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How to Motivate US Students to Pursue STEM (Science, Technology, Engineering and Mathematics) Careers

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STEM (science, technology, engineering and mathematics) has been a powerful engine of prosperity in the US since World War II. Currently, American students' performances and enthusiasm in STEM education are inadequate for the US to maintain its leadership in STEM professions unless the government takes more actions to motivate a new generation of US students towards STEM careers. Despite of coherent actions taken by the government and various institutions, the US cannot ensure the production of a sufficient number of experts in STEM fields to meet its national and global needs. The current situation is that the US is largely dependent on the foreign-born STEM workforce. This paper starts with a deeper look at the participation rate of American students in STEM careers and the basis of career choices by the US students. The discussion is driven by barriers and misconceptions about STEM education. It concludes with recommendations for how to motivate more US students to pursue STEM careers.

Keywords: STEM (science, technology, engineering and mathematics), career choice, barriers, misconceptions, motivation

Introduction

STEM (science, technology, engineering and mathematic) includes some of the most versatile and important careers in the contemporary world. Most new developments that are making the world a better place to live in are from the contributions of STEM fields. As the world becomes more technologically developed, the economy, power and leadership of the US are becoming more heavily based on effective practice and the number of skilled workers in these fields. As a result, the success, security and leadership position of a nation depend not only on the use of technology, but also the number of native workers in STEM fields. The technology-driven economy and skilled workforce in STEM fields are the driving force for innovation of a nation. The US possesses the most innovative and technologically capable economy in the world. Despite of a glorious record of achievement in technology, the US lags behind many less developed nations in STEM education in elementary, secondary and higher education. As the US invests more money and efforts to promote improvement in STEM education, the number of foreign students and workers in these fields is increasing significantly (Borjas, 2004; Kuenzi, 2008; National Center for Education Statistics, 2009).

In the proportion of 24-year-old that earns degrees in STEM fields, the US currently ranks the 20th in the world (Kuenzi, 2008). Once, for the leader in science and technology, the US is now behind many countries on

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several measures in STEM education. Current progress is not satisfactory for the nation to address its ailing economic situation and continue global leadership in technology and innovation. It is assumed that many high-STEM-ability US students fail to realize their full STEM potential at the high-school level, or many of them leave their career choices in STEM fields entirely at the college level. There exist a lot of magnet STEM programs nationwide that are largely responsible for developing much of the talent emerging from the public school system. These programs, however, are not necessarily available to underprivileged students, and some are being cut due to current budget restraints. According to Wasserman (2008), retaining these students in STEM and enhancing their high-school STEM experiences are simpler than recruiting additional students. These students could be considered as the low-hanging fruit in the NSB's (National Science Board) efforts to produce the next generation of innovators. Sometimes, their talent and potential are overlooked, under-developed and underutilized. However, they should be a target group for the nation's strategy for developing a STEM workforce. This is apparently the only way to strengthen the economy and leadership of the nation; by preparing a substantive number of American citizens capable of working and leading in the nations science and technology sectors.

Although many US students excel in STEM, as a whole, US students performance in international comparisons on science and mathematics tests are consistently below average or in the third quartile (PCAST—President's Council of Advisors on Science and Technology, 2010). The situation is that STEM education in the US is failing to motivate American citizens to attain sufficient skills and knowledge required to meet the century's challenging economic and leadership needs (NSB, 2007). There are wide disparities in STEM achievement among various ethnic groups, and too many American students and parents believe that STEM subjects are too difficult, boring or exclusionary (PCAST, 2010). Research evidence indicated that many of the proficient American students, especially the minority and women groups, have been switching their career choices in STEM fields towards other professions (Denson & Hill, 2010). Although Hispanics and the black students in America's college-age population are increasing, their participation rates in STEM fields are significantly lower than those of the white and Asian Americans (Sanders, 2004).

As the nation continues to advance through the first quarter of the 21st century, there is a growing need for educators to be less dependent on the foreign or foreign-born STEM workers and take appropriate actions to inspire and prepare native-born American students towards STEM education.

Statement of the Problem

Over the past two decades, the US STEM workforce has grown at more than four times the rate of total employment. At the same time, the proportion of US citizens qualified to fill STEM jobs is stagnating (University of California, 2010). According to a 2004 high powered US Education Commission, the STEM workforce in the US largely depends on foreign-born mathematicians, scientists and engineers (Sanders, 2004). In this rapidly growing competitive market, industry prefers graduates who have the potential to meet their research and development needs, and compete effectively with their counterparts worldwide.

Too many highly paid STEM jobs are now occupied by the foreign or foreign-born workers in the US. The overall situation is a warning that it is less likely that the US will maintain its local and global leadership in STEM professions unless the government takes remedial action to produce or import enough experts in these fields. As the nation continues to advance through the second decade of the 21st century, there is a growing need to, not only depend on the foreign-born workforce in STEM fields, but also take appropriate initiatives to prepare local expertise in these fields. This, problem is causing difficulty for American educators and legislators during the recovery of the current recession and it hinders the US ability to sustain its competitive position. Thus, the question arises as to whether the US should continue its dependence on other countries for required STEM workers or take action to motivate more American middle and high school students towards the STEM pipeline. Maybe both are needed to generate enough scientists, technologists, engineers and mathematicians to create the new ideas, products and entirely new innovations in the 21st century.

The Participation Rate of American Students in STEM Careers

The current pipeline and participation rates for US trained STEM professionals are thought to be inadequate to meet the nation's needs. Due to lack of proper motivation, many high-STEM-ability students fail to realize their full STEM potential in high school or leave the STEM track in college. According to the EWC (Engineering Workforce Commission) report of 2005, over the past 20 years, the total number of students who received bachelor's degrees in engineering declined by 19.8% in the US. During the 2000-2010 periods, employment in science and engineering occupations would have been expected to increase about three times faster than the rate for all occupations. According to another report from the Computing Research Association, enrollment in undergraduate degree programs in computer science is more than 50% that is lower than that of five years ago. Between 2005-2006 and 2006-2007, the number of new students declaring computer sciences as a major fell 43%, to 8,021 (eSchool News, 2008a). The report did agree with the US Bureau of Labor Statistics in 2008 that between 2006 and 2016, 854,000 professional IT (information technology) jobs will be added, an increase of about 24% with the estimated 1.6 million IT jobs replaced in the ten-year period fields. According to Gellos, a spokesman for Microsoft Corp, all companies have that person down the hall to help with computer issues (eSchool News, 2008a).

In a 2008 report, a public high school authority in the US discovered an extremely low level of interest for participating in STEM related career academics in high school among middle school students; however, the students showed higher interests in arts, literatures, businesses and entertainment related careers, especially the girls (Rogers, 2009). Thus, it sometimes becomes a challenge for many high schools in the US to get a sufficient number of students to choose to enroll in STEM related academics. If low enrollment in STEM fields and low interest in STEM academics continue, all high school academics that link to STEM majors will be at great risk (Rogers, 2009). The Nashville Area Chamber of Commerce in Tennessee and numerous national sources pointed out that the US needed more workers in STEM fields. Experts warn that the US apathetic performance in encouraging students to enter STEM careers can complicate the troubles of the nation's already ailing economical situation (Ramirez, 2008).

Furthermore, science and mathematics teachers face inadequate support, including appropriate professional development as well as interesting and challenging or relevant curricula. School systems lack tools for assessing progress and rewarding success. The nation lacks clear and shared standards for science and math that would help all actors in the system set and achieve goals. As a result, too many American students conclude early in their education that STEM subjects are boring, too difficult or unwelcoming, leaving them ill-prepared to meet the challenges that will face their generation, their country and the world. Studies found that many US teachers are not well prepared to teach math and sciences (EducationNews, 2010). Future mathematics teachers are getting weak training and are not prepared to teach the demanding curriculum needed for US students to compete internationally.

If too many students continue to pursue degrees and careers in other fields more than STEM related areas, the US will find it difficult to compete in the global economy. Furthermore, the US will not be able to meet its future workforce needs. The US needs 400,000 new graduates in all STEM fields by 2015 (Obama, 2009). Since only 15% of all college graduates currently choose STEM as majors or minors, which impacts American competitiveness, there is a projected shortfall of more than 280,000 math and science teachers by 2015 (eSchool News, 2008b). Microsoft reported that only 14% of students graduating with bachelor's degrees in Washington State have the skills that they need (University of California, 2010). Without a solid foundation in STEM, students will not be qualified for many jobs in the workplace, including many jobs beyond traditional engineering and science.

The Basis of Career Choices by US Students

A great number of US students believe that a college degree is an excellent advantage in finding a rewarding job. But many more do not consider postsecondary education as the optimal or even a possible choice. About one-half of US students who leave high school without the knowledge or skills needed to find and maintain a job, and one-third of them are not prepared for even entry-level work (Levinson & Palmer, 2005). Many American students and their parents believe that most of the STEM studies require significant investment and hard work in education. Students who do commit themselves from the very beginning of middle or high school and have the opportunities to take high school or vocational courses in science and mathematics do succeed in the STEM path in their future studies.

A 2004 study found that 72.2% of US parents indicated that the basis of career choice should be based upon a combination of interests/abilities and the job market; 27.6% responded that career choices should be based solely upon interests/abilities, and only 0.2% stated that career choices should be based upon the labor market (J. Taylor, Harris, & S. Taylor, 2004). The study found more than 90% of parents had little or very little influence on their college-age children's career decisions; fewer than 10% parents had great influence on their children's career decision-making. Parental support and encouragement were found as influencing factors in children's vocational outcome. The study also found that regarding influence on students, the father and mother were ranked as the first two, the teacher as the third and the counselor as the fourth in children's choice for career development. However, most of the parents did agree that they did not have or should not have more influence on their children's career decisions (J. Taylor et al., 2004). In another study, Robinson and Ochs (2008) found that friends were another important influencing body for pursuing high school students for taking science.

According to a US Bureau of Labor Statistics, in the 2005 FY (fiscal year), STEM workers, as a group, earned about 70% more than the national average, and every major group of STEM workers enjoyed overall median earnings that were above the national average. Fresh college and university graduates with a degree in STEM fields believe that they will not be paid adequately if they teach in a school or college. For instance, in 2005, biophysicists and biochemists, who often have a Ph.D., had median earnings of $71,000; biological technicians, who often have an associate degree or less education, earned a median of $34,270 (Terrel, 2007).

However, many students who graduated with a STEM degree believe that teaching in the middle and high schools is more socially responsible, but is not paid adequately. For instance, median salary offered for the fresh college graduates for teaching in elementary public schools is $30,000, and the median salary for fresh secondary teachers is $36,000. By contrast, the median salary offered to fresh college graduates in certain

STEM-related fields, including physics, computer science, accounting and engineering, is currently more than $60,000 (PCAST, 2010). Moreover, most of the teaching positions demand a teaching license and/or a teacher education degree that many STEM graduates do not want to acquire.

In addition, STEM teachers' salaries do not keep pace with salaries paid to other STEM professions (PCAST, 2010). For instance, between 1993 and 2003, the median salary for high school science and mathematics teachers increased by 8% adjusted for inflation, while, during the same period, the salary for other STEM professions increased by 21%-29% (NSB, 2008). In international comparison, teachers in the US are paid less than in many developed countries, even though they have to do more challenging and responsible duties, and work more hours on average (OECD (Organization for Economic Co-operation and Development), 2009). According to the finding of PCAST (2010), relative to per capita GDP, the US ranks in the bottom third of OECD countries in terms of teacher salary. Figure 1 shows that the US teachers are paid less than half of Korean teachers, and lag behind more than half of the 33 OECD countries including Mexico, Japan, Czech Republic, Italy, Austria and France. Thus, it is very likely that many graduates with a STEM degree either do not choose a teaching position or leave within the first few years of their teaching career to a non-teaching position.

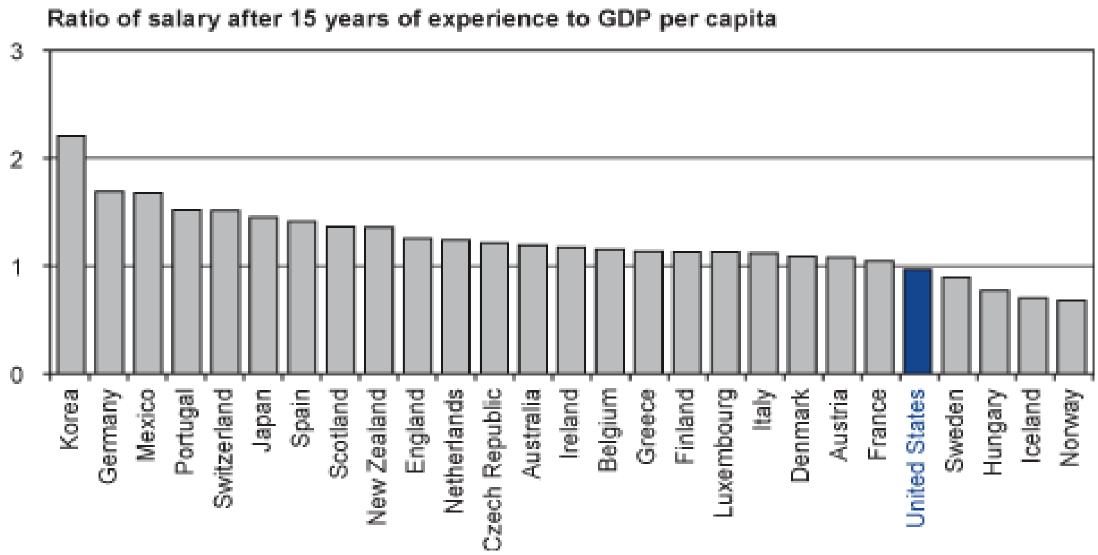

Figure 1. Secondary teachers' salary relative to GDP in OECD nations. Source: OECD, 2007 reported in PCAST, 2010.

Barriers and Misconceptions Toward STEM Education in the US

According to the NCEE (National Center on Education and the Economy) (2006, p. 8), "The core problem in US STEM education and training systems is that they were built for another era, in which most workers needed only a rudimentary education". The NCEE believed that teachers who educate elementary to high school level students get their information and attitudes about STEM disciplines from college and university level courses taken in the teacher education programs. However, technology has not reached its potential in teacher education curricula nationwide. Many newly graduated teachers often do not have sufficient experience to use computers in teaching-learning processes (Kurz & Middleton, 2006). A study showed that teacher preparation for technology integration was minimal (Watts-Taffe, Gwinn, Johnson, & Horn, 2003). A more recent study revealed that many technology preparation classes only adequately prepare pre-service teachers with lower-level technology skills that do not provide pre-service teachers with adequate knowledge to provide sufficient technology-based instructions in their classrooms (Brush, Glazewski, & Hew, 2008).

It is also thought that US STEM education faces barriers and misconceptions that greatly hinder students' motivations and achievement at all levels. Most of the barriers are related to curriculum, credit and funding issues, lack of qualified teachers, inadequate policies to recruit and retain STEM-educated teachers, difficulty in retaining teachers with a STEM background, difficulty in conducting research and continuing to learn about STEM areas while teaching in the classroom, lack of adequate preparation for teachers in higher education, classroom time constraints and difficulty in attracting and keeping kids in STEM careers. These barriers are fueled by some of the following misconceptions against STEM education in US public schools. They include the following long list: STEM education is just another "fad" in education and will soon go away; colleges will not accept credits for high school courses called STEM; technology means the ability to do basic computing and Internet browsing, STEM education consists only of the two bookends—science and mathematics; STEM education addresses only workforce issues; technology education and engineering are disparate and troublesome; mathematics education is not a part of science education; engineers and technology education teachers cannot teach science or mathematics; STEM education includes a lot of laboratory work or the scientific methods; all STEM educated students will be forced to choose technical fields because they do not have a liberal arts foundation; etc. (Setda.org, 2008). In addition, STEM studies seem to be very hard for many students.

There are severe troubling weaknesses, gaps and disconnection among the quality of math and science instructions in the early grades, the performance of high school students on international tests and the content and harshness of pre- and in-service teacher education programs in the colleges and universities in the US (Sanders, 2004). In many elementary and middle schools, students are not being equipped to achieve expected goals in science and mathematics. A significant number of elementary school teachers lack confidence in their abilities to teach mathematics and science. The problem is particularly severe in the elementary grades and also serious for middle and high schools (National Center for Education Statistics, 2009). During the 2007-2008 school years, only 56% of K-12 public school science and mathematics teachers held undergraduate and/or graduate degrees in science or science education, or mathematics or mathematics education (PCAST, 2010).

Among the nation's estimated 426,000 middle and high school STEM teachers, each year about 25,000 of them leave their teaching profession (Ingersoll & Perda, 2010). While reasons for leaving job are numerous, nearly two-third of them cited job dissatisfaction as their reasons for leaving. Due to low remuneration but high accountability and workload and lack of professional support, more than 40% of beginning science and math teachers left their jobs in the first five years (Ingersoll & Perda, 2010; NSTA (National Science Teacher Association), 2008; Woullard & Coats, 2004). Although many of them reenter teaching in different schools or locations, or switch to a different branch of STEM careers, to counter the net turnover rate of STEM teachers, the US still needs to attract more students to STEM fields and ensure an ongoing annual average need for 25,000 new STEM teachers (PCAST, 2010).

The issues are not only due to the quantity and quantity of STEM teachers. There is a crucial issue of quality of teacher education programs as well. Many pre- and in-service teacher education programs prepare their graduates with insufficient skills on technology usage. As a result, many newly graduated teachers do not have sufficient experience to use computers in the teaching-learning processes (Kurz & Middleton, 2006). A 2008 study found that many technology preparation classes adequately prepare pre-service teachers with lower-level technology skills, but do not provide pre-service teachers with adequate knowledge to provide sufficient technology-based instructions in their classrooms (Brush et al., 2008). Even, among teachers who obtain college or university degrees, many do not acquire a strong background in technology integration with pedagogical training, and even among the small fraction of teachers trained deeply in pedagogy in STEM fields, there is a little evidence to evaluate the quality of instructions they received in STEM content or STEM pedagogy (PCAST, 2010).

How Do We Motivate More US Students to Pursue Teaching in STEM Areas?

To address the barriers, misconceptions and problems of STEM education, we need to target STEM education components for students at all levels from elementary to graduate levels. We particularly need to target the pre-service teachers who will become the future STEM undergraduate, graduate or faculty school teachers. To meet the needs of a scientifically and technologically literate workforce, meaningful preparation of STEM teachers needs to be considered as an undoubted necessity. To increase young students' interests and enthusiasm in STEM careers, there are some actions that can be taken. They include the following: Organizing fundraising events with the community or other projects that increase budgeting and math skills; teaching youth at science summer camps or after-school programs; getting students to join math and science clubs; exploring technology hobbies among school children; helping them to participate in science fairs; basic computing and internet browsing; including them in Internet forums and social networking; giving them books and magazines on science and mathematics; motivating them to pursue science and engineering careers; and helping them to learn about computer parts; etc. (Setda.org, 2008). Moreover, students pursuing degree or certification courses in STEM related subjects should be given additional scholarships or financial support by the government or concerned institutions.

The US Federal Government has pursued some of these initiatives, and if they are successfully implemented by 2020, the US will once again have the prospect for the highest proportion of college graduates in the world. The tax credit and grant programs are some of the programs initiated to make US college education more affordable. They can greatly enhance the US ability to compete for the high-wage and high-tech jobs of the future and foster the next generation of the STEM workforce (Obama, 2009). The US 2010 budget provided $115 millions for the DOE (Department of Energy) to launch a program jointly with the NSE (National Stock Exchange) to inspire tens of thousands of American students to pursue STEM careers, particularly in clean energy (Johnson, Chubin, & Malcom, 2010). Even as the US focuses on low-performing students, it should devote considerable attention and resources to all of our most high-achieving students from across all economic and ethnic groups. In the words of President Obama (2009), "We must educate our children to compete in an age where knowledge is capital, and the marketplace is global".

To meet US needs for a STEM-capable citizenry, a STEM-proficient workforce and future STEM experts, the US should focus on the following goal: The US should prepare all students, especially minorities and girls who are underrepresented in these fields, to become more motivated and proficient in STEM subjects. To support this goal, partnership and collaboration of private and philanthropic groups with local and state government are essential. To motivate a greater number of students and the non-STEM workforce to join the STEM pipeline, a number of steps at various levels should be taken and monitored closely. Collaborating with other education organizations, the private sector and local community organizations are the most effective and promising way to accomplish the shared vision for motivating workers to join the STEM pipeline. Initiatives should be started to promote education in the related areas so that students who are enrolled in the industrial areas can do their internships while they are being prepared to study STEM fields in college. Most importantly, students, teachers and educators at all levels should acknowledge that STEM careers require significant investments and hard work during preparation. Students who do commit themselves from the very beginning of middle school and have the opportunities to take high school or vocational courses in science and mathematics can succeed in the STEM path in their future studies.

STEM initiatives should be monitored by the Department of Education and the federal agencies, such as the National Science Foundation and the National Council of Teachers of Mathematics, for effective STEM education in K-12 levels. The Federal Government must actively engage with each of these partners, who must in turn fulfill their own distinctive roles and responsibilities. According to the PCAST (2010), in recent decades, relatively little federal funding has been targeted toward catalytic efforts which have the potential to transform STEM education. Too little attention has been paid to replication and scale-up to disseminate proven programs widely. And, too little capacity at key agencies has been devoted to strategy and coordination.

Most importantly, parents, teachers, school counselors and friends should increase their influences towards STEM careers in multiple ways, such as, become better informed about the need for science literacy in all students; learn more about STEM careers to better advise underserved students on science courses needed for pursuing college majors that lead to STEM career after completing high school or higher education; and present importance of taking high school science and mathematics courses to prepare for future STEM careers, etc..

Thus, coherent strategy and sufficient leadership should be taken by the Federal Government. The Federal Government should provide vigorous support to the state-led effort to develop common standards in STEM subjects by providing technical and financial support to states for high-quality professional development that is aligned with shared standards and the development, evaluation, administration and ongoing improvement of assessments aligned to those standards. Most importantly, the Federal Government should provide vigorous support in setting goals that ensure the recruitment, preparation and induction support of at least 100,000 new middle and high school level STEM teachers with majors in STEM fields and strong content-specific pedagogical knowledge by 2020 (PCAST, 2010).

Last, the US must provide more investment in supporting teacher preparation programs that provide strong content and pedagogical knowledge in STEM subjects. In making investments, special focus should be given on programs that are scalable, because they will have the greatest impact on terms of the number of teachers produced and the greatest opportunity for learning about elements of successful programs (PCAST, 2010).

Conclusions

Despite of coherent actions taken by educators, government and various organizations, the US cannot be certain of producing and certifying the quantity and quality of students, teachers and professionals in STEM fields needed to meet the nation's current demands. The overall situation indicates that it is unlikely that the US will maintain its local and global leadership in science, math and technology professions unless federal planners take remedial action to produce nationally or import enough experts in these fields. This is not a satisfactory outlook for American educators and legislators who are attempting to recover from the current economic hardship and ensure sustainability as a high technology nation. A vital question is whether the US education system and job markets are failing to motivate and encourage American students to pursue STEM education and careers in these fields.

Success in STEM requires both technical and non-technical skills and dispositions. Curiosity, the ability to think logically and creatively in problem-solving, communication skills and the ability to work in teams are all required to succeed in STEM careers. Mathematics and science knowledge are an important base for all STEM workers. Students need to be inspired in STEM subjects beginning in the middle school grades with coursework and extracurricular activities focusing on honing problem-solving skills in the high school grades. After high school, STEM career requirements are more specific to the specific occupations.

The solution to the STEM education problem should be handled in an interdisciplinary manner, which must be grounded in the STEM discipline departments as well as the Colleges of Education and Human Development. STEM education should be considered as a targeted education component for graduate students who will later after work experience become the future STEM undergraduate and graduate faculty. Meaningful preparation of K-12 and higher education STEM faculty should be considered as an undoubted necessity to meet the needs of a scientifically and technologically literate workforce in a modern and technology-driven nation.

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