

***The STEM Promise: Recognizing and Developing Talent and Expanding Opportunities for Promising Students of Science, Technology, Engineering and Mathematics***

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**Overview**

Science, Technology, Engineering, and Mathematics (STEM) are critical to our economy, our national security, and our global leadership in innovation and research. Our key resource lies in students with mathematical and scientific promise, those with potential to become leaders in STEM fields. This includes students who traditionally have been identified as gifted, talented, bright or precocious in mathematics as well as those students with potential who may have been excluded from the rich opportunities that might accompany this recognition. Many of our students with the greatest aptitude are underachieving, languishing in repetitive, unchallenging classes. As with all students, these special needs students deserve a learning environment that lifts the ceiling to currently unknown heights and pushes them to make continuous progress throughout their academic careers. In this competitive, technological world, we cannot afford to waste the talents of students with the greatest potential to lead us to creative and productive futures in mathematics and science.

***What does the research tell us?***

Loveless (2008), in a study of the effects of No Child Left Behind on NAEP mathematics scores across the country, noted that students above the 90<sup>th</sup> percentile have made the least progress. He quotes Susan Goodkin (2005) in the *Washington Post*, “By forcing schools to focus their time and funding almost entirely on bringing low achieving students up to proficiency, NCLB sacrifices the education of the gifted students who will become our future biomedical researchers, computer engineers, and other scientific leaders.” Farkas and Duffett (2008), found that in spite of teachers’ desire to work with all students and the realization that top students needed more challenge than they currently receive, teachers report paying little attention to top students who had already mastered the skills being tested. The percentage of U. S. students majoring in STEM disciplines and choosing STEM careers is decreasing while the percentage of foreign students in these fields is increasing. (National Research Council, 2005) Other countries are recognizing the need to invest in these critical human resources while the U. S. lags in this effort (Colvin, 2007; National Research Council, 2007). Mathematics and science performance of U.S. students has improved on such tests as the National Assessment of Educational Progress, Advanced Placement, ACT, and SAT. However, U.S. students continue to perform below the level of peers in many other industrial countries in mathematics, science and problem solving on assessments from the Program for International Student Assessment (PISA) (National Center for Education Statistics, 2007) and the Trends in International Mathematics and Science Study (TIMSS) (National Center for Education Statistics, 2004). Nearly twice the percent of students in New Zealand and Finland reach the two highest levels on PISA science as students in the U. S. Twenty-three of thirty OECD countries had students at the 90<sup>th</sup> percentile with higher scores than

the U. S. on the PISA mathematics literacy scale. In 1995, on the 12<sup>th</sup> grade TIMSS, the students scoring at the 95th percentile in the U.S. scored about as well as the best 25 percent of students in those other countries. Our most advanced students, defined as the 5 percent taking AP calculus and the 1 percent taking AP physics, scored about as well as 10-20 percent of the most advanced students in the other countries. Unfortunately, because the U. S. has decided not to take part in the 2008 twelfth grade TIMSS, which was last given in 1995, there is no way to determine the direction of recent trends. According to a study from the National Foundation for American Policy, 60 percent of the U. S.' top science students and 65 percent of the top math students are the children of immigrants. (Anderson, 2004) The data seem clear that the top PreK – 12 U. S. students, especially those whose families are native-born, lag behind the top students in many other countries at a time when their talents are sorely needed.

### ***What are the implications for action?***

Given the need to recognize and develop promising and already accomplished students and to provide them with significantly additional opportunities in all the STEM fields in the United States, the following steps are recommended. Each of these is described in detail in the following sections.

#### *Discover the potential.*

Discovery of potential in STEM areas should be conducted in such a way as to maximize the number and level of mathematically and scientifically promising students included in high-level opportunities. Parents, teachers, guidance counselors, the community and the students themselves need to value and celebrate developing STEM abilities, much as we celebrate athletic prowess beginning in early childhood and continuing throughout a student's school career. The development of this potential includes expanding the ability of students to make sense of and appreciate deep mathematical and scientific concepts and ideas, persevering in challenging explorations, believing that mathematics and science are valuable, and that mastery of complex concepts is dependent upon hard work. These variables - ability, motivation, belief, and experience- are not fixed and must be developed and supported by the home, school and community so that students' success is maximized and celebrated. Aptitudes and abilities of students, regardless of gender, ethnicity, language or socio-economic background, can and should be recognized in order to help them achieve their full potential. These identification measures might include self-selection; affective measures; observations of students during the problem-solving process; teacher, parent and/or peer recommendation; standardized tests, especially when used off-level; measures of creativity; insightful solutions to problems; grades in mathematics and science classes; and/or portfolios of research, problems and projects in mathematics and science.

#### *Develop talent and strengthen opportunities at all grade levels.*

All students with STEM potential should be provided powerful and rigorous STEM experiences and held accountable to the highest world-class standards, beginning at the earliest ages and throughout their schooling. Expectations must go beyond minimal proficiency in mathematics and science and assessment must be multi-faceted, lift the ceiling, and encourage depth of reasoning. Opportunities and materials for learning high-level, innovative mathematics and science should be readily available where students can work with peers of similar interests and abilities. These opportunities should include the investigation of challenging, rich, complex problems, conducting authentic scientific research, joining STEM clubs, entering STEM

contests, and accessing mentors. In addition, students need access to systematic, timely, continuous progression through a high-level, challenging, creative curriculum. As noted in the Final Report of the National Mathematics Advisory Panel (2008, p. 81), “Gifted (or academically advanced) students ... need a curriculum that is differentiated (by level, complexity, breadth, and depth), developmentally appropriate, and conducted at a more rapid rate... Mathematically gifted students with sufficient motivation appear to be able to learn mathematics much faster than students proceeding through the curriculum at a normal pace, with no harm to their learning, and should be allowed to do so.” Every high school should offer high-level STEM classes such as Advanced Placement and International Baccalaureate, ensuring that all students take appropriate, rigorous mathematics and science classes every year from elementary through high school. Vertical teams of teachers from elementary, middle and high schools should work together to prepare students for these classes, and students of any age should progress freely to higher-level classes once they demonstrate mastery of a course. State and national content standards and assessment must lift the ceiling and provide opportunities to go beyond the level of proficiency. In addition, the U. S. should participate in the Advanced TIMSS.

Teachers need ongoing professional development experiences beginning in their undergraduate courses to assist them in recognizing and developing students with mathematical and scientific promise, differentiating instruction and providing for continuous progress. Many teachers need more background themselves in the depth and complexity behind the mathematical and scientific content appropriate for the students with whom they work. Fellowships, scholarships, internships and mentorships as well as print, electronic, and human resources and support should be readily accessible for these teachers.

*Create out-of-school programs to develop STEM talent and interest.*

It is the civic responsibility of a wide range of stakeholders - institutions of higher education, community and industry leaders, NASA, leaders in professional organizations both in education and in technological fields, government, and the media - to support, mentor, fund, sponsor, and promote students with mathematical promise for the improvement of society and the development of world class citizens. Mathematicians, scientists, engineers, and technology experts have much to offer, and the education community should collaborate with them in such efforts as mentoring, apprenticeships and lab programs, the development of challenging summer, after-school, and online programs and materials, and support of competitions.

## *Discover the Potential*

In 1980, the National Council of Teachers of Mathematics (NCTM) made a bold statement, "The student most neglected in terms of realizing full potential is the gifted student of mathematics." Research shows this is very similar in science. As test scores indicate, progress since that time in addressing this need has been slow or nonexistent. Clearly, our present system of STEM initiatives is failing. This is especially true for students from economically disadvantaged backgrounds. The first step in nurturing STEM potential is identifying and developing it in students. We must approach this task with fresh eyes and broadened minds.

### *What does the research tell us?*

Research shows that STEM talent is not one-dimensional nor is it the same for all those who possess this gift (Davidson & Sternberg, 1984; Frensch & Sternberg, 1992; Krutetskii, 1976/1968; Sheffield, Bennett, Berriozabal, DeArmond, & Wertheimer, 1999; Sriraman, 2002; Adams & Pierce, 2008). In 1994, the National Council of Teachers of Mathematics (NCTM) Task Force on the Mathematically Promising made recommendations regarding identification and programming (Sheffield, Bennett, Berriozabal, DeArmond, & Wertheimer, 1999). The task force defined mathematical promise as a function of ability, motivation, belief, and experience or opportunity. This definition used the words "mathematical promise" deliberately in order to include students who have been traditionally identified as gifted and to add students who have been traditionally excluded from rich mathematical opportunities that would allow for talent identification and development. (Sheffield et al., 1999). Unlike the NCTM, the National Science Teachers Association (NSTA) has not yet convened a task force to study the identification of and programming for scientifically promising students. Furthermore, NSTA currently has no position papers written expressly about identifying scientifically promising students. Thus, little attention has been given to both the identification of scientifically promising students and programming to meet their needs. In 1988, Paul Brandwein identified three factors for predicting high ability in science: genetic (e.g. high math ability, good neuromuscular control), predisposing (e.g. curiosity, persistence), and activating (e.g. opportunity). Gardner has included the naturalist intelligence within his multiple intelligences (1995). Both researchers address the important role creativity plays in the development of science talent.

Perhaps because standardized intelligence and achievement tests have been vetted so widely and carefully for statistical purposes, they are the most widely used measure for identifying gifted students, including mathematically talented students (Callahan, Hunsaker, Adams, Moore, & Bland, 1995; Sowell, Bergwell, Zeigler, & Cartwright, 1990). However, these tests may not identify many students who are truly gifted in mathematics because they concentrate on tasks that do not require students to think and reason in ways that mathematicians do (Sheffield, 1994). Moreover, the NCTM task force states that traditional methods of identifying gifted and talented mathematics students, such as by way of standardized test scores, may be used to limit rather than broaden the pool of students identified as mathematically promising. Having reviewed research on identification procedures, Sowell et al., (1990) concluded that the use of more than one instrument is the most desirable. This is especially helpful in identifying students from disadvantaged backgrounds with mathematics potential. "NAGC believes that assessments selected for use in the identification of gifted students must be sensitive to and appropriate for the characteristics of the students being assessed and must aim to be inclusive of students from different cultures, races, and economic circumstances. Program administrators should choose the most valid and reliable assessments for their population of

students and programs and use them appropriately for selection (see Lohman, 2005). However, it is also imperative that test users and policy makers understand that alternative type assessments are not panaceas to the issue of under-representation, each come with limitations in terms of reliability and validity, and that these types of assessments should never be used in isolation to identify gifted children.” (NAGC, 2008, p. 8) Likewise, there is no one assessment that can be used to identify science talent. A standardized test of science achievement and a standardized intelligence test are most commonly used by schools to identify students gifted in science. Both Brandwein (1995) and Gardner (1995) suggest actually observing students as they design and work through an experiment; using the same processes scientists use might be a more authentic way to discover science talent. The problem with this notion is that there is little science occurring on a regular basis in elementary school. If clearly articulated, challenging, inquiry-based, authentic activities are not used in the classroom, there will be little chance to observe science talent.

### ***What are the implications for action?***

Each of the factors in the NCTM task force definition of mathematical promise - ability, motivation, belief and experience, should be used as part of the process to help discover the potential in students with mathematical promise. A wider range of instruments and creative use of existing instruments are needed to identify mathematical ability. For example, standardized tests used off-level, such as testing seventh grade students on the mathematics portion of the SAT, may be an appropriate assessment of analytical thinking for younger students since younger students have generally not had explicit instruction in the areas being tested, and in this way, the test provides a sense of mathematical reasoning abilities. This method has been used in the Study of Mathematically Precocious Youth (SMPY) for over 35 years and has identified hundreds of thousands of students who outperform the students for whom the tests were originally developed. Longitudinal studies show that scoring well on the SAT-M in middle school is a good predictor of participating in STEM majors and STEM careers (Lubinski and Benbow, 2006).

However, focusing solely on mathematics or scientific achievement, be it grades or test scores, may not identify those students who possess or are capable of developing creative mathematical and scientific thinking. As noted in the NAGC (2008, p. 2) position paper on *the Role of Assessments in the Identification of Gifted Students*, “Identification of gifted and talented students should not be based on a single assessment. Rather, multiple pieces of evidence should be collected that measure different abilities and characteristics aligned to the gifted program’s definition, goals, and objectives.” In addition, ability, including the structure of the brain, is not fixed and develops with appropriate challenges. With the right support from peers, educators and families, and mathematics and science that is relevant for them, those students with potential could blossom into talented mathematicians, scientists, or engineers. Additionally, there are students who have not been given appropriate experiences to demonstrate their talents in the STEM fields. Some of these students come from impoverished backgrounds, and others come from classrooms in which they never had the opportunity to solve interesting non-routine problems or conduct scientific experiments or research. We need to seek these students and nurture their potential.

How can this be accomplished? Unless parents, educators, and society in general believe in and do not disregard students who may have fewer opportunities, less exposure to excellent teachers and have traditionally been overlooked due to gender, socioeconomic status, or race, we

will miss another opportunity to find students with STEM talent that are desperately needed. We must move beyond standardized testing and broaden our identification measures for identifying promise in STEM fields. Research-based rating scales to identify behavioral characteristics of mathematically talented students, such as eagerness to solve challenging problems, enjoyment in solving mathematical puzzles, exhibiting strong number sense, and solving problems in creative and unusual ways, can be used to uncover math potential in students (Gavin, 2005). Informal observation by teachers during performance tasks and follow-up interviews of students may also help to increase the likelihood of an inclusive and valid identification process. Offering students an interesting high-level mathematical task and seeing how students approach this task can uncover creative mathematical potential in students who may not score well on standardized tests and/or do not do well with memorizing math facts or basic computation. It is important to note that Krutetskii specifically identified swiftness, computational ability, memory for formulas, and other details as “not obligatory” though useful characteristics of mathematical giftedness (Krutetskii, 1976/1968; Sowell et al., 1990). We must look beyond the ability to compute quickly to find students who may be our future mathematicians.

Other identification measures that might be used to supplement standardized tests might include parent/self/peer nominations, measures of creativity, measures of non-verbal ability, student portfolios, and/or projects. Gavin and Adelson (2008) have outlined limitations of various specific individual measures for identification. Along with others, they recommend ongoing use of multiple measures of identification, including both qualitative and quantitative measures, to help insure a more inclusive procedure, as mathematical talent in students can and does manifest itself in unusual ways and at different times. Similarly, to nurture science talent, we first must find students who exhibit these characteristics. Although scores on intelligence tests and science achievement tests can provide some assistance in identifying science talent, alternate measures such as the Group Embedded Figures Test should also be used. Checklists or rating scales developed to address the personality traits of scientists (Adams, 2003) may also provide data to assist with identifying science talent. Creativity tests may add another dimension to the identification process. If observation is an importance process in finding science talent, then we need observation instruments that can be used to gather data about students’ ability to plan, carry out, and complete a scientific investigation as well as to identify the extent to which students’ use basic (e.g. classifying) and integrated (e.g. controlling variables) science process skills (Adams, 2003).

It would be much more fruitful if teachers thought of themselves as talent scouts always seeking new students rather than working as gatekeepers when selecting students for high-level STEM courses and programs. Finally, once students’ levels of potential have been discovered, their talent and enjoyment of mathematics and science needs to be nurtured so that they will continue to pursue STEM fields and perhaps become our next generation of creative mathematicians, scientists and engineers.

## ***Develop Talent and Strengthen Opportunities in Elementary and Early Childhood***

A chief concern with mathematics and science instruction in the United States today is that some of the most promising students are being neglected due to educational initiatives such as No Child Left Behind. An ongoing rationale for this neglect comes from the misconception that if promising students are left alone, they'll succeed academically.

### ***What does the research tell us?***

The notion that promising students will succeed on their own is of course erroneous. (National Bureau of Economic Research [NBER], 2007) empirically illustrate that this neglect of promising students is taking place in the Chicago Public School Corporation with students who are deemed capable of passing the state standardized test. Teachers have been told to, “cross off the students who, if handed the test tomorrow, would pass” (p. 1, NBER, 2007). DeLacy (2004) substantiates this point with data to suggest that average achievers are learning the most and the highest achievers are learning the least in the current school context. Similarly, a study by the Fordham Institute indicates that low achievers are experiencing significantly more improvement in math relative to high achievers (Loveless, Farkas & Duffet, 2008). Data from their studies further indicate that teachers pay greater attention to low performing students than they do high performing students. Clearly, the most promising young mathematicians and scientists are not being served. According to Chamberlin (2005), advanced mathematics students left alone are in danger of perishing academically

In a recent study, Bain, et al. (2007) asked pre-service teachers to respond to the prompt, “Children who are truly gifted are likely to excel even if they do not receive special services.” An astounding 76% of the pre-service teachers felt that these students would do well without any intervention(s). It is possible if the measure of mathematical and scientific competency is a state standardized assessment that promising students will do well. The problem however, comes about when promising students in the United States, who have not been challenged, compete with international students who have been challenged. International students typically fare much better than the American student who has been left unattended Feldhusen and Kroll (1991) documented empirically that the lack of challenge among kindergarten and elementary students led to a reduction in positive attitudes toward an academic area, including mathematics and science. Tomlinson, et al. (1994) document that some teachers use students of promise as tutors for struggling classmates as a substitute form of challenge rather than taking time to provide them with advanced instruction.

### ***What are the implications for action?***

The NBER (2007) findings are troubling. This study shows that classroom teachers are implicitly, and sometimes explicitly, encouraged to neglect students of great promise as well as students requiring significant remediation. One implication is that high-stakes federal and state assessment and accountability systems such as No Child Left Behind need to be reworked so teachers will have an impetus to instruct and pay attention to all students. NBER suggests that using growth models and gain scores might provide schools with a drive to educate all students rather than simply students just under the proficiency demarcation. Another implication is that

differentiation of instruction could be a key element in advancing, although this requires professional development and experience in order to be most effective.

The Bain, et al. (2007) study suggests that it has become acceptable to neglect the gifted student in the elementary classroom. To rectify this problem, increased training in gifted education as well as increased knowledge and cognizance of how curricula are created must be addressed so excessive redundancy can be avoided and coherence can be accomplished in curricula and standards (Schmidt, Wang, McKnight, 2005). Excessive redundancy in curricula can cost as much as a half-year of instruction time.

Ginsburg, et al. (2006) state that few early childhood educators have had (any) preparation in early childhood mathematics. This is not a trivial problem as the formation of concepts at a young age is critical to success at mature ages. It's a safe generalization that the same could be said for science. Undergraduate coursework in mathematics and science content and pedagogical content knowledge needs to be included in teacher preparation for early childhood and elementary teachers as this is perhaps the most critical developmental period for number sense, the basis for much of mathematics and science. Professional development in content knowledge and pedagogical content knowledge in the STEM fields as well as in differentiation and gifted education should continue throughout a teacher's career. In addition, vertical teams of teachers should work together to ensure continuous progress for all students, including those at the top.

The Feldhusen and Kroll (1991) study suggests that boredom is a regular component of the classroom among gifted students, however this need not be the case. It would therefore not be surprising to walk into an elementary mathematics or science classroom to see students of promise disengaged from the content. Boredom can lead to educational complacency. To arrest this problem, teachers need to seek curricula that actively incorporate creative, challenging, and engaging mathematics and science tasks in the elementary classroom. A focus on genuine mathematical problem solving and inquiry in science courses is a step in the right direction. Other opportunities should include access to STEM clubs and contests and mentors in the STEM fields for all students.

## *Develop Talent and Strengthen Opportunities in Middle and High School*

**The United States risks losing its edge in the 21<sup>st</sup> century if our brightest students cannot apply scientific and mathematical knowledge to problems that challenge them in the real world to the degree that students in other nations can.**

### *What Does the Research Tell Us?*

In the most recent analysis of the results from the 2005 National Assessment of Educational Progress (NAEP, 2005) we know that America's students in math and science are still lacking in basic content knowledge, problem-solving skills, and high-order thinking skills. Nationally, 71% of eighth graders scored below the Proficient level on the NAEP in science, indicating that they lack the knowledge necessary to apply scientific concepts and principles, while only 3% performed at the Advanced level. At twelfth grade, 82% were below proficient and just 2% reached the advanced level. Essentially, the percentage of eighth grade science students scoring at or above Proficient in 2005 has not improved since 1996 and worse still, the percentage of students at the Advanced level has declined. Even more distressing is the fact that twelfth grade science scores at all levels declined, including a decline from 3% at Advanced to 2%. Unfortunately at twelfth grade, scores on tests for all fields of science - earth, physical, and life - declined significantly from 1996. Scores on the ACT exam indicate students are unprepared for college level work. For example, on the ACT Science Test, only 28% of all students' scores indicated a readiness for college science (ACT, 2007), and only 5% of African American students met this benchmark. On the international level, American 15-year-olds scored an average of 489 points on the 2006 Program for International Student Assessment (PISA), which measures science literacy, down from 491 in 2003 (Cavanaugh, 2007). According to a report on the Third International Mathematics and Science Study (TIMSS) (USDOE, 1996), if "an international talent search were to select the top ten percent of all students in the 41 TIMSS countries combined," only 13 percent of US students in science would be selected compared to 31% of Singaporean students, 18% of Japanese students, and 19% of those in the Czech Republic."

Eighth grade students at the *Basic* and *Proficient* levels scored higher on the mathematics portion of the 2007 NAEP than in previous years (NAEP, 2007). Although the percentage of students at or above *Basic* increased 19 points from 1990 to 2007 and the percentage of students at or above *Proficient* increased 17 points, the percentage of students at or above *Advanced* during the same time period increased by only 5 points (NAEP, 2007). Asian/Pacific Islanders scored significantly higher than other racial/ethnic groups at all levels, with 17% scoring at or above *Advanced* compared to only 9% of White students, 2% of Hispanic and American Indians and 1% of Black students. Seniors in the class of 2007 performed better on the ACT Math Test than they did on the Science Test, with 43% meeting or surpassing the College Readiness Benchmark (ACT, 2007). On the downside, this means only 43% of students taking the ACT are prepared to be successful in college course work. However, only 15% of those taking the minimum core high school courses (Algebra I, II, and geometry) were deemed ready to take a college algebra class. Of those who took trigonometry in addition to the core classes, 40% met or surpassed the benchmark (ACT, 2007). Although math was not tested in as much depth on the 2006 PISA as science, U.S. students still performed poorly. Their average score was 474, 24 points below the international average for industrialized nations. In fact, only Italy, Greece, Turkey, and Mexico scored lower (Cavanaugh, 2007). The Education Longitudinal Study (ELS)

followed a national sample of tenth grade students in 2002 who were re-assessed in 12<sup>th</sup> grade in 2004 (NCES 2007). This assessment of their mathematics performance looked at both specific skills and overall performance. The specific skills were leveled from simple arithmetic operations using whole numbers to solving complex multi-step word problems. While 96% of seniors reached proficiency in simple arithmetic operations, the percentages reaching proficiency decreased as the skill level increased. At the highest skill level, only 4% of seniors were proficient in solving complex, multi-step word problems.

What is happening in middle and high school classrooms that causes such abysmal showings on national and international assessments? Why do even our brightest students wane in comparison to bright students in other nations? We know that there is little instruction occurring in elementary science for students in general and gifted students in particular (Adams & Pierce, 2008), implying that many gifted students do not begin a serious study of science until middle school. Unfortunately, several studies of middle school science texts indicate they are inadequate, contain irrelevant material, are fraught with misconceptions, and are not conceptually-based, leading to content that scratches the surface on many topics and covers nothing in depth (AAAS, 2002, Hubisz, 2003). Since these texts are selected for general use in middle school science, these issues affect all students, whether identified as gifted or not. Teachers may not be adequately prepared to teach mathematics or science, especially at middle school. Many never had laboratory experiences themselves and have little inclination to set up one if the text they are using doesn't suggest appropriate labs (Hubisz, 2003). In mathematics, many have only experienced lectures and have not been actively involved in solving complex problems themselves. This makes it difficult to lead these types of experiences for students. In addition, there may be a disconnect between students' (and their parents') notions of the amount of math and science required for certain career choices. In a study of adolescent girls who were considering a science-related career, Adams (1994) found that many had no notion of the amount of math and science that would be required to meet their career goals, and in some cases had not planned on taking math beyond algebra

### ***What are the Implications for Action?***

Scores at the most advanced levels of national and international assessments demonstrate the need for clearly articulated, scientifically accurate, relevant, science and mathematics curriculum. High-stakes state and national assessment must move beyond minimal levels of expectations and lift the ceiling for our highest-achieving students. Schools must offer more advanced courses in math and science with highly qualified math and science teachers to teach these courses, as well as focusing the teaching on challenging material. If students are choosing to pursue careers in STEM fields by middle school, then it is vital that good science, mathematics and career planning begin early, particularly for gifted students. Teachers must be prepared to meet the needs of all students, including advanced students. An overemphasis on students who have not reached proficiency often prevents teachers from meeting the needs of students in their classes who have reached and often surpassed proficiency.

All middle and high schools must offer high-level mathematics and science courses, including Advanced Placement, International Baccalaureate, and quality dual-credit college courses at the high school level. To prepare for these courses, teachers must work together in vertical teams from middle grades through high school to plan articulated experiences to ensure continuous progress, interest and readiness for greatly increased numbers of students.

## *Create Out-of-School Programs to Develop STEM Talent and Interest*

Elementary school curricula play a key role in establishing mathematical and scientific foundations for all students. As addressed in other paper(s) in this series, however, few promising students get the foundation they need to succeed in mathematics and science at upper levels. Another source of enrichment and talent development for many gifted students is found outside of schools. These programs held after hours, on weekends, or during the summer attract young people who are interested in investing free time to learn about STEM and interact with other youth with similar interests. Based on preliminary evidence, they play an especially important role in developing talent of secondary students.

### *What does the research tell us?*

Two important points must be noted. First, many gifted adolescents have uneven profiles; that is, they can demonstrate gifts in one area but low competence or even a lack of ability in another area (Winner, 2000a, 2000b; Newman & Sternberg, 2004). For example, some students have great acuity in mathematics or spatial visualization but little in verbal reasoning. Second, each subject area has its own trajectory, and passage from one stage of talent development to the next takes place at different ages in different subjects (Simonton, 1989; Simonton, 1991a; 1991b). For example, mathematical abilities can be harnessed and recognized early (Feldman & Goldsmith, 1986), while the accumulated experience and content exposure necessary to produce historical analyses makes it hard to recognize talent in humanities, such as history, until adolescence. Talent development involves successive transformations of abilities into competencies, competencies into expertise, and finally expertise into scholarly productivity (Jarvin & Subotnik, 2006). The progression from one stage to the next results from an interaction of personal and environmental factors, and, although the age at which one reaches each stage is domain-specific, the middle stage, developing competencies into expertise, represents a “make it or break it” point with regard to continuing pursuit in a domain. This transition will typically take place in adolescence. Schooling, particularly at the secondary level, is usually not rich enough to support transforming high-level talent development in mathematics and science into creative productivity. Unless the school has specialized curricula, including research seminars or apprenticeship programs, almost all advanced talent development happens after school and in the summers. Three out-of-school program models exist to identify and develop STEM talent:

- 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;
- Summer and after-school courses – for middle and high school students.

Subotnik, Edmiston, and Rayhack (2007) reviewed websites from over 100 out-of-school programs and came up with the following analysis.

### *Apprenticeships/Laboratory Experiences.*

Apprenticeship/laboratory programs provide introductions by mentors into professional networks and associated values. Fifty percent of the apprenticeship and laboratory programs reviewed by Subotnik et al. 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.

### *Competitions*

Competitions, e. g. Mathcounts, in general, aim to promote STEM fields and make them accessible to a wide variety of students. For that purpose, initial entry 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 Intel Science Talent Search 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 6 Nobel Prizes, 3 National Medals of Science, 2 Lasker awards, 10 MacArthur Foundation Fellowships and 2 Fields Medals.

### *Summer and After School Courses*

Adolescents who are not satisfied with the quantity or quality of their schools' STEM curriculum can take summer and after school courses at various universities. Subotnik et al. examined 19 providers of enrichment courses that offer talented students classes that are challenging and stimulating including those under the Talent Search umbrella. Seventeen of the providers have admissions criteria, 11 of which include STEM 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.

### *Implications for Research, Policy, and Practice*

Information about the opportunities available by way of out of school programs is not widely accessible to school counselors. Nor do many students have the support of peer groups, educators, or families to seek existing opportunities. In many areas of the country, opportunities to pursue STEM interests outside of school are not readily available. The high costs of some programs also put them out of reach for some talented students, although scholarships are available at times. Teachers, administrators and counselors should work with parents and interested community members to offer programs, ensure that information is disseminated and to encourage students to take advantage of interesting and challenging experiences such as competitions, mentorships, apprenticeships, math and science clubs, and summer and after-school programs.

Further, rigorous studies to demonstrate the effectiveness of out-of- school programs to funders and government agencies are needed. The scarcity of such studies is most likely due to the fact that foundations that support these programs do not provide sufficient funding for evaluations. Currently there is evidence that there is greater student achievement in fast-pace courses of the Talent Search model than in school settings (Olszewski-Kubilius, 2007). Additional research to explore whether one program model is more efficacious than another at particular stages of talent development in STEM is also needed. A strong research agenda will be able to enhance what is known about practice and about the role of out-of-school instruction --- that it meets a crucial need by providing talented young mathematicians and scientists with expert instruction, a challenging peer group, and socialization into the values of these important disciplines.

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