

## **Needed: A Reform of America's 20<sup>th</sup> Century Education System to Enter the 21<sup>st</sup> Century Global STEM Economy**

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### **Abstract**

Science, Technology, Engineering, and Mathematics (STEM) occupations have powered the American economy for many years. As technology continues to develop and be used in all aspects of life, American citizens will need to be educated in a way that equips them to meet employer needs for the remainder of the 21st century and beyond. Despite America's past leadership in STEM achievements, American students can no longer compete with their global peers in STEM during their K-12 education. Too many American school systems still hold the 20th century belief that students have deficits which can be fixed by providing more resources. American students do not need to be fixed to fit into the existing American education system; the existing American education system needs to be fixed to provide American students with opportunities to succeed. Many studies support the American education system taking a holistic approach that provides students with engaging and rigorous curricula, integrated and project based learning opportunities, teachers that are well trained and supported to teach integrated STEM curriculum, increased parental involvement opportunities and expectations, opportunities for students to develop interest and self-efficacy in STEM subjects and careers, and interactions with role models.

**Keywords:** STEM, education, mathematics, technology, curriculum, teachers, project-based learning

In many school districts across the U.S. it is no secret that the American education system needs to be retooled in order to prepare students for the 21st century workforce and economy. The need to update and revamp the educational process is particularly acute in schools and districts that serve students that come from minority and low-income households. When American schools fail to provide an integrated, technologically advanced education to any population of students, those students are prohibited from pursuing lucrative STEM careers that could increase their standard of living, enhance their communities, and provide the United States with the technical expertise needed to maintain a leadership position in the global economy.

Science, Technology, Engineering, and Mathematics (STEM) occupations have powered the American economy for more than 50 years, creating good jobs for American citizens, allowing for a relatively high standard of living, and keeping America in a global economic leadership position (Atkinson, 2012). As technology continues to develop and be used in all aspects of life, American citizens will need to be educated in a way that equips them to meet employer needs for the remainder of the 21st century and beyond. Improving access to quality STEM education for all K-12 students will strengthen the caliber of the American workforce, drive economic growth, keep the United States competitive, and prepare students to participate in the 21st century global economy, regardless of their career choice (U.S. Congress Joint Economic Committee, 2012). Furthermore, even if students do not intend to pursue a STEM career, they still need to be STEM literate in order to adapt to changes driven by new technology, work with others, anticipate multilevel impacts of their actions, communicate complex ideas to a variety of audiences, and find creative and measured solutions to the problems of tomorrow that do not yet exist today (Kennedy & Odell, 2014).

Despite America's past successes and achievements in STEM, American students can no longer compete with their global peers in STEM curriculum and career choices (Reisel, Jablonski, Munson, & Hosseini, 2014). Lehman (2013) stated, "Evidence shows that the United States is falling behind other countries in STEM education and workforce by not adequately enrolling and preparing students for higher education in these high technology fields" (p.12). The use of 20th century, discrete, STEM education methods and practices is contributing to workforce shortages in the United States. The use of 20th century educational methods is also prohibiting employers from finding the talent and skills they need to stay ahead of ever-increasing global competition (Zimenoff, 2013). The most disadvantaged students in the current education system are minorities and students from low income households. The Presidents' Council of Advisors on Science and Technology (2010) stated, "African Americans, Hispanics, Native Americans, and women are seriously underrepresented in many STEM fields" (p.6).

Quality STEM education is not accessible to all American students, even if they are not considered to be at risk populations (minorities, low income groups) (Mastroianni, 2015). Students who are not prepared to enter a post-secondary STEM major in college due to under preparedness in their K-12 education are simply not prepared for the 21st century workforce or economy. An inadequate K-12 STEM education limits groups of individuals from participating in growing, well-paid professions, relegating them to the bottom rungs of the American socio-economic class system.

The data produced by standardized national and global assessments demonstrate the immediate need for an educational overhaul in American schools, particularly in schools that serve large populations of at risk students. A study by the Education Testing Service Center for Research on Human Capital showed that America has the widest gap among industrialized nations between the achievement of K-12 students in the top 10 percent and the students in the bottom 10 percent of performance (Sparks, 2015). According to 2012 statistics from the National Math and Science Initiative, students from 26 industrialized nations performed better in math than United States students and students in 19 industrialized nations performed better than United States students in science (Mastroianni, 2015).

The proficiency gaps between American students and their global industrialized peers with respect to STEM skills becomes obvious at a variety of checkpoints in K-12 education. For example, American eighth-graders are outperformed by students in many European and Asian countries (for example: Singapore, Republic of Korea, Hong Kong, SAR, Chinese Taipei, Japan, Belgium, Netherlands, Australia, Slovak Republic, Russian Federation, Latvia, Malaysia, Hungary, and Estonia) in mathematics proficiency (Eberle, 2010). Only 26% of American high school seniors perform at or above proficient levels in mathematics and 21% of American high school seniors perform at or above proficient levels in science (Bennett, 2012). American students rank 29th in math and 22nd in science among their global peers (U.S. Department of Education, 2015).

Even American middle- to upper-class students are scoring far below their international peers on standardized tests that rank America behind 14 other industrialized countries in mathematics proficiency (Sparks, 2015). America's best students cannot compete with their global peers in STEM education achievement. America's most at-risk students are even less prepared to succeed in STEM leaving them unqualified to participate in high paying careers that could serve to increase the quality of life for them, their families, and their communities. The typical 20th century educational content and methods are simply not working for America's 21st century students.

Education reform has been a political priority for more than 50 years in the United States. There has been limited success, but not enough to keep the American education system globally competitive or to equip American students for the 21st century global workforce and economy. Without mastery of STEM subjects, students are not prepared to collaborate, compete, or interact locally or globally (Baron, 2015). Unfortunately, the federal government has proved incapable of singularly and adequately resolving the STEM deficiencies in education (Machi, 2009). Federal dollars have been spent on education initiatives for decades with little to no accountability for how it is spent and little evidence of increased student achievement. Education reform must be a partnership between policy makers, funders, educators, communities, and the parents of students. Each entity is a stakeholder in the education system and must be held accountable for the results of America's education system.

There are several key strategies that can be used to better equip American schools to education students in STEM. Giving students more access to technology, training teachers to use technology in ways that promote STEM simply replace 20th century teaching techniques, providing students with integrated and open ended project based learning opportunities, providing students with role models in STEM, engaging parents in the education process, providing teachers and students with rigorous curriculum, and increasing student interest and self-efficacy in their STEM abilities are all researched based 21st century educational methods that will improve the quality of STEM education in K-12 schools for all students. Some of these strategies are clearly technology based, 21st century solutions that require additional funding or reallocations of current funding. Other strategies are common sense 20th century strategies that seem to have disappeared during the past several decades. These best practice solutions will need to be combined in different ways across each school to yield success. Each student, group of students, community of stakeholders is different and each combination of strategies will need to be different in order to maximize student achievement.

Access to technology in K-12 classrooms, and teachers that are trained to use technology, are an important part of student preparedness for the 21st century. Research has shown that students who use technology to explore STEM with teachers who have experience with teaching STEM are more likely to develop an early interest in STEM than their peers who attend schools with teachers not qualified to use technology and teach STEM (Lichtenberger & George-Jackson, 2013). Teachers who use traditional pedagogical methods and resources often find they are ineffective and underprepared to inspire 21st century students to pursue STEM education and careers (Kulturel-Konak et al., 2011). School districts need to invest in sustained professional development opportunities for teachers to learn how to successfully integrate technology into their classrooms.

The classroom environment and curriculum in K-12 classrooms is a powerful determinant of persistence in STEM (Osborne et al., 2008). Good STEM curricula introduce students to STEM topics at a demanding yet developmentally appropriate level (Feuer, 2013). Students must be able to explore complicated STEM topics in a classroom environment that encourages curiosity, allows for failure and persistence, and excites students in their pursuit of knowledge. Students must be invited to take risks because risk is fundamental to advancement and breakthrough thinking (Marshall et al., 2011). Classrooms where students are expected to repeat memorized information correctly does not promote long term STEM development. Traditional 20th century classrooms do not invite exploration, experimentation, risk, or acceptable failure, they simply expect students to memorize rote procedures and repeat memorized content. Classrooms that still utilize 20th century teaching and learning methods are not prepared students for a 21st century economy and workforce.

Standardized test scores reflect our 20th century educational failures. As students' progress through the K-12 pipeline, higher percentages of students score below proficiency in mathematics each academic year (Mickelson et al., 2013). This is a disturbing notion because mathematics is one of the most reliable predictors of success in college and the workplace (Mickelson et al., 2013; National Academy of Science, 2011). Furthermore, mathematics interest and success has a positive impact on students' interest in STEM careers (Institute for Broadening Participation, 2016). Memorizing procedures to perform mathematical calculations without context is not effectively preparing students for the 21st century.

During the 20th century, students learned mathematics, science, English, Social Studies, and even technology in discrete classes and without integrating content areas. The 21st century economy and workforce requires students to think in an integrated way and apply STEM knowledge to solve authentic problems. Project based learning is a pedagogy that requires students to design, build, manufacture, and communicate processes which are all part of STEM skills and integrated curriculum. Project based learning has been shown to increase student achievement and help students learn more by giving them opportunities to actively participate in the learning process while interacting with their peers and instructors in meaningful ways (Verma, Dickerson, & McKinney, 2011). Project based learning helps students develop critical thinking skills, communication skills, and problems solving skills, but it is not a common pedagogy in K-12 schools. K-12 schools are still offering discreet content based classes that require students to memorize information and procedures without expecting them to apply it.

There are several examples of project based, integrated learning successes around the world that can serve as models for the American school systems. Finland, as one example, has one of the best education systems in the world with their 15 year-old students regularly scoring among the highest performers on the PISA exam in reading, mathematics, and science compared to students in other industrialized nations (Spiller, 2017). Schools in Finland have transitioned from discrete, isolated subjects in schools to an integrated project approach to teach students skills, not simply subject matter. The global workforce and economy need creative, critical thinkers who can solve complex problems where individuals must make sense of information provided more quickly and via more mediums, than ever before (U.S. Department of Education, 2015). Project based learning that focuses on skills and critical thinking provide students with the opportunity to practice solving intricate problems using a variety of competencies that cannot be taught in isolated subject matter classrooms.

Korean students are another group who consistently score among the highest on the international PISA exam in reading, mathematics, and science. Currently, the Korean schools are not using a project based learning approach but instead use an algorithmic approach which require students to memorize subject matter content without making sense of the background processes (Han, 2017). The result of the current Korean educational approach is a shortage of students who pursue STEM careers because they have negative attitudes about learning mathematics and science (Han, 2017). The shortage of STEM workforce candidates in countries such as Korea, regardless of how well students score and rank on international exams, has prompted a discussion regarding the implementation of project based learning approaches to help students develop positive attitudes about STEM careers. Project based learning is gaining momentum around the world as a way to teach students how to solve complex problems using multiple, integrated approaches in much the same way global, real world, 21st century problems need to be addressed.

Engaging K-12 students in high quality STEM education requires schools to provide rigorous curriculum, instructions and assessment which integrates technology and

engineering into the science and mathematics curriculum and also promotes scientific inquiry and the engineering design process (Kennedy & Odell, 2014). The engineering design process is different than traditional scientific inquiry and involves the formulation of a question or problem that can be solved through investigation, construction, and evaluation which requires critical higher order thinking skills (Kennedy & Odell, 2014). Students learn better when they have the opportunity to apply learning instead of observing lectures, which is what project based learning, particularly in STEM, provides. Part of the resistance to transition from 20th century educational methods to 21st century pedagogies may be, in part, due to high stakes testing requirements by individual states or the federal government. Furthermore, resistance to pedagogical change may be due to, in part, a lack of teacher training, and a lack of funding for technology and curriculum. Whatever the reasons, students are simply not prepared for the 21st century workforce and economy.

The most important intermediary between intended and implemented curriculum, and the biggest impact on student learning, is a classroom teacher (Feuer, 2013). Many teachers in America's K-12 classrooms genuinely want to reduce achievement and performance between their students and students in other industrialized nations around the world but do not have the training, resources or experience to effectively reduce those achievement gaps. Teachers' ability to implement integrative learning opportunities for their students is highly dependent on their individual characteristics when accepting a new instructional method, perceptions toward the integrative approach, the school context, and the delivery methods they are comfortable using in the classroom (Becker & Park, 2011). Effective teachers must be comfortable teaching in their content area. Research has shown that teacher qualifications in the subjects they teach have a significant impact on student success in a course (Museus et al., 2011). Furthermore, as teachers acquire more years of experience in the subject they teach, they generally become more effective in helping students learn (Harris & Sass, 2011; National Science Foundation, 2014; Rice, 2010).

As STEM evolves from discreet content based courses to integrated project based learning opportunities for students, the STEM teacher attrition rates continue to rise. Stohlmann et al. (2012) noted teacher attrition can have negative effects in terms of school cohesion, teaching effectiveness, and most importantly, student achievement. Lodaya (2013) reported between 40 and 50 percent of all teachers leave the profession within their first five years. This is a devastating statistic for an education system that needs to be reimaged, retooled, and re-staffed. One substantial problem with keeping excellent teachers in STEM classrooms is the plethora of employment opportunities and higher wages outside of education (U.S. Congress Joint Economic Committee, 2012). When students do not have access to qualified STEM instruction (from experienced teachers), they find themselves unprepared or underprepared to pursue a STEM career.

Parental involvement and support is a significant factor that positively influences the success of students in K-12 education (Kennedy & Odell, 2014). Parental involvement includes staying informed about students' school and classroom activities, coordinating academic efforts and interventions with teachers, and participating in school activities. Parental involvement in their children's education is a 20th century practice that seems to have diminished during the 21st century. Parental influence and a K-12 students' interest in STEM careers are closely linked (Buschor et al., 2014). It is incumbent on parents to connect with schools but it is also incumbent on schools to reach out to parents. Schools and districts which invite and welcome parental involvement are more likely to have higher rates of parental involvement than schools which discourage it (Barton & Coley, 2009). Schools must ask for parental involvement and provide parent education. Parents of current students likely completed their K-12 education in the 20th century when classes were offered in disjointed content areas. To ask them for help encouraging students to treat education in an

integrated way, parents must understand what integrated means, how it is put into practice, and how to encourage their children to approach integrated education opportunities. Perhaps parents are not as involved with their children's education as they were in decades past because schools do not engage them as much or in the ways they used to. Perhaps parents are not as involved as they were in decades past because the family dynamic has changed: more single parent homes, more parents working to make ends meet, less time and flexibility to participate. Regardless of the cause, parental involvement is good and the American education system needs to find a way back to the level of parental participation that was documented during the 20th century.

Student self-efficacy and interest in STEM domains occurs early in the K-12 STEM circuit (Museus et al., 2011). The development of student engagement, student self-perceptions, identity, and interest in STEM is a critical determinant of STEM career choices (Sadler et al., 2012). The 21st century pedagogy of integrating mathematics and science content has a positive impact on student attitudes and interest in STEM subjects, students' motivation to learn STEM subjects, and students' academic achievement in STEM subjects (Stohlmann et al., 2012). Providing students with 21st century integrated learning opportunities helps them build interest and self-efficacy in STEM subjects with the result of increased interest in STEM careers.

American students need role models to help them develop a self-image in STEM. Increasing students' exposure to include successful STEM professionals who look like them or come from similar backgrounds helps students self-identify with STEM careers and enhances positive attitudes, feelings of self-efficacy, and motivation to pursue STEM careers (Institute for Broadening Participation, 2016; Stout et al., 2011). American students today do not have as much access to role models as in decades past. 20th century families were more involved with religious organizations, community and civic organizations, and school organizations where students regularly encountered adults with a variety of identities and expertise. Today, K-12 students may not have nearly as many encounters with adults at school, in religious institutions, or through civic and community organizations, often leaving them with few role models other than their immediate family members.

High levels of academic achievement can be obtained for students in K-12 classrooms by applying research-based practices shown to increase STEM students' learning. Too many left over 20th century interventions are based on the wrong belief that American students have a deficit which can be fixed by giving them the correct tools and teaching them the right skills to enable them to fit into the current system (Baron, 2015). American students do not need to be fixed to fit into the existing education system; the existing education system needs to be fixed to provide students with an opportunity to succeed. The American education system must take a holistic approach and provide students with engaging and rigorous curriculum, integrated and project based learning opportunities, teachers that are well trained and supported to teach an integrated STEM curriculum, increased parental involvement opportunities and expectations, opportunities for students to develop interest and self-efficacy in STEM subjects and careers, and interactions with role models. When the American education system enters the 21st century, American students will become competitive once again with their global peers. Without a major and intentional increase in K-12 educational efforts in the United States to produce more qualified STEM professionals, America risks losing its international economic leadership and superior quality of life for all American citizens (Lehman, 2013).



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