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The Teacher is Key to STEM Education for All: A Catalyst for Competitive Workforce and Economic Development

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ABSTRACT

The teacher is key to reforming K-12 science, technology, engineering, and mathematics (STEM) education for all students (Powell et al., 2018) in the United States, and a catalyst for a competitive workforce and economic development. Reports based on Free or Reduced-Price Lunch (FRPL) and percent schools offering STEM courses, along with FRPL and per pupil expenditure in science adjusted for inflation, show disparity between the highest and lowest quartiles (U.S. Government Accountability Office, 2018; Banilower et al., 2018). Strategies to promote STEM for All and turn STEM education into a dependable human resource pipeline for a competitive workforce and economic development are discussed. The strategies include, promoting diversity and inclusion towards STEM for All, providing adequate STEM teacher training, increasing teacher retention in STEM subjects, and building a supportive environment for STEM teachers and teachers in general. These strategies are essential to connecting K-12 STEM education, a competitive workforce, and economic development.

Keywords: K-12 education, STEM education, competitive workforce, economic development, FRPL, inclusion, diversity, teacher training, teacher retention

Introduction

Strategies for reforming Kindergarten through grade twelve (K-12) science, technology, engineering, and mathematics (STEM) education in the United States as a dependable human resource pipeline for a competitive workforce and economic development are explored. Selected STEM and STEM education information and data from the U.S. contribute to this discussion. Connecting STEM education, workforce readiness, and the economy is a trend not only in the U.S. but also a global trend (World Economic Forum, 2020). According to the U.S. Department of Commerce, Economics and Statistics Administration, Office of the Chief Economist (OCE) (Noonan, 2017), STEM workers play a significant part in “innovation and competitiveness by generating new ideas and new companies” (p. 1).

Accordingly, the OCE (Noonan, 2017) reports that in the private sector, the average hourly wage of a STEM worker based upon educational level is higher than a non-STEM worker as presented in Table 1. For example, STEM hourly wage average ($27.53) for workers with a high school diploma or less is 69.8%, over a similar non-STEM worker average hourly wage ($16.21) (Noonan, 2017). Additionally, for STEM workers with less than a graduate degree, regression-based hourly earnings premiums have increased over time since the mid-1990s compared to non-STEM workers with graduate degrees (Noonan, 2017). Calculations by OCE (Noonan, 2017) based on Bureau of Labor Statistics Employment Projections and the National Bureau of Economic Research, indicate the projected growth in STEM employment is 8.9% compared to non-STEM jobs during 2014-2024.

Table 1

Private Sector Average Hourly Wage (USD) by Educational Level, STEM vs. non-STEM

Educational Level	STEM Hourly Wage Average (USD)	Non-STEM Hourly Wage Average (USD)	Percentage Increase for STEM Hourly Wage Average (USD)
High School Diploma or less	$27.53	$16.21	69.8%
Associate Degree or Some College	$30.79	$19.09	61.3%
Bachelor's Degree	$39.28	$28.34	38.6%
Graduate Degree	$45.37	$35.16	29.0%

Note. Office of Chief Economist calculations based on Current Population Survey public-use data. (Noonan, 2017)

According to the U.S. Department of Labor, Bureau of Labor Statistics (2017), in May 2015, 8.6 million (6.2%) U.S. jobs were in STEM fields, of which 750,000 were in applications software development and 333,010 were in wholesale and manufacturing sales of scientific and technical products. When looking at these statistics, it is not a surprise that the Committee on STEM Education of the National Science and Technology Council (2018) outlined the following three goals in the document entitled *Charting a Course for Success: America's Strategy for STEM Education*: 1) Build solid foundations for STEM literacy, 2) Prepare the STEM workforce for the future, and 3) Increase work-based learning and training through educator-employer partnerships. As usual, along with a plethora of similar ambitious rhetoric, the Committee on STEM Education of the National Science and Technology Council (2018) report failed to address significant strategies key to strengthening STEM education at the K-12 level. To maintain a steady pipeline of STEM-trained human resources, it is necessary to promote STEM subjects in K-12 schools. Facilitating STEM education early at the elementary school level is an especially important strategy supporting the first goal of building solid foundations for STEM literacy (Committee on STEM Education of the National Science and Technology Council, 2018; Oberoi, 2016). To further support this goal, strategies focusing on K-12 STEM education such as, promoting diversity and inclusion towards STEM for All; providing adequate STEM teacher training; increasing teacher retention in STEM subjects; and building a supportive environment for STEM teachers as well as teachers in general, are discussed.

What is STEM Education?

STEM education is an integrated approach to teaching science, technology, engineering, and mathematics with real-world applications (Southeast Comprehensive Center, 2012). It is a "meta-discipline – a convergence of science, technology, engineering and math – that offers a student-centered, inquiry-based method of addressing and solving problems" (Southeast Comprehensive Center, 2012, p. 7). The overall purpose is to raise awareness of STEM in society, motivate students, and increase interest in STEM. The anticipation is that an increasing number of students will pursue STEM subjects in college and then careers in STEM fields. Problem-based learning (PBL), Project-based learning, and hands-on discovery/inquiry learning are a few pedagogies advocated for STEM education (Euefueno, 2019). Additionally, the report, *STEM 2026: A Vision for Innovation in STEM Education* (U.S. Department of Education, Office of Innovation and Improvement, 2016) called for "educational experiences that include interdisciplinary approaches to solving grand challenges" (p. ii).

The term STEM representing science, technology, engineering, and mathematics disciplines, arguably, was introduced within the U.S. education system in the early 2000s. The term STEM appears in federal policy within the *America Competes Reauthorization Act of 2010* (2011). Considering the interdisciplinary nature and broader impacts of STEM disciplines, it is possible that if properly designed and implemented, STEM curricula including PBL teaching and learning through hands on activities could be integrated with arts, language arts, reading, and social studies to help students explore the world around them. This interdisciplinary approach to STEM education may lead to higher student motivation in subjects such as science and mathematics and prevent knowledge fragmentation by teaching subjects in isolation (Drake & Burns, 2004). This may be because separation or compartmentalization of subject areas where content is taught discretely during different times of the school day disrupts the learning of many students. Often student comprehension of complex topics increases through an interdisciplinary approach to teaching and learning (Fogarty, 1991). Including interdisciplinary pedagogy is an important aspect of defining STEM education (Drake & Burns, 2004).

STEM Education, Competitive Workforce, and Economic Development

The link between STEM education, a competitive workforce, and economic development is explored, debated and established (Croak, 2018; Hanushek & Kimko, 2000; Hanushek & Wößmann, 2008; Lazio & Ford, Jr., 2019; Oberoi, 2016; World Economic Forum, 2020). There is much discourse in support of K-12 STEM for a competitive workforce by heads of states, legislators, policymakers, industrialists, and business leaders and educators (Kumar, 2019). Croak (2018) in an international analysis, explained a positive link between post-secondary STEM education, human capital and competitiveness, and overall economic development. According to Oberoi (2016), the impact on the economy of introducing STEM at an early age in schools along with academic interventions and support is considerable. K-12 STEM education influences success in post-secondary STEM disciplines, with the subsequent connection to a skilled workforce and economic impact. On the other hand, critics of STEM education would argue, that "focusing on STEM is not enough. Educating young people in these subject areas may ensure they are experts on specific topics, but it does not necessarily create conscientious citizens who can make responsible social and financial decisions" (Billimoria, 2017, n.p.). Though this criticism is aimed at STEM education, it reflects the general state of K-12 education in the U.S.

Challenges to K-12 STEM Education

Though STEM is often portrayed as a priority in K-12 and college settings, the challenge remains on motivating students who repeatedly failed to develop an interest in STEM subjects during their K-12 school years to pursue STEM education in college. If the aptitude and interest for STEM subjects are cultivated in students during the K-12 school years, then the chances of students pursuing STEM degrees in college are remarkably high (Banilower et al., 2018). The National Science Teachers Association (NSTA) has presented position statements for early childhood (NSTA, 2014) and elementary grades (NSTA, 2002) calling for engaging, exciting, and meaningful science learning opportunities for students from age 3 through preschool, and children from elementary levels (K-grade 5) through middle school levels (grades 6-8) respectively. This recommendation is based on research that children "have the capacity for constructing conceptual learning and the ability to use practices for reasoning and inquiry" (NSTA, 2014, p. 1).

However, the results from the National Survey of Science and Mathematics Education (NSSME+) (Banilower et al., 2018) do not paint an encouraging picture of how one of the STEM subjects, science, is taught in U.S. K-12 classrooms. For example, in 37% of the elementary school classes, 30% of the middle school classes, and 31% of the high school classes, students watched while teachers conducted scientific demonstrations. In comparison, 16% of the elementary school classes, 11% of the middle school classes, and 12% of the high school classes, engaged students in hands-on/laboratory activities. Also, only 8% of elementary teachers, 8% of middle school teachers, and 6% of high school teachers involved their students in Project-based learning activities, an essential pedagogy of STEM education aimed at developing critical thinking and problem-solving skills in real-world contexts (Banilower et al., 2018).

The NSSME+ (Banilower et al., 2018) showed that 54% of science teacher professional development offered locally addressed ways of engaging students in hands-on science. However, only 17% of science teacher professional development offered locally addressed ways to integrate student's cultural backgrounds into science teaching. Notably, only 25% of locally provided science teacher workshops addressed building students' confidence in pursuing science/engineering careers. The survey also noted an unfortunate situation, that time spent on science learning in grades K-3 is18 minutes per day, and in grades 4-6 is 27 minutes per day (Banilower et al., 2018). In terms of educational qualifications of science teachers, 3% of elementary teachers hold undergraduate degrees in science/engineering, 1% in science education, and 3% in science/engineering/science education (Banilower et al., 2018). For 65% of elementary science teachers, the route to educator certification is a bachelor's degree, 22% is a master's degree, 11% is post-baccalaureate program (no master's degree) (Banilower et al., 2018).

With regards to equity, there is a disparity in K-12 STEM education. For example, in the U.S., public schools are classified into four quartiles based on the number of students eligible for Free or Reduced-Price Lunch (FRPL) (U.S. Government Accountability Office, 2018). Under the National School Lunch Program, a child whose family's income does not exceed 130% of the federal poverty level is eligible for the free lunch program. Children whose families' incomes are between 130% and 185% of the federal poverty level may receive a reduced-price lunch (U.S. Government Accountability Office, 2018). Also, children in Head Start and Migrant Education programs, children in foster care, and children receiving public service under the Runaway and Homeless Youth Act are eligible for FRPL (U.S. Government Accountability Office, 2018). Based on the U.S. Government Accountability Office (GAO) (2018) report on K-12 education, there is disparity in the offering of high school courses in STEM disciplines between the high (FRPL recipients 75-100%) and low poverty (FRPL recipients 0-24.9%) schools. High-poverty schools are less likely to offer science (i.e., Physics, Chemistry) and mathematics courses that most colleges expect their students to have in high school except for Biology. This is a severe concern when accounting for considerable differences in demographics of high and lowest poverty schools as presented in Table 2 (U.S. Government Accountability Office, 2018).

With respect to students with disabilities, as classified under the U.S. Individuals with Disabilities Act (IDEA) (2004), the situation is not encouraging. The GAO (2018) found a negative association with schools enrolling increasing percent students with disabilities and the likelihood of offering high school courses in Biology, Chemistry, Physics, and AP Science. As Schneiderwind and Johnson (2020) noted "students with disabilities therefore remain underrepresented in STEM fields, and a need exists to help uncover barriers that students with disabilities encounter in STEM laboratories, for example" (n.p.).

Another hindrance to STEM education is the ongoing disparity in per-pupil expenditure, as revealed by the National Survey of Science and Mathematics Education, NSSME+ (Banilower et al., 2018). In the U.S., for schools with students eligible for FRPL, there is inequality in the median amount of dollars spent per pupil between the highest quartile and the lowest quartile in 2018 and 2012. Figure 1 includes the original data by Banilower et al. (2018) and Banilower et al. (2013), adjusted for inflation.

Table 2

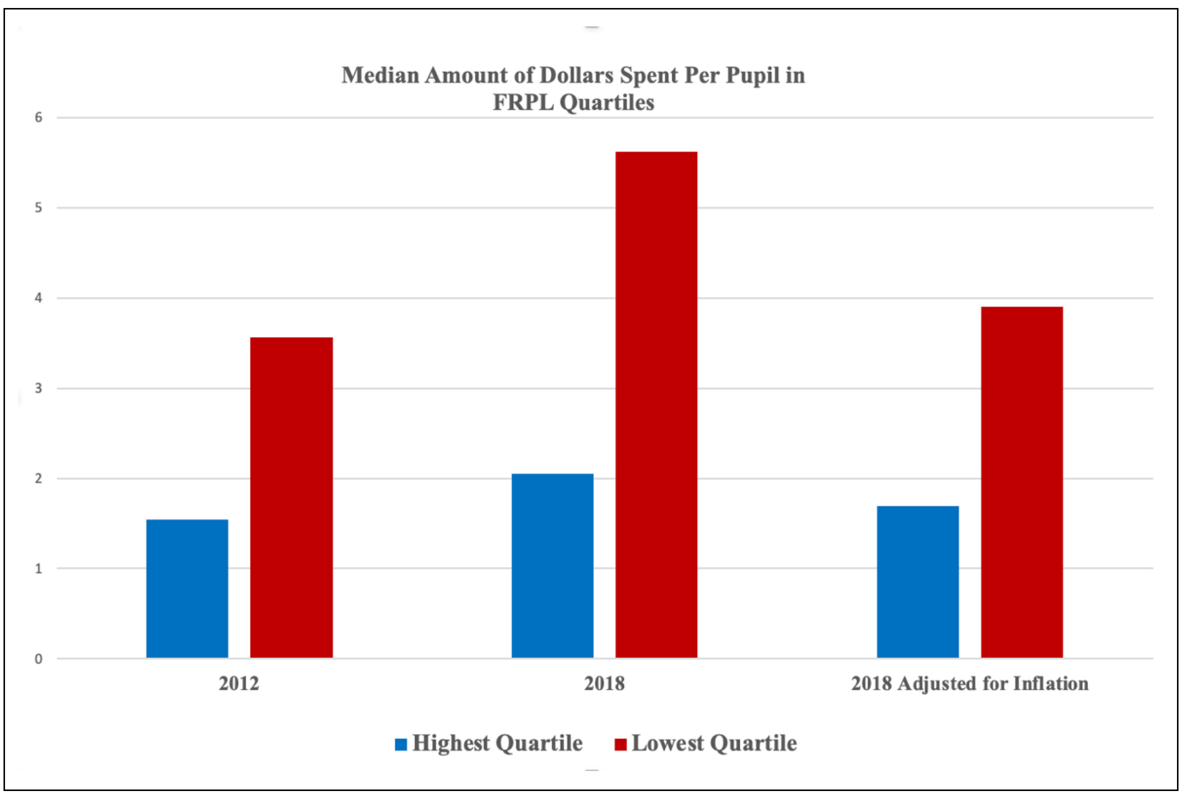
Poverty Level and STEM Course Offerings in School Year 2015-2016

Poverty Level Based on FRPL Eligibility	Demographics	Percent Schools Offering STEM Courses
Highest (FRPL 75-100%)	White 13%, Black 29%, Hispanic 52%, Asian 4%, Other 4%	*Biology 94.35% Chemistry 81.2% Physics 62.5% Advanced Placement Science 69.6% Advanced Placement Math 75.2%
Lowest (FRPL 0-24.9%)	White 71%, Black 6%, Hispanic 11%, Asian 9%, Other 4%	*Biology 97.6% Chemistry 93.5% Physics 89% Advanced Placement Science 88.7% Advanced Placement Math 94.1%

Note: *Trend in Biology seems different compared to other science disciplines.

Figure 1

FRPL Per Pupil Expenditure in Science Adjusted for Inflation



Per pupil expenditure in 2018, in the highest quartile is $2.05 ($1.69) and lowest quartile $5.62 ($3.90) compared to 2012, where it is $1.54 and $3.56, respectively. Percent increase of 33% (10%) in the highest quartile and 58% (10%) in the lowest quartile reveals a large socioeconomic disparity, before adjusting for inflation. To complicate things further, according to NSSME+*,* overall, 52% of classes in the highest quartile with a high proportion of FRPL students are less likely to be taught by teachers with a substantial science background, in terms of having a degree or at least three advanced science courses, compared to classes in the lowest quartile (66%) (Banilower et al., 2018). This is a clear indication of the ongoing socioeconomic divide in science education, a key component discipline of STEM education, needing constructive long-range solutions.

Another challenge to STEM education involves teacher assigned grades, as indicated in a study of a large metropolitan school district in California (Kunnath & Suleiman, 2018). Teacher assigned grades indicated that educators in mid and high poverty schools assigned significantly less "A" grades than low poverty schools (Kunnath & Suleiman, 2018). This study used a survey method to determine the extent to which grading practices and grading influences are used by teachers across subject areas, between poverty levels based on FRPL, when preparing report card grades for students. A possible explanation of why students at mid and high poverty schools are assigned less "A" grades might be that "students of high-poverty schools often come from low-SES households and are less likely to have parents who are actively involved in school, lowering the likelihood of adding pressure on teachers to alter grading practices" (Horvat et al., 2003; Lee & Bowen, 2006 cited in Kunnath & Sulieman, 2018, p. 11). If this is the situation in U.S. K-12 schools, then the goal of education for all, and especially in STEM for All is difficult to reach, perpetuating inequity in the U.S education system. Accordingly, how to address these challenges is a critical question facing U.S. K-12 STEM education. In this context, strategies for addressing these challenges in reforming STEM education as a human resource pipeline for a competitive workforce and economic development are explored.

Strategies for Reforming K-12 STEM Education

It is apparent that in its current state, K-12 STEM education is not a dependable human resource pipeline for any projected competitive STEM workforce and economic development (Banilower et al., 2018). To reform STEM education into a dependable pipeline, the following strategies are essential.

STEM for All

To promote STEM for All, everything possible should be done to promote diversity, and the inclusion of marginalized student groups in STEM education. "Articulate a clear vision for, and long-term commitment to, broadening participation in STEM" of persons with disabilities, women, and under-represented racial/ethnic groups in STEM education (Powell et al., 2018, n.p.; Southeast Comprehensive Center, 2012; Hill & Kumar, 2013; Kumar & Chubin, 2000). Based on poverty levels, race/ethnicity, and disabilities, there is apparent bias in terms of STEM course offerings and the amount of dollars spent per pupil (Banilower et al., 2018). Moreover, most teachers lack training in strategies to integrate students' cultural backgrounds into science pedagogy. Additionally, any bias in teacher assigned grades in STEM classrooms, needs to be addressed without delay. Inequitable, variable, and inconsistent grading practices may negatively affect education for all (Feldman, 2018), especially STEM for All.

These are complex matters that demand committed efforts from the stake holders of K-12 STEM education to find creative solutions towards STEM for All students and promote broad participation. If STEM education is truly a priority in U.S. schools, as touted by U.S. legislatures and leaders in business, then concerted and organized efforts to provide STEM for All should be taken. As the teacher is key to classroom reform, it is critical to emphasize the role of teachers through professional development, retention, and a supportive working environment.

Teacher Training

The most crucial strategy deals with offering appropriate training for teachers in preparation, and teachers currently working in K-12 classrooms, to improve their content and pedagogical knowledge and understanding of STEM education (Kumar & Moffitt, 2022). This will allow teachers to implement meaningful STEM lessons in their K-12 classrooms. The National Commission on Teaching and America's Future (1996) stated that teachers' knowledge and practices are the most significant factors affecting student learning. Therefore, for successful systemic reform in STEM education, it is imperative that classroom teachers are equipped with the knowledge and skills to teach STEM subjects meaningfully to all students. The *National Science Education Standards* (National Research Council, 1996) calls for giving practicing teachers the "same opportunities their students will have to develop understanding" (p. 60) of science, and recommends professional development with more emphasis on "inquiry into teaching and learning; learning science through investigation and inquiry; integration of science and teaching knowledge; etc." (p. 72). Teachers also need assistance in realizing their "blind spots" to create awareness of appropriate teaching and learning strategies for all students. Schools, school districts, and university/college teacher training programs should partner to strengthen the professional development of both teachers in preparation and in service teachers (Schneiderwind & Johnson, 2020).

One consideration is recent deregulation and the subsequent rise in alternate teacher preparation programs, which often replace the requirement of a bachelor's degree in education and the specific discipline (i.e., science and mathematics) and have compromised training in STEM content areas (Perez & Kumar, 2018). Individuals who entered teaching via alternative certification programs often have fewer courses or training hours to complete and are "25% more likely to leave their schools and the profession" (Carver-Thomas & Darling-Hammond, 2017, p. vi). In the name of education reform and politically motivated attempts to sideline university-based teacher training programs, alternative teacher training programs have grown all over the U.S., offering less comprehensive, and inadequately regulated teacher training where STEM subjects, especially science, are often not a priority (Ildiko & Berliner, 2002).

Teacher Retention

Increasing teacher retention, particularly in STEM subjects is critical to the successful implementation of STEM education. Teacher attrition is not only an educational crisis, but it also has severe economic and human resource implications. For example, from an economic standpoint, it costs approximately $21,000 USD to replace each teacher in an urban school, therefore reducing attrition in half would save $10,500 USD per urban school teacher (Carver-Thomas & Darling-Hammond, 2017). During the 2015-2016 school year, 40 U.S. states and the District of Columbia (D.C.) reported a teacher shortage in science, and forty-two states and D.C. reported a teacher shortage in mathematics (Sutcher et al., 2016). Disparities in the teacher labor market change from U.S. school district to district in critical shortage subject areas (Sutcher et al., 2016). High teacher attrition also contributes to low student achievement. It is disheartening that an economically prosperous nation such as the U.S. does not want to pay its teachers a competitive market salary. However, teachers are expected to train students into a STEM competent workforce. Senior teachers' turnover rate at the top of their district salary (average $78,000 USD) schedules is 31% lower than teachers with top district salaries below $60,000 USD (Carver-Thomas & Darling-Hammond, 2017), indicating that higher salaries may support a lower attrition rate. Overall, the predicted turnover rate of mathematics and science teachers is 37% higher than elementary teachers (Carver-Thomas & Darling-Hammond, 2017). So, if the U.S. wants to support K-12 STEM education, teachers need to be compensated adequately.

Supportive Environment for Teachers

An analysis of a teacher follow-up survey by the Learning Policy Institute (2017) showed that among several other reasons, 21% of teachers leave the field because of dissatisfaction with the administration, and 25% leave teaching positions due to dissatisfaction with school assessment policies. Schools where "principals generally describe their leadership responsibilities as facilitators, collaborators, team leaders, or leaders of leaders" have low teacher attrition rates (Learning Policy Institute, 2017, p. 2). To reform STEM education, it is imperative that the school administration provides a supportive environment for teachers to utilize their abilities to lead and inspire students to learn (Kumar & Chubin, 2000). School districts throughout the U.S. should not only aspire towards improving the work environment for teachers, but also for school administrators (i.e., principals) to enhance teacher retention in K-12 education (Carver-Thomas & Darling-Hammond, 2017). In a study limited to a large school district in Arizona, Sulit (2020) found that the distributive leadership framework significantly increased teacher retention in elementary and middle grades. This indicates that there is still hope for improving teacher retention. Suitable policies are needed in this area in K-12 education, not only for the sake of STEM disciplines, but also for all disciplines since K-12 education is an extremely critical human development process in a child's life.

Concluding Thoughts

STEM education is a human enterprise needing human, material, and fiscal resources to be successful. In this context, the classroom teacher is a significant catalyst for transforming K-12 STEM education as a dependable pipeline for a competitive workforce and economic development. The strategies discussed will work, provided socioeconomic disparities that impact public education in the U.S. are adequately addressed and resolved. It is extremely important that leaders of industries and businesses collaborate with legislators, policymakers, school administrators, classroom teachers, and parents to transform K-12 STEM education as a dependable human resource pipeline for a competitive workforce and economic development.

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