberg and R.F. Subotnik (eds.), Optimizing Student Success with the Other Three Rs: Reasoning, Resilience, and Responsibility. Information Age, Greenwich, CT, 2006, pp. 227-240.
[13] C. Good, and C.S. Dweck, Motivational Orientations that Lead Students to Show Deeper Levels of Reasoning, Greater Responsibility for Their Academic Work, and Greater Resilience in the Face of Academic Difficulty. In: R.J. Sternberg and R.F. Subotnik (eds.),Optimizing Student Success with the Other Three Rs: Reasoning, Resilience, and Responsibility. Information Age, Greenwich, CT, 2006, pp. 39-58.
[14] R.F. Subotnik and J. Calderon, Developing giftedness and talent. In: F. Karnes & K Stephens (Eds.), *Gifted Education*, (In Press) Pearson.

[15] Science and Engineering Indicators, National Science Foundation, 2002.