STEM EDUCATION IN THE UNITED STATES

A Thesis

by

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ABSTRACT

STEM education is described as a systematic teaching and/or learning process in the STEM fields and a positive correlation exists between STEM education and the economic prosperity and power of a nation in the globalized world. In recent years, rising concerns have emerged about American STEM education. Many stakeholders wonder that whether the nation has enough well-qualified STEM students, teachers and workforce to maintain its current competitive edge. They are also curious about whether federally funded STEM education programs are sufficient and work effectively. This study seeks to answer those questions, presenting a unique view about the concerns.

American students in elementary and secondary schools have relatively mediocre scores compared with their international peers (especially Asians), although they perform better than earlier American cohorts. The quality of STEM teachers also leads to concerns. The lowest certification rate of teachers is found in science and mathematics, and approximately half of the teachers do not have a degree in the subject that they teach. Furthermore, higher education is more significant for STEM workforce.

Concern is growing that China is gaining a competitive edge against the United States in its STEM workforce. China now has about the same graduation rate as the United States in Science and Engineering (S&E) fields.

All these concerns raise concerns about the role of the federal government in STEM education. Over time, the government has created and funded a variety of STEM education programs. In recent years, has become more focused on the coordination and administration of these programs to improve effectiveness and efficiency. Several reports have been published that have analyzed the programs and provided information about duplications, overlaps, and the participation

rates of underrepresented population, among others. In consideration of the findings of these studies, the government has created policies to improve STEM education by using resources more effectively. Whether these will stem the tide is unknown.

However, hope exists. Although American STEM education does not create enough well-trained graduates and the Chinese graduation rate in the S&E fields has dramatically increased, the United States one key advantage. Even if China has a larger STEM workforce than the United States, the United States likely will maintain its superpower because the American workforce comprises a wide variety of people. This diversity quite likely brings with it more innovative ideas and research, which has made (and will keep) America great.

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NOMENCLATURE

ACC	Academic Competitiveness Council
AYP	Adequate Yearly Progress
CNCS	Corporation for National and Community Service
DIPF	German Institute for International Educational Research
DoE	The Department of Energy
DoEd	The Department of Education
ESEA	The Elementary and Secondary Education Act
ESSA	The Every Student Succeed Act
FY	Fiscal Year
GAO	Government Accountability Office
GDP	Gross Domestic Product
HHS	The Department and Health and Human Services
HSUS	Trends in International Mathematics and Science Study
IAE	International Association for Educational Evaluation for Educational Achievement
IASA	The Improving America's School Act
JEC	Joint Economic Committee
LEAs	Local Educational Agencies
NAEP	National Assessment of Educational Progress
NAGB	National Assessment Governing Board
NASEM	National Academies of Sciences, Engineering and Medicine

NASSP	National Association of Secondary School Principals
NCES	National Center for Educational Statistics
NCLB	No Child Left Behind Act
NRC	National Research Council
NSB	National Science Board
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTPS	National Teacher and Principal Survey
OECD	The Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget
OSTP	The Office of Science and Technology Policy
PGB	PISA Governing Board
PIRLS	Progress for International Reading Literacy Study
PISA	Program for International Students Achievement
S&E	Science and Engineering
SASS	School and Staffing Survey
SAT	Scholastic Altitude Test
TIMSS	Trends in International Mathematics and Science Study
US	United States

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1. INTRODUCTION

1.1. STEM

Before the introduction of current acronym, “STEM”, the National Science Foundation (NSF) was using an acronym of “SMET” that referred to four distinct fields: science, mathematics, engineering and technology (Sanders, 2009). In recent years, STEM has been a buzzword among American stakeholders (Breiner, Harkness, Johnson & Koehler, 2012). Despite its buzzword status, an ambiguity exists in the definition of STEM (Madden, Beyers & O’Brien, 2016). The ambiguity has led to different definitions and occupational applications among stakeholders across the United States (Ntemngwa & Oliver, 2018) because several programs within various scientific communities have utilized it (Breiner, et al., 2012). Thus, the definition differs depending on who has employed it (Sanders, 2009).

As a term, STEM has gained a remarkable ground since 2001 (Breiner, et al., 2012). Today, quite a few occupations in STEM and non-STEM fields have required more knowledge of STEM (Gonzales & Kuenzi, 2012), which is significant for individual`s life because STEM skills are used in manufacturing smarter products to grow the economy (NSTC, 2013). Hence, the National Research Council (NRC) defines STEM as “cultural achievements that reflect people`s humanity, power of economy and constitute fundamental aspects of our lives as citizens, workers, consumers, and parents” (NRC, 2011; p. 3)

1.2. STEM Education

STEM education has gained attendance and has defended its own sovereign territory for a century (Sanders, 2009), so it is now widely used by institutions or individuals in the STEM fields

(Bybee, 2010). Despite the wide use, “STEM education” is often used interchangeably with the term “STEM” in the literature. However, STEM and STEM education are two different terms having two different meanings because STEM education means a lot more than the four-letter acronym of STEM (Sanders, 2009). Some argue that STEM education explains only science and mathematics; others believe that STEM education is a variety of activities that include more inquiry and project-based teaching strategies instead of traditional lecture-based ones (Breiner, et al., 2012). From a broader perspective, STEM education could be described as a systematic teaching and/or learning process in the STEM fields (Ntemngwa & Oliver, 2018). Consequently, no certain operational definition exists because it is variously perceived by the stakeholders; therefore, focusing on the goals of STEM education is needed to best understand the concept.

STEM education aims to improve students` science and mathematics scores and prepare them for their future education and careers (Becker & Park, 2011 S1). STEM education, additionally, aims to have more students graduating from the STEM fields (Breiner, et al., 2012). Therefore, almost all stakeholders agree that STEM education is about creating more qualified teachers, students and workforce (Breiner, et al., 2012) to maintain or to gain a competitive edge across the global (Machi, 2009) That is because STEM education would instill a passion for inquiry, discovery and the application of gained knowledge to new situations (Tananbaum, 2026).

1.3. Integrated STEM education

It is not incorrect to state that STEM education merely focuses on how the best practices would be implemented in the STEM fields (Mills, 2017), and STEM education has begun to be stated in more an integrative context in recent years (Madden, Beyers & O’Brien, 2016). Sanders (2009) explained integrated STEM education as the approaches that “explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (p. 21). In other worlds, it is the interdisciplinary approach that tries to meld two or more STEM subjects into a single project (Ntemngwa & Oliver, 2018). Another definition is that integrative STEM education is a means to increase a student`s understanding of a course, a unit or a lesson by integrating two or more STEM areas (Brown et al., 2017). In light of these definitions, the major goal is to enhance student learning (Tananbaum, 2026) and to acquire several skills like problem solving by increasing motivation via project-based learning in a more student-centered education (Laboy-Rush, 2011).

Sander`s (2009) definition comprises other non-STEM subjects to integrate them to the STEM fields because any development in STEM fields cannot be related to the social/behavioral sciences. Therefore, some stakeholders like the NSF define STEM fields in a broader perspective that includes the four fields of science, mathematics, engineering and technology as well as social/behavioral sciences like psychology, economics, sociology and political science (Green, 2017), although some agencies have a narrower perspective

1.4. Problem

Today, the significant correlation among STEM education, economic prosperity and a nation’s power has been recognized more in the globalized world (Machi, 2009). The United States is one of the world’s most outstanding nations, and the nation has maintained its current position through science, technology, engineering and mathematics. However, a concern is growing that the United States does not currently have good standing in STEM education and this situation could lead the country to fall behind its international counterparts including China in an increasingly competitive global market. Therefore, the condition of STEM education in the United

States and the federal government`s role in STEM education has become more crucial now than in the past. Thus, this study examines four pertinent questions related to this condition below:

1. Does American STEM education create well-qualified and sufficient numbers of STEM students, teachers and members of the workforce to maintain a competitive edge in a globalized world?

2. How does the federal government take responsibility for improving STEM education?

3. Are federally funded STEM education programs sufficient?

4. Do these programs work effectively?

Thus, the study will present a useful context about American STEM education in via a broad perspective. The second section will be about conditions of the STEM education in the United States. The third section of the study will explore the federal role from the past to the present regarding STEM education. Lastly, a discussion of the findings is included at the end of the study.

2. AMERICAN STEM EDUCATION

Science, Technology, Engineering and Mathematics (STEM) have been crucial areas in the educational curriculum for United States to maintain its dominant position since the launch of the Soviet Union's Sputnik satellite in 1957 because a strong connection was seen to exist among a nation’s welfare and power and STEM education (Gonzalez & Kuenzi, 2012). Even if they are interested in non-STEM subjects, workers in the job market should understand STEM subjects that are basic to their daily live (Mullis & Martin, 2017). Thus, as Gonzalez & Kuenzi, (2012) noted “today the economic and social benefits of scientific thinking and STEM education are widely believed to have broad application for workers in both STEM and non-STEM occupations” (p. 1).

In this century, a wide range of collaborative studies of various fields have said that a broad range of innovations and suggestions to solve world problems are brought to market by the STEM workforce (Mullis & Martin, 2017). A deficiency in any STEM field is seen as causing irreversible damages affecting all related fields and producing a detrimental domino effect (Machi, 2009). Hence, governments the world over are allocating more funds from their budgets to STEM education to improve students` scores in science and mathematics and to make students ready for their future educations or careers (Becker & Park, 2011) by increasing student motivation through project-based learning (Laboy-Rush, 2011). In other words, by giving more appropriations to STEM education, governments ultimately aim to develop a qualified STEM workforce that is expected to help their countries to gain a competitive edge in the globalized world.

Many American stakeholders have several concerns about American STEM education. The most recent concern is whether the nation has enough well-qualified STEM students, teachers and workforce to maintain a competitive edge (Kuenzi, Matthews & Mangan, 2006). To determine this, the condition of STEM education in the United States must be evaluated to have a perspective on this the concern.

Characterizing of the condition of STEM education in the United States is difficult because no single fact or statistic completely identifies the condition (Gonzalez & Kuenzi, 2012). However, some inferences can be captured from student performances in academic achievement tests.

2.1. American Students` Performance

Students in elementary and secondary schools are required to take many types of tests to be assess their academic performance, and these are considered critical for learners, educators, policymakers and families stakeholders in the educational setting process as they use them to assess the situation. Students are given several types of assessment tests in the United States. The tests are listed below:

> *State-required reading, mathematics, and science assessments,*
> *High school exit exams,*
> *National Assessment of Educational Progress (NAEP,*
> *International Assessments (including)*
> *Trends in International Mathematics and Science Study (TIMSS),*
> *Program for International Students Achievement (PISA), (and)*
> *Progress for International Reading Literacy Study (PIRLS), and*
> *Assessment to identify children for special services* (Skinner, 2017, p. 2).

Assessment policies in the United States are related to various educational acts, and federal legislation efforts on education have a critical role on assessment policies in elementary and secondary schools. The Elementary and Secondary Education Act (ESEA) Title I -A of 1965 and its subsequent revisions, therefore, have greatly affected assessment policies. The first revision under the ESEA was made in the Improving America's School Act of 1994 (IASA). States wishing to maintain eligibility for Title I – A grants were required to develop curriculum content, academic achievement and assessments to meet IASA`s requirements, but a deadline was not set for them (Skinner & Caffrey, 2010).

Another revision of ESEA called the No Child Left Behind Act of 2001 (NCLB) was signed by President George W. Bush in 2002. The NCLB had new requirements for the states. Unlike the IASA, the act sets specific deadlines regarding student assessment policies for states and Local Educational Agencies (LEAs) under Title I – A. Through scheduled deadlines, state assessments are administered annually in mathematics and reading for all students in grades 3-8 and once in high school; science assessments are administered at least once during each of the following grades: 3-5, 6-9, and 10-12 (Skinner, 2017). Furthermore, the act ensures that states make Adequate Yearly Progress (AYP) reports to meet state achievement standards (Skinner & Caffrey, 2010). The stated aim of the AYP was to improve student performance and achieve state proficient levels within 12 years by the end of the 2013-14 school year (Canales et al., 2002). The most recent revision on ESEA was signed by President Barack Obama in 2015. This most recent revision, the Every Student Succeed Act (ESSA), did not attempt to change the assessment requirements for states. As a result, the ESEA and its reauthorizations; IASA and NCLB have played crucial roles in improving assessment policies over the years.

Thus, the performance of students in the United States on STEM subjects could be identified by focusing on several tests on mathematics and science. From this perspective, comparing the scores on national and international assessments would be appropriate for achieving a more accurate view on the status of American students.

2.1.1. The performance of American students from a global perspective

American students are expected to achieve high scores on international achievement tests because the United States has one of the highest GDPs per capita in the world, and investment in education (especially STEM education) is directly proportional to GDP per capita. However, students from the United States do not perform well in comparison with some of their peers especially those from Asian countries. Thus, the performance of American students versus their peers in international assessments is relatively mediocre despite of the wealth of their nation.

The lower scores of American students create a disadvantageous situation and negatively impact the ability of the United States to remain competitive in the world. In 2010, then Secretary of Education, Arne Duncan, speaking at the annual meeting of the Association of American Publishers, noted the threat to the long-term economic prosperity of the United States of the low achievement of American students. Calling for reform, he said "The urgency has never been greater. Our children and our future are at risk, so let us together do the difficult but necessary things our schools demand. We have a moral and economic imperative that requires us to act" (Duncan, 2010). One of the most critical elements of his concern was whether the nation has enough well-qualified STEM students to compete in the world.

To determine the current situation, evidence about previous and the most recent assessments of the performance of American student at international level is presented in the following section. Three international assessments, TIMSS, PISA and PIRLS, are administered periodically. However, only TIMSS and PISA will be explored because PIRLS is designed to measure reading achievement.

2.1.1.1. TIMSS

2.1.1.1.1. What is TIMSS?

The Trends in International Mathematics and Science Study (TIMSS) as an international comparative study is designed to measure students` science and mathematics performance in elementary and secondary schools and to collect educational information in various contexts including the such as students` schools, teachers and homes of students (Stephens, Landeros, Perkins & Tang, 2016). The TIMSS is one of the major assessments used to compare the science and mathematics achievement of students in the United States with students in other countries (Lim & Sireci, 2017). The TIMSS has been conducted at four-year intervals since its first administration in 1995 (Stephens et al., 2016); the most recent assessment was completed in 2015 and next cycle will be administered in 2019. Therefore, TIMSS is a useful resource that provides comparative information for grades 4 and 8 on science and mathematics from 1995 to 2019. In 1999, United States did not participate in the assessment at fourth grade because it was not conducted as a cross-national study (Mullis & Martin, 2017).

2.1.1.1.2. Who runs TIMSS?

The International Association for Educational Evaluation for Educational Achievement (IAE), which is headquartered in Amsterdam, administers the TIMSS (Karakoc, Alatli, Ayan, Polat Demir & Uzun, 2016). The roots of IAE date to 1958, when a group of scholars met at the UNESCO Institute for Education in Hamburg. Concerned with effective education, they wanted to identify data-based information about the influences of high-quality education. From that time, they have organized international studies to evaluate aspects of education such as student's mastery of subjects; citizenship and civic education; computer and information literacy; and early childhood and teacher education (IEA, 2018).

The studies of IAE aim to present a useful framework to understand the effectiveness of current educational policies to allow them to be improved (Mullis & Martin, 2017). Although the headquarters of the IAE is in Netherlands (Karakoc Alatli et al., 2016), several divisions existed in Germany and the United States. The IAE`s TIMMS & PIRLS International Study Center is located at the Lynch School of Education in Boston College and is responsible for organizing the assessment of TIMSS over the world (Mullis & Martin, 2013).

2.1.1.1.3. Content and Reporting of TIMSS

Experts in mathematics, science and measurement from participating countries are key actors in developing TIMSS assessment frameworks (Stephens et al., 2016), and content and cognitive domains are assessed in the frameworks (Mullis & Martin, 2013). Each item in a content domain covers a range of cognitive skills of knowing, applying and reasoning for grade levels in the fields. (Mullis & Martin, 2017), and the grade levels are 4 and 8. However, the percentage of the domains in the fields varies in each assessment cycle and grade level. Thus, the frameworks include specific content domains in mathematics and science (NCES, 2007), which are shown in Appendix A.

The results of the assessment are reported with only numerical scores (Kuenzi, et al., 2006) in a scale ranging from 1 to 1000, with a center point value of 500 and a standard deviation of 100 (Unlu & Schurig, 2015). The interpretation of the results is done (Unlu & Schurig, 2015) via international benchmarks including 1) advanced, 2) high, 3) intermediate and 4) low (Mullis & Martin, 2013), which are divided with a band width of 75 points (Stephens et al., 2016). The international benchmarks are used to provide a deeper analysis and interpretation of a student's proficiency in the assessed subject, which varies at different points on the TIMSS scale (Stephens et al., 2016).

2.1.1.2. PISA

2.1.1.2.1. OECD

The Organisation for Economic Co-operation and Development (OECD), an international organization, was founded in 1960 with 18 European countries along with Canada and the United States, and today has 35-member countries and other partner countries like the People's Republic of China, India and Brazil (OECD, n.d. a). OECD, headquartered in Paris, France, collects data on a broad range of topics related to economic and social well-being and aims to help countries to foster built more effective policies by analyzing and comparing the results (Dossey & Funke, 2016). The OECD is also interested in educational inputs and outputs to analyze competitiveness and the qualifications of each nation`s young people for the future (OECD, n.d. a); therefore, an international assessment program was developed to measure student achievement across the world.

2.1.1.2.2. What is PISA?

PISA, which was created in 1997 (OECD, 2017), is an international comparative program to measure student knowledge and skills in reading, science and mathematics within a real-world context (Hopstock & Pelczar, 2011), so it does not only measure mastery of school curriculum but also the knowledge and skills that are essential for an adult to participate in society (NCES, 2007). The assessment also collects educational information in various contexts such as students` schools and home backgrounds as well as their learning approaches to explain student performance (Karakolidis, Pitsia, & Emvalotis, 2016). PISA's target population is only 15-year old students nearing the end of compulsory education in many member countries (Karakolidis, et al., 2016). The population include the students from 15 years and 3 months to 16 years and 2 months at the beginning of the testing period (NCES, 2007). PISA is one of the major assessments that is used to compare the science and mathematics achievement of students in the United States with students in other countries.

PISA has conducted at three-year intervals since its first assessment in 2000 (Karakolidis, et al., 2016), and the most recent assessment was completed in 2015. The next cycle will be implemented in 2018. The United States has participated in all assessment cycles and is also on the list of participant countries for 2018 cycle. In 2015, all subjects were delivered for first time as computer-based assessments to the countries that prefer to have a digitally based test (OECD, 2017).

2.1.1.2.3. Who runs PISA?

Several institutions and teams have responsibility for conducting PISA. The PISA Governing Board (PGB) "determines the policy priorities for PISA and makes sure that these are respected during the implementation of each PISA survey" (OECD, n.d. b). The OECD Secretariat monitors assessment implementation builds consensus among participant countries, and serves as intermediary between the PGB and the PISA Consortium (OECD, 2017). The Consortium comprises contractors charged with the design and implementation of the surveys (OECD, n.d. b). In the United States, the National Center for Education Statistics (NCES) was responsible for the implementation of the international standards set by PGB (Hopstock & Pelczar, 2011). Furthermore, national project managers are responsible for ensuring high quality of implementation by overseeing the process (OECD, n.d. b).

Additional subcontractors play a vital role in the development process. The development and adaptation of the frameworks in the three core subjects of reading, mathematics, science as well as optional subjects such problem solving, and finance are the responsibility of expert groups from Pearson (OECD, 2017), while the German Institute for International Educational Research

(DIPF) is the main foundation for developing questionnaires for students, teachers, principals and parents in PISA (DIPF, 2018). The Educational Testing Service (ETS) has responsibility for developing the electronic platform of PISA (OECD, 2017).

2.1.1.2.4. Content and Reporting of PISA

PISA uses the term “literacy” in each subject area to describe the broader approach of desired knowledge and skills (Lau, 2009). The test frameworks are developed by considering the literacy terms of the related subjects (OECD, 2017b). Each framework, therefore, includes various domain organizations to better measure student performance, and items are expected to be designed and distributed based on the decided organization. Each PISA administration has a unique design that focuses on one of the three core subjects, although all the core subjects are assessed in each cycle (Hopstock & Pelczar, 2011).

Science assessment has 100 items derived from three major systems: Physical (36%), Living (36%), and Earth and Space (28%). The items are assessed based on three types of knowledge: content (54%-66%), procedural (19%-31%) and epistemic (10%-22%). However, these items are designed to measure students` use of three competencies in situations set in personal, local/ national and global contexts in the ratio 1; 2; and 1 respectively (OECD, 2017). The competencies are the abilities to explain phenomena scientifically, to evaluate and design scientific inquiry, and to interpret data and evidence scientifically (OECD, 2017).

Mathematic assessment like science has 100 items that are equally weighted from four content categories: chance and relationship, space and shape, quantity, and uncertainty and data. However, the items are balanced and designed to measure students’ use of three competencies set in personal, occupational, societal, and scientific contexts. The competencies are the abilities to formulate situations mathematically (25%), to employ mathematical concepts, facts, procedures and reasoning (50%), and to interpret, apply and evaluate mathematical outcomes (75%) (OECD, 2017).

PISA results are reported only in terms of numerical scores ranging from 1 to 1000 with a center point value of 500 and a standard deviation of 100, and these scores represent degrees of proficiency (Karakolidis, et al., 2016). There are six proficiency levels ranging from (1) below level to (6) the highest level of proficiency, which vary at different points on the PISA scale (OECD, 2017b). Additionally, the levels of science proficiency were expanded in 2015, to 1a and 1b to better describe the students that have the lowest level of ability (OECD, 2017a).

2.1.1.3. Results

2.1.1.3.1. TIMSS

The most recent TIMSS cycle was administered in 2015 for 4, 8 and 12 grade students in Science and Mathematics. (NCES, n.d. b). There are 49 IEA member countries and 6 other educational systems at grade 4, and 38 IEA member countries and 6 other educational systems at grade 8. In 2015, 10,029 American students from 250 schools at the fourth-grade level and 10, 221 American students from 4,246 schools at the eighth-grade level participated to the assessment excluding Florida students (NCES, n.d. b). The results of the assessment were published in November 2016.

On the TIMSS mathematics assessment (Appendix B), the average score increased by 21 points 518 to 539 for the fourth-grade level (despite a 2-point decrease from 2011 to 2015) and by 26 points 492 to 518 for the eighth-grade level since the first year of administration in 1995. In addition, a stable increase in high and above level students was experienced for both grades in mathematics over the 20-year period.

In the last cycle that was in 2015, Singapore, Hong Kong, South Korea, Chinese Taipei and Japan had the top average scores, which were 54 points higher at the fourth-grade level and 68 points higher at the eighth-grade level compared to the scores of American students. The average score at fourth-grade level of the United States was significantly higher than the scores of 26 education systems, while the scores of 9 systems were significantly higher than US average scores at the .05 level. The average score at the eighth-grade level of the United States was significantly higher than the scores of 19 education systems, while 6 systems were significantly higher than the US average scores at the p = .05 level. Additionally, 37% of American students at the eighth-grade level performed at the high and above levels, and six educational systems had significantly higher percentages at that level. At the fourth-grade level, 47% of American studies reached the high and above levels on mathematics, and eight educational systems had significantly higher percentages at that level (Mullis, Martin, Foy & Hooper, 2016).

In the TIMSS Science assessment (Appendix C), the average score increased by 4 points 542 to 546 for fourth-grade students and by 17 points 513 to 530 for eighth-grade students since 1995. In addition, high and above level students slightly decreased for both grades in science over the 20-year period.

In the last cycle, the top performing countries in mathematics including as well as the Russian Federation had top average scores that were 9 points higher at the fourth-grade level and 14 points higher than at eighth-grade level when compared with the scores of American scores, which were 546 at grade 4 and 530 at grade 8. The average score at the eighth-grade level of American students was significantly higher than the scores of 20 educational systems, while 7 systems were significantly higher than US average scores at the .05 level. The average score of American students the fourth-grade level was significantly higher than the scores of 30 educational systems, while 7 systems were significantly higher than US average scores at the .05 level. Additionally, 43% of American students at eighth-grade level performed at the high and above levels; eight educational systems had significantly higher percentages at that level than the United States, while 51% of American fourth-graders reached the high and above levels on science; six education systems had significantly higher percentages at that level than the United States (Martin, Mullis, Foy & Hooper, 2016).

2.1.1.3.2. PISA

The most recent PISA cycle was administered in 2015 for 15-year-old students. More than 500.000 students participated in this assessment cycle, representing a population of 28 million students in 72 countries and economies (OECD, n. d. b). Country participation in the PISA across the world increased by about 70% rising from 20.3% to 33.95% since 2000 (Lockheed, 2015). Students were assessed in three core subjects (science, mathematics, reading) and optional subjects (collaborative problem solving and financial literacy) (OECD, n.d. b), and the dominant subject was science in 2015 like previous cycle in 2006 (Hopstock & Pelczar, 2011). The test was designed to take two hours; one hour for science and one hour for other two core subjects (OECD, 2017). The results of the assessment were published in December 2016 (OECD, n.d. b).

With respect to the United States on the PISA mathematics assessment, the average score decreased by 13 points from the 2003 to the 2015 administration. The scores significantly decreased by 17 points from 487 to 470 between 2009 and 2015 and by 11 points 481 to 470 between 2012 to 2015 with no other significant differences among the years. The average score in science increased by 7 points 489 to 496 between 2006 and 2015, but the average score decreased after 2009. The scores in 2012 and 2015 were respectively 497 and 496, which were lower than they were in 2009 when the score peaked at 502 (Appendix E).

In the last cycle that is shown in Appendix D, the top performers countries in mathematics (Singapore, Hong-Kong, Macau-China, Chinese Taipei, Japan and B.S.J.C - China) had top average scores at least 61 points higher than US average score of 470. The students in the countries of Singapore, Japan. Estonia, Chinese Taipei, Finland and Macau-China scored at least 33 points higher than the average score of their American peers in science, which was 496 (Appendix F). The OECD average score on mathematics in the last cycle was 490, but for the United States the score was 470; 20 points lower than average score. Just more than half of the participant countries or economies (37) had a significantly higher score than United States at the .05 level. The US average score in science was 496, which was just more than the OECD average score of 493. Nineteen countries including Chinese provinces had significantly a higher score than United States at the .05 level. Additionally, 20.3% of American students performed below level 2, while 8.5% of the students achieved at level 5 and above in science literacy. There were 15 countries that a had a significantly higher percentage of students at level 5 and above at the .05 level. In mathematics literacy, 29.4% American students performed below level 2, while 5.9% of the students had an achievement at level 5 and above (Kastberg, Chan & Murray, 2016). There were 38 countries that had a significantly higher percentage of students at level 5 and above at the .05 level.

2.1.2. American Science and Mathematics Education from a Historical Perspective

The growing concern about academic achievement trend in science and mathematics for US students should be analyzed from a distinct perspective rather than as just another part of the concern for the relatively lower achievement of US students compared to their several counterparts over the world. To do so, evidence about previous and current American students must be placed in historic context. The National Assessment of Academic Progress (NAEP) is used as the most appropriate assessment to track the changing trends in the subjects, and NAEP and its results are discussed below.

2.1.2.1. NAEP

2.1.2.1.1. Seed of the NAEP idea

NAEP, which is the most representative and continuing assessment at the national level, aims to determine how well American students know various subject areas (Horkay, 1999). The NAEP has tracked students since 1969 (Skinner, 2017). The genesis of its story began in 1957 when the launch of the Sputnik satellite created a rising concern about America`s scientific superiority. This event led to the National Defense Educational Act of 1958 (Beaton et al., 2011), under whose auspices testing was conducted to analyze the talents of students in the United States.

In 1962, President John F. Kennedy appointed Francis Keppel as head of the Office of Education, which was part of the Department of Health, Education, and Welfare. Keppel, when he arrived in Washington, D.C., discovered that the Office of Education had been tasked with reporting the progress of student in an 1867 law but had never done so. As a result, he set in motion as series of activities that eventually led to the creation of the NAEP (Beaton et al., 2011).

As the NAEP grew, a series of events provided impetus for its further development and the expansion of its usage. In 1983, Terence Bell, then Secretary of Education under President Ronald Regan, received the *Nation at Risk: The Imperative for Educational Reform* report that the National Commission on Excellence in Education Scholastic had issued. This report decried the state of the American Educational System. A year later, Bell presented his soon-famous wall chart, which showed the steady decline of ACT and SAT scores (Beaton et al., 2011). Shocking as these were, as Bell pointed out, these scores were only for college-bound students. Thus, he pointed out the need for a more comprehensive set of metrics to measure the academic status of all high school seniors (Beaton et al., 2011). Consequently, the NAEP emerged to analyze the nation's education and provide to objective information about overall student performance for policymakers (Horkay, 1999).

2.1.2.1.2. NAEP: past to future

The NAEP has evolved over time, with changes in both frequency, design, and methodology. From 1969 to 1979, the NAEP conducted annual assessments, and from 1980 through 1996, assessments were made every two years, but annual assessments began once again in 1997 (Horkay, 1999).

Another milestone for NAEP was the development of a new assessment design. NAEP now has two strands. The main NAEP reports findings for grade levels and the long-term findings report trends NAEP (Beaton et al., 2011). The test items in the main assessment have been revised over time regarding content and structure to reflect current educational views and practices (Skinner & Caffrey, 2010), whereas the long-term trend NAEP measures change over time (Horkay, 1999). Moreover, the main NAEP represents grade samples for grades 4, 8, 12 on mathematics, reading, science, writing, the arts, civics, economics US history and other subjects (Skinner, 2017) and students at ages 9, 13, and 17 years are measured on reading and mathematics in the long-term assessment (NCES, n.d. a).

The most recent development of NAEP permits Digitally Based Assessment for mathematics and reading and was first administered in 2017 and additional subjects are to be added in 2018 and 2019 (NCES, n.d. a)

The participation the NAEP has also changed over time. Although participation had been voluntary until the 2002-03 school years, NCLB mandated that all states participate in the NAEP in grades 4 and 8 for reading and mathematics assessment, which is conducted every other year for all states (Canales et al., 2002). Additionally, these subjects must be tested on a national level for grades12 at least as often as it is done in the past or every four years (Beaton et al., 2011). The schedule of the assessments through 2024, which was approved by National Assessment Governing Board (NAGB) on November in 2015, are found in the webpage of the assessment.

2.1.2.1.3. Who Runs the NAEP?

The NAGB is responsible for setting NAEP policy and for establishing a framework and other specifications (NCES, 2007) by organizing various panels from which a series of reports are produced as a consequence of collaborative NAEP study utilizing a wide range of experts and participants from government to public sectors (Horkay, 1999). Moreover, the Commissioner of Education Statistics who heads the National Center for Educational Statistics in the United States manages the NAEP (NCES, n.d. a).

2.1.2.1.4. Content and Reporting the NAEP

In the beginning, the NAEP used average scores on a scale of 0 to 500 with five levels set at anchor points as Rudimentary = 150, Basic = 200, Intermediate = 250, Adept = 300 and Advanced = 350 (Beaton et al., 2011). In 1990, the anchor points approach was replaced with achievement levels, identified by NAGB as Basic, Proficient and Advanced to demonstrate competency over the NAEP subjects (Kuenzi, et al., 2006). These levels help to recognize a student's proficiency in related subjects at different points on the NAEP scale by qualitatively describing criteria for each level of students need to have expected knowledge or skills. The long term NAEP uses the performance level similar with the anchor level. The results are interpreted as Level 150, Level 200, Level 250, Level 300 and Level 350 (NCES, 2013). In 2005, the scale for the NAEP was changed from 0 to 300; thus, the most recent scale of science achievement ranges from 0 to 300. However, mathematics scale has continued with the previous range of 0 to 500 for both the fourth and eighth grades to maintain consistency with past reporting results (Beaton et al., 2011).

The NAEP mathematics assessment includes five content domains that are shown in Table 1 for each grade. The content domains do not differentiate for each grade but have a different number of items for each content area (NAGB, 2017).

Table 1 Percentage distribution of items by grade and mathematics content domains

Mathematics Content Domains	Grade 4	Grade 8
Number Properties and Operations	40	20
Measurement	20	15
Geometry	15	20
Data Analysis, Statistics, and Probability	10	15
Algebra	15	30

Source: NAGB. (2017).

The NAEP science assessment includes three different content domains; Physical Science, Life Science and Earth and Space Sciences. The weight of these content areas is based on student response time; respectively 30%, 30% and 40% at the eight-grade level but are equal on the fourth-grade level. The items were developed by using performance expectations derived from science practices (NAGB, 2014), which are converted based on the percentage of student response time. For example, using science principles is less important in grade 4 than in grade 8 and identifying science principles is more crucial in grade 4 than in grade 8. See Table 2.

Table 2 Percentage distribution of items by grade and science practices

Science Practices	Grade 4	Grade 8
Identifying Science Principles	30	25
Using Science Principles	30	35
Using Scientific Inquiry	30	30
Using Technological Design	10	10

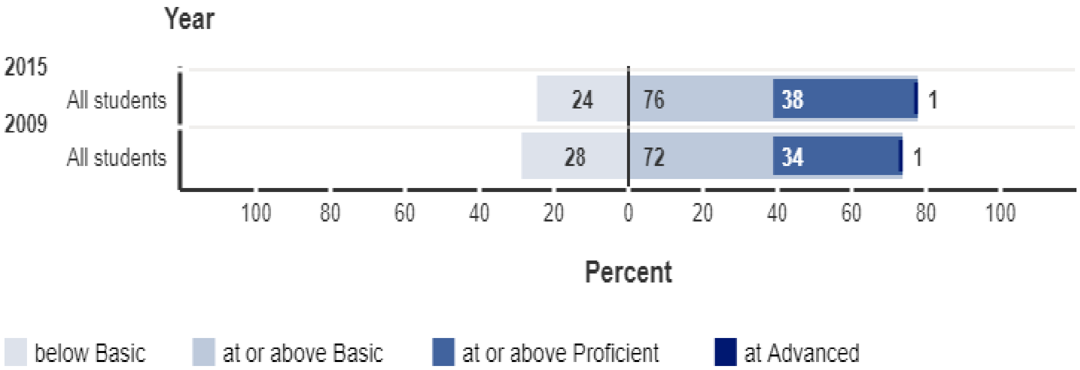
Source: NAGB. (2014).

2.1.2.1.5. NAEP results

The most recent science assessment was administered in 2015 for the fourth and eighth grades. The assessment was conducted with 115,400 students from 7,650 schools for grade four and 110,900 students from 6050 schools for grade eight. Note that science assessment in 2011 was conducted with only eighth grade students because of linking effort with TIMSS.

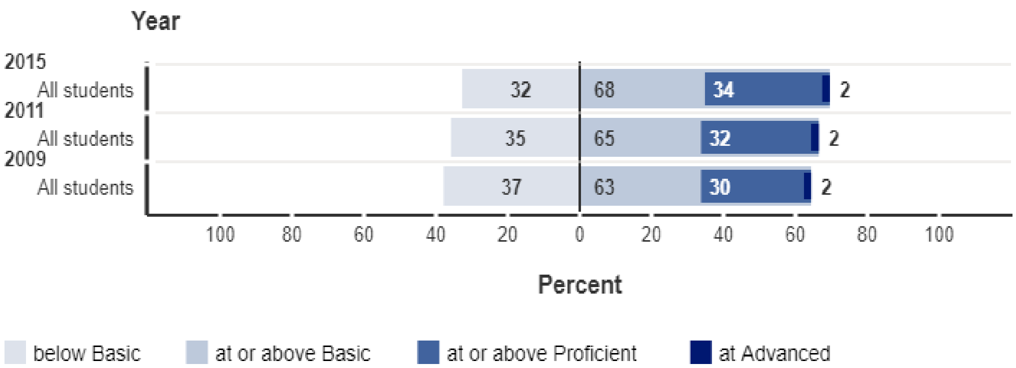
Figures 1 and 2 demonstrate the available results for both grades 2009 to 2015. The six years witnessed a 4-point increase on average scores; 150 to 154 for both grades. The percentage of both grades at the advanced level did not change with just 1% and 2% of fourth and eighth grade students respectively over the time. Additionally, a slight decrease was present for both grades at the below basic level. In the most recent assessment in 2015, more than one third of fourth and eighth grade students had a score of at or above proficient level; 38% and 34% respectively. In 2015, 24% and 32% of the sample for fourth and eighth grade students respectively performed below the basic level.

Figure 1 Achievement-level results for fourth-grade students assessed in NAEP science: 2009 and 2015



NOTE: Some apparent differences between estimates may not be statistically significant.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2009 and 2015 Science Assessments.

Figure 2 Achievement-level results for eighth-grade students assessed in NAEP science: 2009 and 2015



NOTE: Some apparent differences between estimates may not be statistically significant.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2009, 2011, and 2015 Science Assessments.

The most recent long-term NAEP assessment was conducted in 2012. From 1973 to 2012, the average math scores of students at ages 9 and 13 increased significantly while those at age 17 did not change significantly. Thus, the average score at age 9 was 25 points higher than in 1973, whereas the average score was 19 points higher for the students at age 13 (NCES, 2013).

The most recent main mathematics assessment was administered as digitally based assessments between January and March 2017 and reported in April 2018. The assessment was conducted with 149,400 students from 7,480 schools for grade four and 144,900 students from 6,500 schools for grade eight. Figures 3 and 4 demonstrate the available results for both grades from 2003 to 2017. In the fourteen years, there was a 5-point increase on the average scores; 235 to 240 for fourth grade and 278 to 283 for eighth grade. The percentage of fourth and eighth grade students at the advanced level increased exactly twice with a slight decrease for both grades at the below basic level. In the most recent assessment in 2017, more than one third of the both grades of students scored at or above proficient level; 40% and 34% respectively. In 2017, 20% and 30% of the sample for fourth and eighth grades respectively performed below the basic level in 2017.

Figure 3 Achievement-level results for fourth-grade students assessed in NAEP mathematics: 2003, 2005, 2007, 2009, 2011, 2013, 2015 and 2017

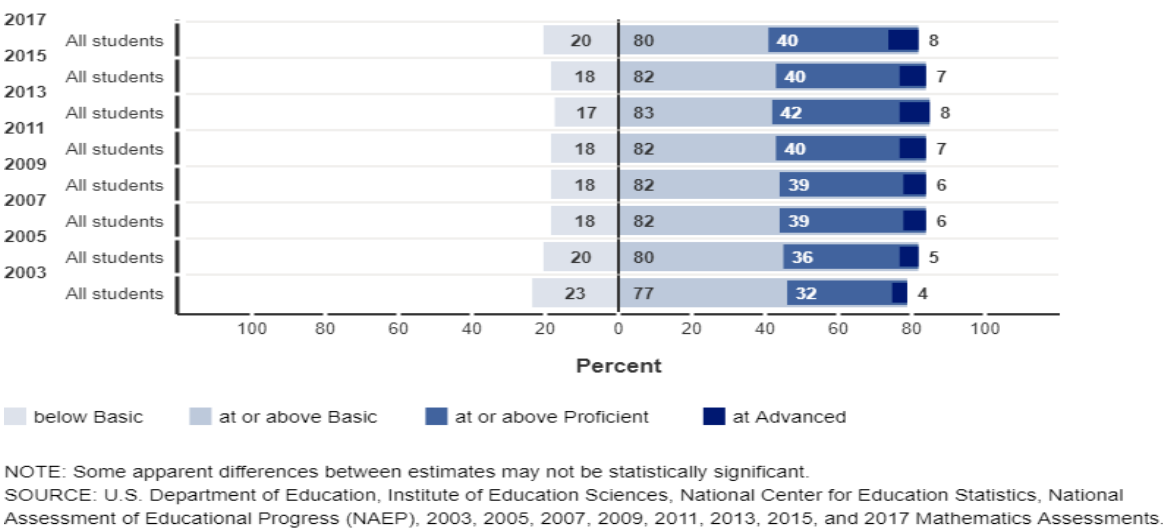
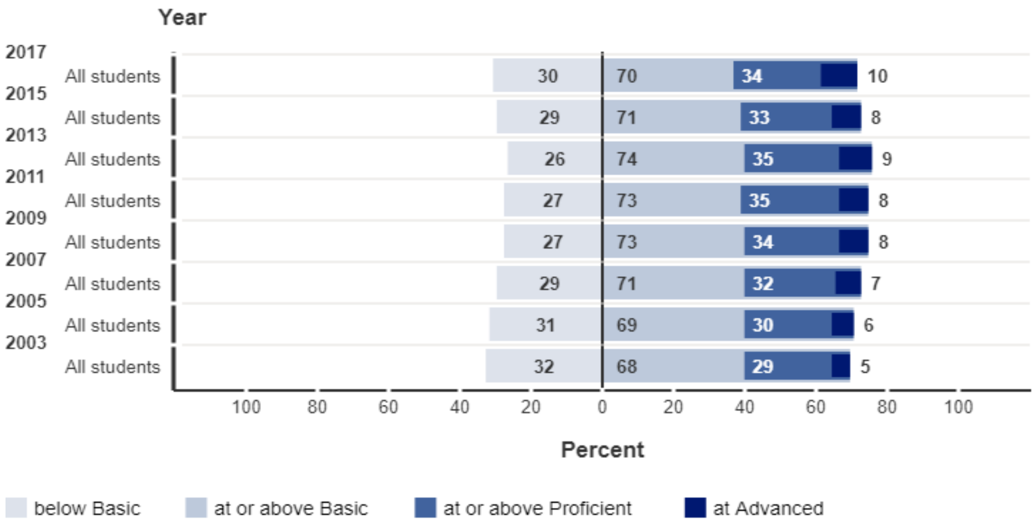


Figure 4 Achievement-level results for eighth-grade students assessed in NAEP mathematics: 2003, 2005, 2007, 2009, 2011, 2013, 2015 and 2017



NOTE: Some apparent differences between estimates may not be statistically significant.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003, 2005, 2007, 2009, 2011, 2013, 2015, and 2017 Mathematics Assessments.

2.2. Teacher Quality

Many policymakers, educators and other stakeholders have growing concern about how the United States can keep it current economic dominant position given the mediocre performance of its educational systems compared with the rest of the world (Killewald & Xie, 2013). As Francis Eberle, who was executive director of the National Science Teachers Association from 2008 to 2012, explained it; “other countries are investing, and we can see their progress. Do we want to be average?" (Toppo, 2008). Some stakeholders put forward the idea that the US teaching force is a source of the insufficient performance of students on science and mathematics in the national and international assessments (Kuenzi, Matthews, & Mangan, 2006).

Indeed, prior research has shown an association between teacher education/certification and student outcomes (Hill & Stearns, 2015). In other words, whether teachers hold regular or standard professional certification is a crucial issue for student achievement in American education. Thus, analyzing subject-based teacher certification, including those in science and mathematics, can provide deeper information. Holding a certificate in the field that is taught in the classroom has been found to be important as recent research has highlighted that holding a major/certificate in the subject taught in class has a positive relationship with student achievement (Allen, 2005). Thus, this section presents evidence of subject-based teacher certification to gain a perspective about quality of teachers in the United States.

The School and Staffing Survey (SASS) is a national survey designed to collect data about educational components such as such as teachers, principals and libraries from public and private schools at elementary and secondary level (Baldi, Warner-Griffin & Tadler, 2015). The SASS was being conducted biennially by the NCES from 1987 to 2011. After which, a new survey, called the National Teacher and Principal Survey (NTPS) (NSB, 2018a), was utilized. The main goal for the NTPS was to provide a more flexible and timely survey that was integrated with other Department of Education methods (NCES, n.d. c). Although the new survey includes the same core topics as SASS, it also includes newer topics like the use of information technologies by teachers in the classroom (NSB, 2018a). The following paragraphs provides some statistical information about teacher certification from both surveys.

The most recent data available from NTPS is 2015-16. From a general perspective, 90.3% of 3.827,100 US teachers in all fields have regular or standard professional state certification while 1.4% of all teachers work without the certification (Table 3). So, it could be stated that most US teachers held teaching certificate during the 2015-16 school year.

Table 3 Total number of public school teachers and percentage distribution of public school teachers, by type of teaching certificate, 2015–16

Type of teaching certificate Total number of teachers 3,827,1000				
Regular or standard state certificate/advanced professional certificate	Probationary certificate	Temporary or provisional certificate	Waiver or emergency certificate	No certification
90.3%	3.1%	4.3%	0.9%	1.4%

Source: U.S. Department of Education, National Center for Education Statistics, National Teacher and Principal (NTPS), *Public School Principal Data File*, 2015–16.

Additionally, statistical information about subject-based teacher certification in English, science and mathematics should be examined. The most recent subject-based information based on the SASS was conducted in 2011-12. The most recent SASS results illustrate that teacher certification rates differ by subjects (Appendixes G & H). In the public middle schools, the percentage of all teachers holding certificates in English, mathematics and science were 56.8%, 52.9% and 56.8%. In English, mathematics and science 46.1%, 28.1%, and 44.9% of the teachers respectively held a major in their main assignment while 53.7%, 71.9% and 55.1% of teachers in these subjects respectively lacked a major in their main assignment. However, the rate of having certification in public high schools was higher than the rate in middle grades in the three subjects as 82.1% of English teachers had certification, 80.9% of mathematics teachers had certification and 85.7% of science teachers had certifications. Teachers holding a major in their main assignment was 79.4% for English, 70.1% in mathematics and 79.7% in science while 20.6%, 29.9% and 20.3% of teachers respectively lacked a major in their main assignment.

2.3. STEM Labor Supply

After the 2007-2008 world economic crisis, economic balances changed fast, and Asian countries with the leadership of China have been gaining more ground in the global economy. By 2030, Asian economies are projected to have 40% of the global GDP approximately and half of that will be from the Chinese economy (Fensom, 2017). GDP growth slowed significantly in China falling from a 14.2% yearly increase in GDP in 2007 to 6.9% in the ten years between 2007 to 2017 (Morrison, 2018). In fact, the slowdown is result of the Chinese policy to rebalance the growth model (Fensom, 2017) to avoid a middle-income trap (Morrison, 2018).

Two ways exist to avoid this trap: technological innovation and industrial upgrading (Hutchinson & Das, 2016). Thus, innovation has been a top priority in certain sectors in the Chinese economic plan (Morrison, 2018). For example, China is gaining significant ground in the Internet-based economy and in some manufacturing industries (Hutchinson & Das, 2016) as well as in electrical engineering and computing (Machi, 2008). The Chinese efforts to avoid the middle-income trap have led to concerns in the United States that China eventually aims to dominate global market by decreasing reliance on foreign technology, U.S. Trade Representative Robert Lighthizer has described this as "a very, very serious challenge, not just to US, but to Europe, Japan and the global trading system" (Morrison, 2018).

In the global world, the STEM workforce provides innovations, which separate developed nations from developing nations (Machi, 2008); hence, the Chinese economic plan is closely associated with STEM education. Chinese policies under the plan are a source of rising concern about STEM education in the United States. The stakeholders related to STEM subjects agree that any deficiency in US STEM education either has either resulted in or will result in workforce shortages and that this problem has impacted US global economic competitiveness and national security negatively (Gonzales & Kuenzi, 2012). Therefore, data about US higher education should be examined to see whether the United States has either a high quality or a sufficient number of members of the STEM workforce.

Although a popular view is that American top students are reluctant to enter upon a scientific career (Benderly, 2010), statistical data about the pursuit of higher education in STEM subjects would serve as an indicator for condition of the labor supply. This may be examined in terms of degree enrollment and degree awarded statistics.

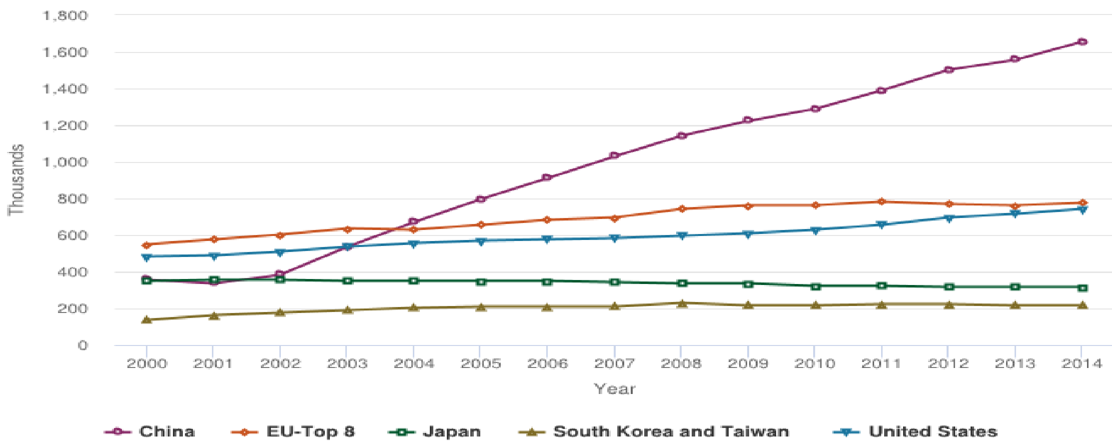
Enrollment in institutions of higher education in the United States significantly increased from 17.5 million to 20.0 million in the ten years from 2005 to 2015 (Hussar & Bailey, 2017). However, the increase differs between the undergraduate and graduate levels. There was a 14% an increase in enrollment from 15 million to 17 million for total baccalaureate enrollment with a peak of 18.3 million in 2010 (Hussar & Bailey, 2017) whereas the enrollment rate in post-baccalaureate degree experienced 17% growth increasing from 2.5 million to 2.9 million in the same ten-year period (Snyder, de Brey & Dillow, 2018).

From the S&E perspective, 45% of freshmen intended to study S&E subjects in which biological and agricultural sciences and engineering are rising majors (NSB, 2018a). Almost 668,000 graduate students were enrolled in S&E majors in 2015, and graduate students are becoming more interested in computer sciences, mathematics and statistics, medical sciences, and engineering with respect to previous years (NSB, 2018a).

The number of undergraduate (bachelor's) and graduate (master's and doctorate) degrees in S&E and non-S&E fields awarded by US higher institutions increased during the period from 2000 to 2015. These increases were 50% in baccalaureate, 59% in master's and 48% in doctorate degrees (Hussar & Bailey 2017).

In S&E fields, more than 7.5 million students are globally awarded a bachelor's degree (NSB, 2018b). The number of awarded bachelor's degrees in S&E by US higher institutions increased by almost 50% rising from 483,000 to 742,000, which is almost 10% of all awarded bachelor's degree at the global level. However, the number of Chinese awarded degrees more than quadrupled during the same period, growing from 359,000 to more than 1,600,000, which is just less than 25% in S&E fields over the world. (See Figure 5). Additionally, the proportion of S&E fields of all bachelor's degree in China is 48%, while it is 39% in the United States (NSB, 2018b). Thus, China would seem to have a competitive edge against the United States.

Figure 5 Bachelor`s degree awards in S&E fields, by selected region, country or economy, 2000, 2014



Note(s): EU-Top 8 is the eight European Union countries with the most bachelor's degree awards in 2014: UK, Germany, France, Poland, Italy, Spain, Romania, and the Netherlands.

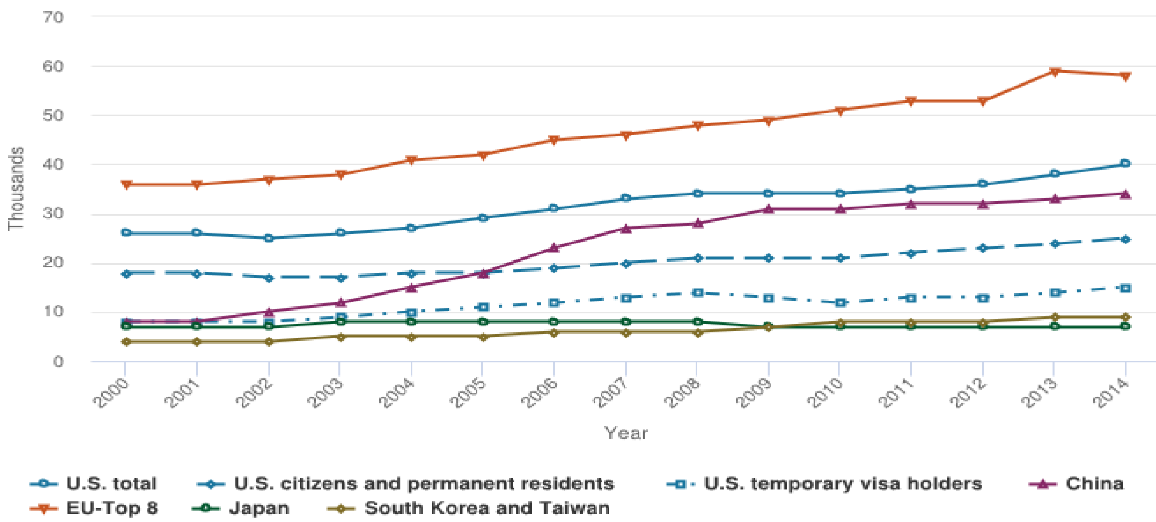
Indicators 2018 : First University Degrees in S&E Fields, Chapter 2.

Source: NSB. (2018b).

The number of awarded S&E doctoral degrees in United States had a trend similar to that of bachelor's degree during the 2000 to 2014 period, rising from 26,000 to 40,000. China had about same number of graduates awarded doctorate degrees in S&E fields as the United States in 2014.

In 2000, the United States (24,000) had three times more graduates than China did (8,000) in 2000. Additionally, just less than 40% of doctorate recipients in S&E fields in the United States were temporary visa holders (Figure 6).

Figure 6 Doctoral degree awards in S&E fields, by selected region, country or economy, 2000, 2014



Note(s): EU-Top 8 is the eight European Union countries with the most doctoral degree awards in 2014: Germany, UK, France, Spain, Italy, Portugal, Sweden, and Romania.

Indicators 2018 : International Comparison of S&E Doctoral Degrees, Chapter 2.

Source: NSB, 2018b.

Recipients of post-baccalaureate degrees are seen as bringing advances in research that will lead to innovations profoundly impacting a nation's competitive edge in the global world. The dramatic increase of baccalaureate and post baccalaureate degrees conferred in China has been seen as a critical factor income by rebalancing the country's scientific and technological capabilities with the United States. The citizens of China and the United States publish the most S&E research papers. In 2014, China has 426,000 research articles rising from 87,000 in 2000 while the United States had 409,000 articles in 2014 rising from 22,000 in 2000 (NSB, 2018b). These results provide a perspective regarding on how China has gained ground and is gaining a competitive edge against the United States in the global world.

3. FEDERAL GOVERNMENT AND STEM EDUCATION

The acronym STEM refers to four distinct fields: science, technology, engineering and mathematics (Sanders, 2009). The STEM fields are given more attention among nations or economies, which aim to develop their innovative and science capacity to gain ground in the global economy. Having a high-quality and sufficient STEM workforce helps in several aspects, ranging from space systems to better national security to advanced healthcare (NSTC, 2013). From this perspective, STEM knowledge is a requirement for workers even if they interested in non-STEM fields (Gonzales & Kuenzi, 2012). Hence, STEM education, which is described as the instruction process in the STEM fields (Ntemngwa & Oliver, 2018), is a top priority the world over because most of the world's population has already recognized the strong relationship between STEM education and national welfare (NSTC, 2013).

Some researchers argue that the United States has a sufficient number of STEM workforce, whereas others believe that the capacity of the United States to fill the demands of a large number of STEM-related occupations is inadequate (GAO, 2014). Furthermore, some countries like China and India are on course to gain a competitive edge against the United States by way of improving STEM education (Sanders, 2009). When considering these thoughts as well as the insufficient performance of American students on international tests, concern has grown about US STEM education. Many stakeholders in the United States, hence, believe that the country should invest more heavily in STEM education in the future to maintain the country's competitive edge in the global market (ACC, 2007).

3.1. Federal Efforts in STEM Education

Federal, state and local governments, higher institutes and the private sector in the United States have taken responsibility for improving STEM education by providing STEM education opportunities (programs) (GAO, 2014). The programs are defined by the Government Accountability Office (GAO) as programs funded by allocation or congressional appropriations (GAO, 2018). STEM education programs play a significant role for the United States by helping to prepare learners and educators for careers in the STEM fields and by enhancing the global competitiveness of the United States (GAO, 2018). Over the decades, the Congress and the federal government through federal agencies have funded several existing programs and provided new education programs as well. See Figure 7.

The Graduate Research Fellowship Program (GRFP), The Mathematics and Science Partnership (MSP) and the Ruth L. Kirschstein National Research Service Award (NRSA) had the highest appropriations in the NSF, the U.S. Department of Education and the U.S. Department of Health and Human Services respectively. The GRFP is the oldest fellowship program supporting graduate students in science, technology, engineering and mathematics fields. The GRFP aims to ensure the vitality of human resources in science and engineering and reinforce its diversity. The target population of the program is outstanding graduate students in science, technology, engineering, and mathematics disciplines at accredited United States institutions. The MSP program is a partnership effort between STEM departments of higher education and high-need school districts. The program aims to improve the academic achievement of students in mathematics and science and increase teacher quality. NRSA is a research training grant for institutions and researchers (pre and post-doctoral) in biomedical, behavioral, and clinical fields. The award aims to have a diverse and well-trained workforce in these fields.

Figure 7 Agencies Administering Science, Technology, Engineering, and Mathematics (STEM) Education Programs

Agency	Mission
Department of Agriculture	To provide leadership on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management
Department of Commerce	To promote job creation, economic growth, sustainable development, and improved standards of living for all Americans by working in partnership with businesses, universities, communities, and our nation's workers
Department of Defense	To provide the military forces needed to deter war and to protect the security of our country
Department of Education	To promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access
Department of Energy	To ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions
Department of Health and Human Services	To enhance the health and well-being of Americans by providing for effective health and human services and by fostering sound, sustained advances in the sciences underlying medicine, public health, and social services
Department of Homeland Security	To ensure a homeland that is safe, secure, and resilient against terrorism and other hazards
Department of the Interior	To protect and manage the nation's natural resources and cultural heritage; to provide scientific and other information about those resources; and to honor its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities
Department of Transportation	To ensure a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future
Environmental Protection Agency	To protect human health and the environment
National Aeronautics and Space Administration	To drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth
National Science Foundation	To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes
Nuclear Regulatory Commission	To ensure the adequate protection of public health, safety, and the environment while promoting the common defense and security

Source: GAO, (2014, p. 7).

However, a United States Government Accountability Office report in 2005 highlighted a deficiency about the effectiveness of federal STEM education programs because agencies reported little about that whether the programs work effectively (GAO, 2005).

A little after the report, President George W. Bush signed the Deficit Reduction Act of 2005 that established of the Academic Competitiveness Council (ACC) to review federal STEM education programs and to report the findings to Congress within one year (ACC, 2007). The ACC aims to increase US competitiveness in the global market by ensuring the greatest returns from federally funded STEM education programs (OMB, 2006). There were 105 stem education programs in the ACC report funded at $3.12 billion in Fiscal Year (FY) 2006 (ACC, 2007), which was different from the GAO report of 2005, in which 207 programs was funded at a total of $2.8 billion in FY 2004 (GAO, 2005). The program inventories are distinct because the programs provided by ACC are verified by the Office of Management and Budget (OMB) while the GAO reports rely on only agency-reported data (ACC, 2007). Both studies demonstrate that the National Science Foundation, the Department and Health and Human Services and Department of Education hold most of the total funding (about 80%) (GAO, 2005; ACC, 2007).

In 2007, the report entitled the *National Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, also called the Augustine Report (Kuenzi, Matthews & Mangan, 2006), said that the federal government should more give attention to STEM education, highlighting the weakness of existing US STEM education (Gonzales & Kuenzi, 2012). The heightened awareness of the federal government in STEM education led to the America Competes Act "to invest in innovation through research and development, and to improve the competitiveness of the United States" (America Competes Act, 2007; 121 STAT. 572). In the act, several programs were authorized to promote STEM education. Congress reauthorized the America Competes Act in 2010, which has continued to support some existing programs and to giving funding to new ones. Additionally, the act brought about reforms in the coordination and administration of the STEM education programs (America Competes Reauthorization Act of 2010).

The Office of Science and Technology Policy (OSTP), founded in 1976, provides advice to the President of the United States about scientific engineering and technological aspects of domestic and international affairs (OSTP, n.d.). The office is responsible for scientific and technological analysis and judgment regarding the major programs or policies of the federal government (NSTC, 2016).

The National Science and Technology Council (NSTC), founded by executive order in 1993, established US federal science and technology goals in all kinds of areas including the mission of federal government (NSTC, n.d.). The OSTP over sees the council's activities (NSTC, n.d.). The American Competitive Reauthorization Act of 2010 charged the OSTP with establishing a committee under the NSTC that aims to inventory, review and coordinate the federal STEM education programs and activities across federal agencies by collaboratively working with the OMB. (America Competes Reauthorization Act of 2010).

The committee on STEM education, named CoStem (NSTC, 2013), is responsible for:

1. Coordinating STEM education programs or activities conducted by federal agencies with the Office of Management and Budget and ensuring they do not duplicate of similar efforts among the agencies;
2. Striving to increase the teaching of innovation and entrepreneurship in STEM education programs;
3. Documenting the participating rates of women, underrepresented minorities and persons in rural areas, and
4. Developing and implementing 5-year STEM education strategic plan that is updated every 5 years (America Competes Reauthorization Act of 2010).

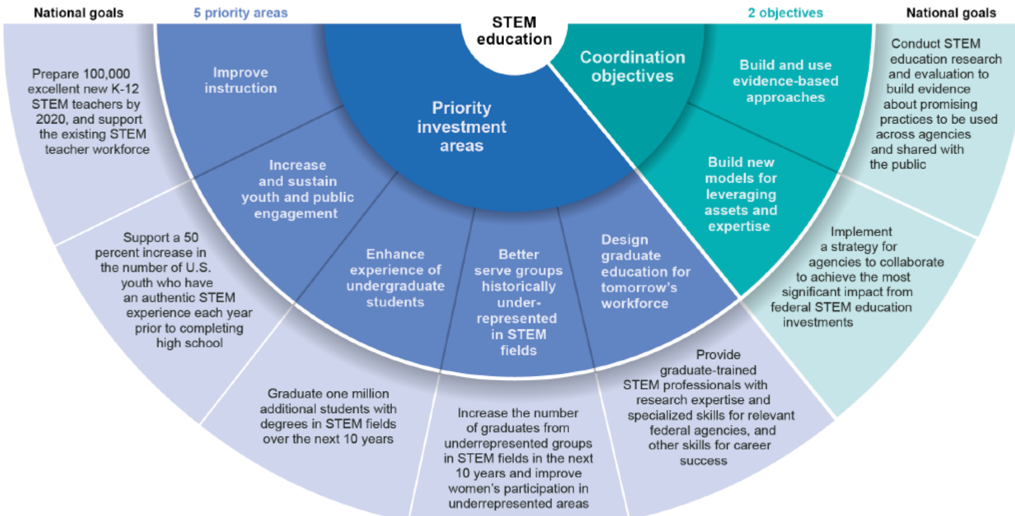
The America Competes Reauthorization Act of 2010 stated that the 5-Year Federal STEM Education Strategic Plan should include: 1) short and long-term priorities, 2) state the standards to be used for assessing the progress of the objectives and describing the approaches to assess effectiveness of the objectives, 3) identify the role of participating agencies of STEM education programs, and 4) report the inventory of federal STEM education programs and activities for the assessment of the same aspects of effectiveness of the programs and activities (America Competes Reauthorization Act of 2010).

As a result, CoSTEM inventoried all existing Federal STEM education investments in December 2011 to create a clear picture by providing information about duplication, overlap, and fragmentation among the federal investments (NSTC, 2011) and published a report entitled *The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio* (NSTC, 2012). The findings of the inventory contributed to the development of the strategic plan (NSTC, 2013).

CoSTEM, furthermore, released a report of the interim strategic plan in February 2012, which was entitled *Coordinating Federal STEM-Education Investments: Progress Report* (NSTC, 2013). The report, launched when the strategic plan was almost completed, provided a description of the plan and the STEM programs that were already established or under development (NSTC, 2012). A brief time after interim report, the strategic plan was completed and released in May 2013.

The major goal of the plan is to improve federally funded STEM education investments in the aspects of efficiency, coordination and impact (NSTC, 2013). The strategic plan described five priority investment areas and two goals for the coordination of STEM education with specific national goals for each areas and goals. The priority areas aim to: 1) improve P-12 STEM instruction, 2) increase and sustain youth and public engagement in STEM, 3) improve undergraduate STEM education and better serve groups historically underrepresented in STEM fields, and 4) design graduate education for today`s STEM workforce (NSTC, 2013). Additionally, two coordination approaches included building new models for leveraging assets and expertise and identifying using and sharing evidence-based approaches (NSTC, 2013).

Figure 8 Science, Technology, Engineering, and Mathematics (STEM) Education National Goals, Priority Investment Areas, and Coordination Objectives



Source: GAO. (2018, p. 6).

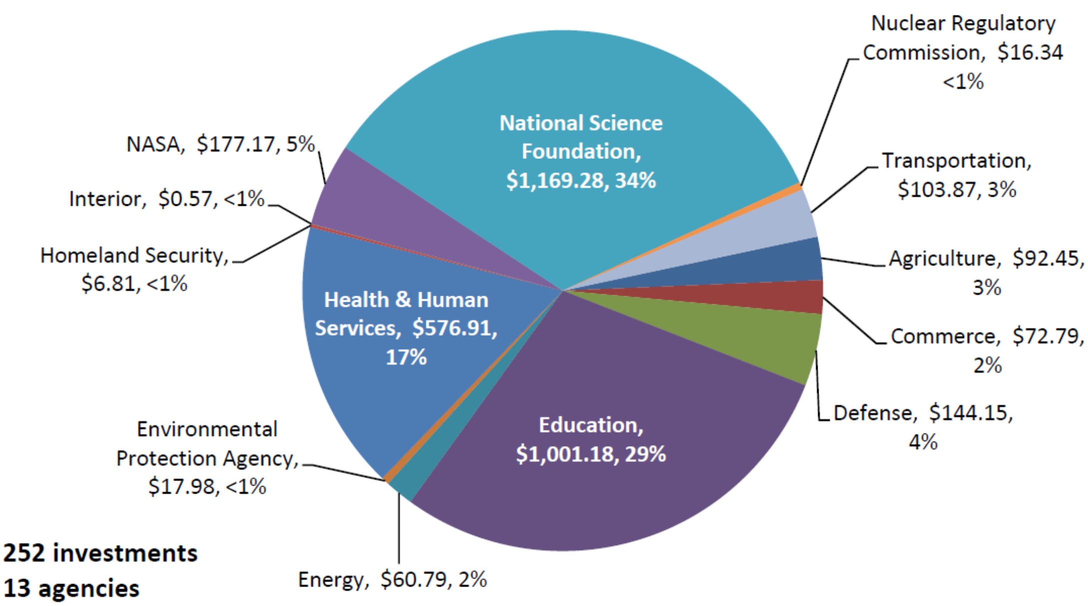
The American Innovation and Competitiveness Act of 2017 also brought some changes for OSTP and CoSTEM and created additional new requirements as well. The AICA dictated that the OSTP would create another working group under the NSTC to focus better on identifying and coordinating international science and technology cooperation. Furthermore, four additional responsibilities were added to CoSTEM. These were: 1) to study collaboratively with the STEM Education Advisory Panel and other outside stakeholders to ensure the engagement of the STEM education community, 2) to review the measurement standards or tools that federal agencies use to evaluate their STEM education programs, 3) to collect and analyze the feedback from the states about how they are utilizing federal STEM education programs, and 4) to make recommendations for reform, termination, or consolidation of federal STEM education programs (American Innovation and Competitiveness Act, 2017).

3.1.1. Efforts to assess Federal STEM Education: FY 2010

3.1.1.1. National Science and Technology Council of 2011

There were 252 STEM education programs that were administered by 13 agencies with a total funding of $3.44 billion in FY 2010 (NSTC, 2011). As Figure 9 shows, about 80% of total spending on all STEM education programs were by three agencies; the National Science Foundation (NSF; $1.16 billion), the Department of Education (DoEd; $1 billion), and the Department of Health and Human Services (HHS; $576 million).

Figure 9 Federal STEM Education Investments by Agency in FY 2010

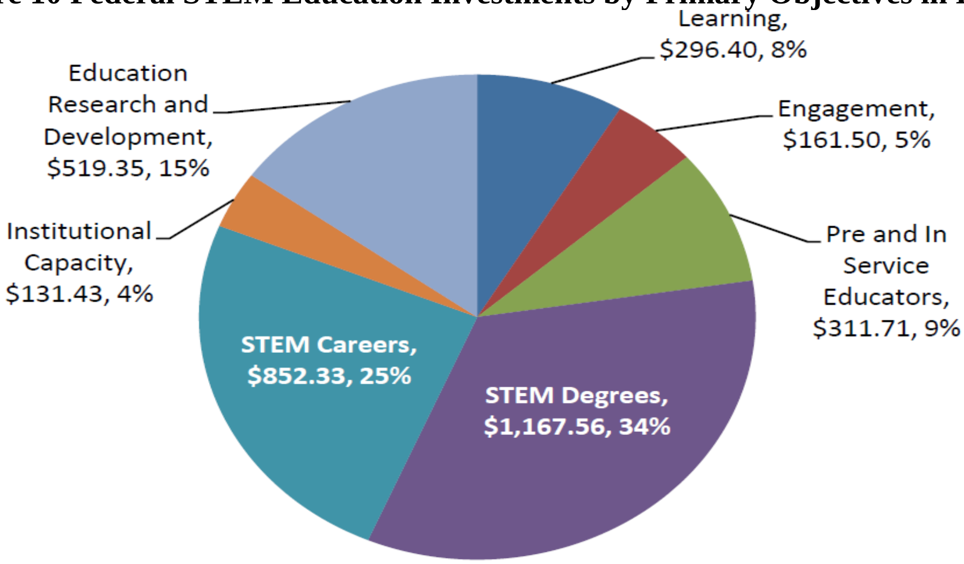


Source: NSTC (2011, p. 10). The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio.

Moreover, the percentage of federal funding for STEM education programs was used for the following primary objectives; 34% for STEM degrees, 35% for STEM careers, 15% for education research and development, 9% for pre- and in-service educators, 8% for learning, 5% for engagement and 4% for institutional capacity (NSTC, 2011).

The report gives information about funding for underrepresented groups. In total, 79 (31%) of programs had targeted groups that were underrepresented, and 22 of these programs were aimed at reaching a narrower set of underrepresented groups (NSTC, 2011). Furthermore, post-secondary STEM degrees (47%), pre-in-service educator support (17%) and institutional capacity (10%) were the largest concentrations of funding for the underrepresented populations (Figure 10).

Figure 10 Federal STEM Education Investments by Primary Objectives in FY 2010

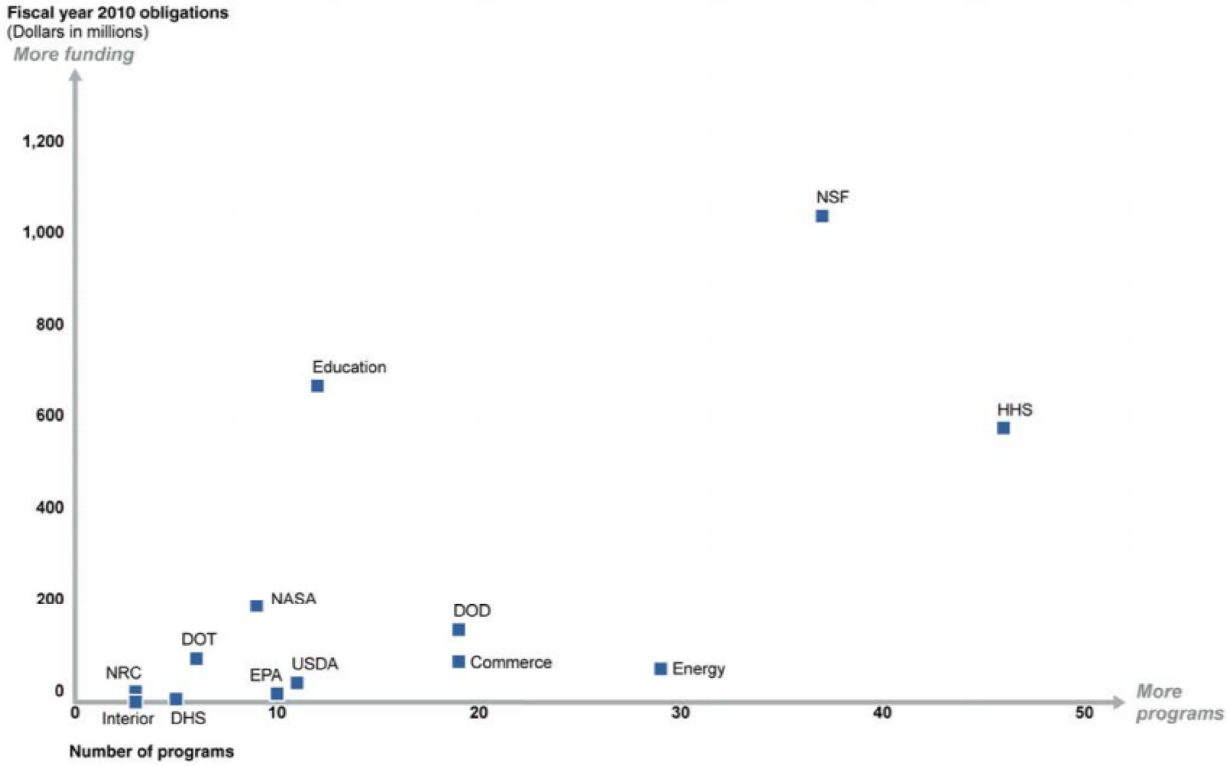


Source: NSTC (2011, p. 14). The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio.

The largest amount of this funding, $1.086 billion, was provided by the Department of Education (DoEd; $496 million) and the National Science Foundation (NSF; $238 million). The National

Science Foundation and Department of Education respectively allocated 22% and 46% of their total funding of STEM education programs to support underrepresented populations in STEM education. Finally, the report provided an analysis of duplication and overlap in STEM investments. There were 129 investments that overlapped with at least one other investment and no duplication was found within the 252 Federal STEM investments (NSTC, 2011). See Figure 11.

Figure 11 Federal STEM Education Investments by Agency in FY 2010



Source: GAO (2012, p. 10).

3.1.1.2. General Accountability Office of 2012

There were 209 STEM education programs administered by 13 agencies with a total of $3.1 billion of funding in FY 2010 (GAO, 2012). One third of the all programs were first funded between 2005 and 2010. About two-third of the total spending all STEM education programs was held by three agencies; the National Science Foundation, the Department of Education, and the Department of Health and Human Services (Figure 10). Moreover, the total federal funding for STEM education programs was used for the following primary objectives: 34% for STEM degrees, 35% for STEM careers, 15% for education research and development, 9% for pre- and in-service educators, 8% for learning, 5% for engagement and 4% for institutional capacity (GAO, 2012). In addition, three agencies, the National Science Foundation (37 programs), the Department of Energy (29 programs), and the Department of Health and Human Services (46 programs) are responsible for administering more than half of all the STEM education programs.

Finally, the report provided an analysis of overlap among STEM investments, saying that "... 83 percent of STEM education programs overlapped to some degree with another program in that they offered at least one similar service to at least one similar target group in at least one similar STEM field to achieve at least one similar objective" (GAO, 2012; p 14). Thus, 209 programs provided at least one similar service, 173 programs provided at least one similar field of focus and same number of programs had at least one similar program objectives while all programs had at least one similar target population (GAO, 2012).

3.1.2. Efforts to assess federal STEM education: FY 2016

After the releasing of the American Competitiveness Reauthorization Act of 2010, several efforts have made to assess the federal STEM education programs. After the launch of the 5-year

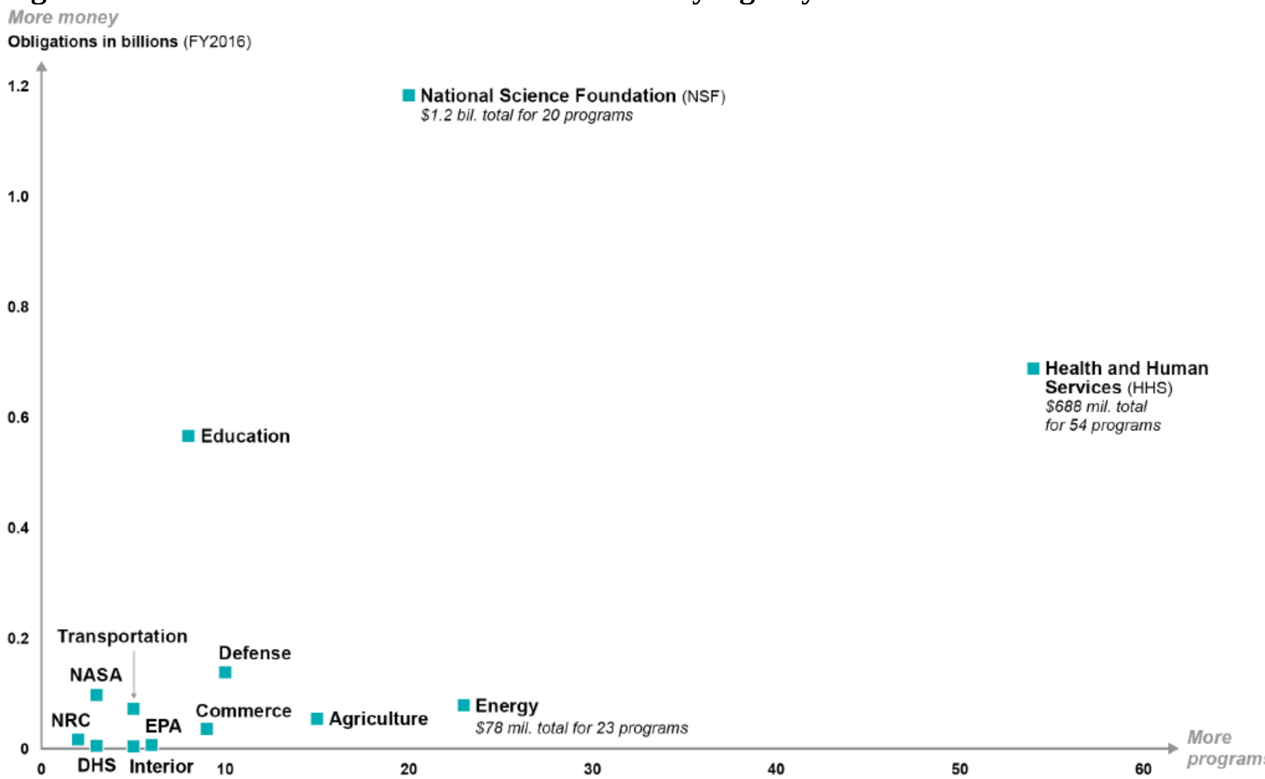
STEM education strategic plan in 2013, reports were released by the GAO in 2016 and NSTC in 2018, which both examined programs in FY 2016.

3.1.2.1. General Accountability Office of 2016

The main goals of the GAO study were to analyze how the STEM education programs funded by the federal government changed from 2010 to 2016 and to examine the extent of assessed STEM education portfolio (GAO, 2018). In FY 2016, 163 programs administered by 13 agencies were reported while the same agencies administered 209 programs in FY 2010. However, 54 new programs were added to the inventory despite a decrease in the total number of programs in the six-year period (GAO, 2018). In addition, three agencies, the National Science Foundation (20 programs), the Department of Energy (23 programs), and the Department of Health and Human Services (54 programs), were responsible for administering more than half of all STEM education programs.

The total spending for the 163 programs totaled $2.9 billion in FY 2016, which was $3 million lower than the spending for 209 programs in FY 2010. However, if the total is adjusted for inflation, the total spending of the STEM education programs in FY 2016 was $5 million less than that in FY 2010. Furthermore, three agencies were responsible for 80% of the total spending in FY 2016; the National Science Foundation ($1.2 billion), the Department of Education ($566 million), and the Department of Health and Human Services ($688 million). See Figure 12.

Figure 12 Federal STEM Education Investments by Agency in FY 2016



Source: GAO (2018, p.11).

The report furthermore provided an analysis of overlap among STEM investments in FY 2016. Almost all STEM education programs overlapped with at least one another program. The rate of overlap programs occurred was similar to FY 2010 (GAO, 2018), in which the overlap rate was 83% in the GAO 2012 report (GAO, 2012).

Finally, about 39% of the all programs (64 in 163 programs) in FY 2016 were primarily intended to serve underrepresented groups. However, the agencies did not report the participation rates of underrepresented groups in the STEM education programs although the agencies were required to report the rate in the America Competes Reauthorization Act of 2010.

3.1.2.2. National Science and Technology Council of 2016

The NSTC released a report in 2016, in which 137 programs were reported at total of $2.97 billion in funding. Three agencies, the National Science Foundation (22 programs), the Department of Energy (20 programs), and the Department of Health and Human Services (19 programs) were responsible for administering just less than half of all STEM education programs (NCST, 2016). The programs were administered by 16 agencies in which one more agency was recognized in the report of Corporation for National and Community Service (CNCS).

In addition, the three agencies accounted for about $2.352 billion (79%) of total spending for all STEM education programs in FY 2016; these were the National Science Foundation ($1.19 billion), the Department of Education ($531 million), and the Department of Health and Human Services ($629 million). See Table 4.

3.1.3. Recommendations to improve US STEM education

The federal government needed suggestions to improve US STEM education and to make policies or programs to develop high quality STEM education. Governmental offices, scientists, and private sectors have made several assessments and recommendations. Although several studies have made valued suggestions, two reports have had more impact on the government than the others. The Augustine report in 2007 helped the federal government to wake up to the status of STEM education in the United States (Gonzales & Kuenzi, 2012). The report provided four recommendations: 1) increasing the US talent pool by improving science and mathematics education at the K-12 level, 2) supporting long-term basic research to maintain the flow of new ideas about economy, security and quality of life, 3) making the United States the most attractive place to develop, recruit and retain the best students, scientists, and engineers in the world, and 4)

Table 4. Federal STEM Education Investments by Agency in FY 2015, 2016 and 2017

	2015 Actual	2016 Enacted	**2017 Budget**
Agriculture	90	91	**90**
Commerce	35	35	**24**
Defense	142	138	**130**
Education	528	531	**561**
Energy	50	52	**60**
Health and Human Services	616	629	**629**
Homeland Security	5	5	**5**
Interior	3	3	**3**
Transportation	90	98	**100**
Environmental Protection Agency	19	8	**10**
NASA	164	155	**136**
National Science Foundation	1,258	1,192	**1,222**
Nuclear Regulatory Commission	16	15	**1**
Corp. for Nat'l and Community Service	14	32	**32**
Total Federal STEM Education Funding	2,946	2,979	**3,003**

NSTC (2016, p. 21).

making the United States a premier place in which to innovate (NASEM, 2007). Furthermore, the strategic plan`s priority areas with the national goals would be described as recommendations for the federal government to improve STEM education. (See Figure 8).

Moreover, several other studies also have provided recommendations (NRC, 2011; JEC, 2014; NASEM, 2007, DeJarnette, 2012). When considering these studies and the reports above as well, the suggested recommendations share similar objectives for having better STEM education in the United States.

3.1.4. Selected Major Legislation Affecting US Stem Education

Several laws have been authorized to obtain quality education in the United States. Although several acts have specifically focused on STEM education, major acts about elementary and secondary education have created an infrastructure for the development of more specific acts for STEM education. Thus, brief information is provided below about the acts related to elementary and secondary education.

One of them, the Elementary and Secondary Education Act (ESEA), was signed by President Lyndon B. Johnson in 1965 (P.L. 89-10). He evaluated the ESEA as a national goal of full educational opportunity (ESSA 2018), and the president considered the act as a part of his War on Poverty (McLaughlin, 1975). Hence, the act focused on providing funds for disadvantaged children, library resources, textbooks, and other instructional materials to be used in elementary and secondary schools. Moreover, the act authorized several grants for higher institutions, agencies, and individuals to conduct research in education. The act has been updated several times in last five decades (National Association of School Psychologists, 2018)

3.1.4.1. The Improving America's Schools Act (IASA)

The Improving America's Schools Act (IASA) was signed by President William Jefferson Clinton in 1994 (P.L. 103-382). It reauthorized the Elementary and Secondary Education Act of 1965 (ESEA) to extend its programs for five years to increase the quality of the teaching- and learning-process for the students as well as beginning a trend of state assessments (U.S. Department of Education, 1995).

The intention of the act was to provide high-quality education for all students struggling with poverty. Thus, areas having more low-income families would receive more of funds than those with high-income families. Furthermore, states wanting to continue to receive grants were required to develop a plan of content and a plan of assessment. Additionally, states were required to develop and to conduct the assessments in at least mathematics and reading or language arts within four years. Moreover, the act established several programs to improve the quality of education.

The Eisenhower National Clearinghouse was, in addition, established in 1992 to maintain a repository of instructional materials and programs at elementary and secondary schools in science and mathematics and to coordinate databases including science and mathematics curriculum and instructional materials. The Dwight D. Eisenhower Professional Development Program of 1994 was geared to improve teaching and learning of students by providing high-quality professional development activities and funds in the core academic subjects (including science and mathematics) to educational agencies and to higher institutions (Dwight D. Eisenhower Professional Development--Federal Activities Program, CFDA No. 84.168).

Another program was the National Teacher Training Project, which was aimed at nonprofit educational institutions and designed to train selected teachers who set in-service studies for their colleagues. The act, moreover, provided funds for improving the professional development of educators. Each state was required to review and reform state requirements for teacher licensure and certification, to develop performance assessments, and to provide for the improvement of the ability of teachers in the use of technology to understand student understanding in the core subjects. Science and mathematics were given priority in improving professional development.

The Improving America’s School Act of 1994 authorized several funds to support the use of technology in the teaching and learning process at the elementary and secondary schools. According to the act, the secretary of education, was to develop a national long-range plan in consultation with stakeholders like agencies and higher institutions. The states receiving the funds were required to develop a statewide educational technology plan (*Education Week*, 1994).

Furthermore, the IASA authorized funds to raise the quality of instruction in science and mathematics in the US elementary schools. One program was the Elementary Mathematics and Science Equipment Program. Equipment and materials purchases necessary for hands-on instruction were also funded through the act (The Improving America's School Act of 1994).

Additionally, the Eisenhower Regional Mathematics and Science Education Consortia was established in 1995 to disseminate exemplary mathematics and science education instructional materials and to assist elementary and secondary school students, teachers and administrators for implementing of the teaching methods and using of the materials. The consortia comprised 10 regional centers (U.S. Department of Education, 2005).

Finally, the National Center for Educational Statistics, existing in some form since 1967, was placed under the umbrella of the United States Department of Education's Institute of Education Sciences. The Center continues to support the collection and the reporting of statistics and information to examine the condition and progress of education in United States and other nations to improve US education (National Center for Educational Statistics, n.d. d; Snyder, 1993).

3.1.4.2. The No Child Left Behind Act (NCLB)

The No Child Left Behind Act (NCLB), signed by President George W. Bush in 2002 (P.L.107-110), reauthorized the Elementary and Secondary Education Act of 1965 (ESEA) and was the main law for K-12 from 2002 to 2015. The main focus areas were student assessment, accountability systems, and the quality of teachers (Lee, n.d.).

One major goal of the act was to provide all students equally with high-quality education and to have knowledge, which reached at least at the minimum level, to meet state standards. Each state was to demonstrate that they had adopted challenging content and assessment standards; therefore, states were to have academic standards for all students at least in mathematics, reading or language arts, and science. The goal was to have all students at grade level by 2014. Additionally, each state had to have statewide annual measurable objectives that were to be set separately for the assessments of mathematics and reading or language arts (Education Policy, n.d.; Education Post, n.d.).

The act required states, in yearly assessments, to measure student academic achievement in several subjects. Under the NCLB law, states had to test students in reading and math in grades 3 through 8 and once in high school. They were required to report the results for the student population as a whole and for specific “subgroups” of students, including English-learners and students in special education, racial minorities, and children from low-income families. States were required to bring all students to the “proficient level” on state tests by the 2013-14 school year, although each state got to decide, individually, just what “proficiency” should look like, and which tests to use.

Under the law, schools were required to assess the achievement of their goals through a “adequate yearly progress” or AYP report. If a school missed its state’s annual achievement targets for two years or more, either for all students or for a particular subgroup, it was identified as not “making AYP” and was subjected a series of increasingly serious sanctions (Klein, 2015).

3.1.4.3. The Every Student Succeeds Act (ESSA)

The Every Student Succeeds Act (ESSA), signed by President Barack Obama in 2015 (P.L. 114-95). It reauthorized the Elementary and Secondary Education Act of 1965 (ESEA). The main characteristic is curtailing federal authority over the states (NASSP, n.d.)

A major goal of the act was to provide high-quality education for disadvantaged and high-need students. Each state must give an assurance that they have adopted content and achievement standards. States are to have academic standards in mathematics, reading or language arts, and science as well as in other subjects determined by the states. The adoption and implementation of the standards is not mandated, directed, coerced or exercised by the secretary of education (NASSP, n.d.)

ESSA required the states to implement a set of high-quality assessments in mathematics, reading or language arts, and science. Additionally, the state could implement assessments in any other subjects that the state deemed was an important measure of student achievement. In addition, states could exempt students in grade 8 from the mathematics assessment. The states have the right to set alternate assessment and alternate achievement standards for students with cognitive disabilities. The act required that the states must identify a statewide accountability system based on academic standards for reading or language arts and mathematics to increase student and school success (NASSP, n.d.).

ESSA has several programs to improve quality of education. One of them, the STEM Master Teacher Corps, aims to develop a statewide STEM master teacher corps. The corps seeks to increase the status of the science, technology, engineering, and mathematics teaching profession by awarding, attracting and recruiting outstanding science, technology, engineering, and mathematics teachers (American Association of Physics Teacher, n.d.).

3.1.4.1. America Competes Act Reauthorization of 2010

The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Reauthorization Act of 2010 (P.L. 111-358), signed into law by President Barack Obama in 2011. The main characteristics of the act were the authorization of a variety of

STEM education program at several federal agencies, which administer the programs, and improving the coordination and administration of STEM programs. The act required the OSTP to establish a committee under the NSTC to coordinate and review the programs to develop a plan for coordination to ensure that the programs do not duplicate and to report to Congress (America Competes Reauthorization Act of 2010).

3.1.4.1. American Innovation and Competitiveness Act of 2017

The American Innovation and Competitiveness Act of 2017 (P.L. 114-329), signed by the President Barack Obama in 2017. The act includes several programs at several federal agencies to promote STEM education. Additionally, it especially supported cybersecurity research. The act of 2017 aims to coordinate and administer STEM education programs. From this perspective, the act required the OMB with the consultation of OSTP to establish a body for reducing administrative burdens by focusing better on identifying and coordinating international science and technology cooperation. Moreover, an advisory panel, which evaluates CoSTEM's progress in carrying out its responsibilities and advising the coSTEM, was established. The act also aims to increase the participation of underrepresented populations in STEM education programs. Finally. The act established the responsibilities of coSTEM (American Innovation and Competitiveness Act of 2017).

4. SUMMARY AND CONCLUSIONS

4.1. Summary

STEM, which refers to science, technology, engineering and mathematics (Sanders, 2009), is as term widely used by stakeholders (Breiner, et al., 2012). From the educational perspective, science, technology, engineering and mathematics (STEM) explain the educational process in the STEM fields (Ntemngwa & Oliver, 2018), and this is called STEM education. STEM education is critical to gain a competitive edge in global market. Nations like the United States desire to have a strong power in the competitive world by having a well-trained STEM workforce. However, in recent years grave concerns about American STEM education have arisen. The most recent concern is whether the nation has well-qualified and sufficient numbers of STEM students, teachers and workforce to maintain its current competitive edge (Kuenzi, Matthews & Mangan, 2006). Another is concern is whether the federally funded STEM educational programs are sufficient and work effectively (GAO, 2005).

The metrics paint a complicated picture. American students have generally increased their scores in the national and international assessments over years, but the scores are still average and lower than many of their international peers. Moreover, the quality of teachers is significant for US STEM education. The certification rates of science and mathematics teachers are variously distributed. Although the majority of teachers hold certificates, this picture is uneven. Middle school teachers, who hold a certificate in English, mathematics and science have the lowest rate for subject matter certification, and 46.1%, 28.1%, and 44.9% of teachers in English, mathematics and science respectively have a major in their main assignment.

From the perspective of labor supply, higher education is significant for competing with the world and requires a qualified STEM workforce. In recent years, the American STEM workforce has fallen behind that of China because China has gained advantages in STEM fields. For example, the number of Chinese with doctorate degrees in science and engineering has grown enormously. In 2010, the United States had three times more graduates than China, but by 2014, the countries had about same number of doctorate degree recipients.

The US federal government has had an active and enduring interest in STEM education through STEM education programs. The government, in fact, in the center of the STEM education. At the elementary and secondary levels, the government has addressed teacher quality, accountability and standards to increase student performance. Furthermore, the government has attempted to make STEM education programs more effective by examining duplication and the overlap rate as well as participation rates of underrepresented groups.

In NSTC reports, the number of federally sponsored STEM programs was 252 in 2010 and 137 in 2016. The annual appropriations were and $3.44 billion in 2010 and $2.9 billion in 2016 across agencies. In GAO reports, the number of federally sponsored STEM programs was 209 in 2010 and 163 in 2016. The annual appropriations were $3.1 billion in 2010 and $2.9 billion in 2016 across all agencies. Studies about the coordination of the STEM education programs have included duplication and overlap rates. For example, 129 investments that overlapped with at least one other investment and no duplication was found within the 252 Federal STEM investments in NSTC reports in FY 2010. The National Science Foundation, the Department of Education and the Department of Health and Human Services are the three main agencies that use the majority of the federal funds.

This current study was intended to present an outline of US STEM education including the condition of STEM education in the United States and federal efforts. The study also discussed selected major legislative actions.

4.2. Discussion

Concern has grown about American STEM education in recent years. Many stakeholders who are interested in the STEM fields argue that the United States has lost its competitive advantage in the world due to the weakness of STEM education. If the weakness continues, this would be the beginning of the end for American dream. Therefore, it is crucial to consider whether American STEM education has created a well-qualified population in various STEM fields and to consider whether the United States can maintain its position as a superpower with its current STEM education.

The national assessments demonstrate that the American students` performance in science and mathematics has gained ground over years compared with earlier cohorts. However, in the globalized world, many stakeholders wonder if American students should only compete with their parents. The belief is that the students should compete with their international peers instead of their parents to maintain the American competitive edge. Thus, the international assessments should be given attention more than national assessments.

Because the economy of the United States has one of the biggest GDPs per capita in the world and the biggest economy overall, the investment in science and mathematics is expected to be higher than other countries across the world. Hence, the scores of American students are expected to be one of the most outstanding scores over the world. Although current American students have achieved relatively higher performance than earlier American cohorts in international assessments, these students have relatively mediocre scores compared with their international peers, especially with respect to top performing Asian countries. The scores of American students are lower than those of Asian countries, which suggests that American STEM education does not create a well-qualified population in various STEM fields.

Two possible reasons exist for this situation. One is that American investment in STEM education is not as sufficient compared to other nations. Another is that the STEM education investments are not coordinated or administered effectively. Indeed, the data suggest that this is so because students in some countries, having smaller economies and lower GDPs per capita than the US, show higher performance than American students. In other words, if these countries have higher scores with limited economic sources compared with the United States, then American STEM education investments are not used effectively.

Thus, the federal government's effort in STEM education should focus on improving STEM teaching and learning, expanding opportunities for underrepresented students as well as better coordinating and administering STEM education programs. Although federal funding over the years has not increased for STEM education, the argument cannot be made that the federal government has not focused on STEM education because the federal government has tried to better coordinate and administer through programs through its efforts to explore duplications and overlaps of programs. Consequently, even if the total spending for STEM education is reduced, government support would be more effective than in the past. Hence, if the argument that the American sources are now be used in a more effective way than that in the past is correct, then American students will possibly have higher performance than their current mediocre level.

Furthermore, some educators have argued that teacher quality has an impact on student performance. When the consideration is made that science and mathematics are the least certified fields among all others and almost half of science and mathematics teachers do not hold a degree in science and mathematics, the argument could be made that graduates from the STEM fields do not desire to be teachers. Several options to improve this might include higher salaries and higher status for teaching. Therefore, the federal government should take responsibility for increasing the financial and social status of teachers. Otherwise, American students will wait a long time to have the well-trained STEM teachers necessary to compete with their international peers.

Furthermore, the American strong workforce, which plays a significant role in maintaining American superpower in the world, relies on higher education. Despite the difficulties in the American system, there are some interesting trends. While the United States has created the largest number of baccalaureate and post baccalaureate degrees in STEM fields over the world, in the recent years China has gained an advantage by increasing the number of recipients dramatically. Post-baccalaureate recipients are the resource of advanced research, which leads to innovations that impact the competitive edge of a nation in the globalized world; thus, the United States and China have the biggest capacity to have advance research. In addition, the number of temporary visa holders in the United States, which have doctorate degrees in S&E fields from American higher institutions, is higher than in China.

Many people would argue that if the current trends continue, then the possibility exists that the United States will lose its dominant position in STEM. However, even if China has a larger STEM workforce than the United States, it is quite likely that United States will maintain its superpower status because the American workforce comprises a wide variety of people. This diversity quite likely brings with it more innovative ideas and research, which has made and will keep America great.

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APPENDIX A

A- Target Percentages of the TIMSS 2015 Science Assessment Devoted to Content and Cognitive Domains at the Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Life Science	45%
Physical Science	35%
Earth Science	20%

Eighth Grade

Content Domains	Percentages
Biology	35%
Chemistry	20%
Physics	25%
Earth Science	20%

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	35%
Reasoning	20%	30%

Source: Mullis, I.V.S. & Martin, M.O. (Eds.) (2013). TIMSS 2015 Assessment Frameworks. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/frameworks.html

B - Target Percentages of the TIMSS 2015 Mathematics Assessment Devoted to Content and Cognitive Domains at the Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Number	50%
Geometric Shapes and Measures	35%
Data Display	15%

Eighth Grade

Content Domains	Percentages
Number	30%
Algebra	30%
Geometry	20%
Data and Chance	20%

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	40%
Reasoning	20%	25%

Source: Mullis, I.V.S. & Martin, M.O. (Eds.) (2013). TIMSS 2015 Assessment Frameworks. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/frameworks.html

APPENDIX B

TIMSS average mathematics scores of grades 8 and 4, by education system: 1995-2015

Average score 1995		s.e.	2011		s.e.	2015		s.e.	Education system
609	▲	4.0	611	▲	3.8	621	▲	3.2	Singapore[2]
581	▲	2.0	613	▲	2.9	606	▲	2.6	Korea, Republic of
—		†	609	▲	3.2	599	▲	2.4	Chinese Taipei-CHN
569	▲	6.1	586	▲	3.9	594	▲	4.6	Hong Kong-CHN
581	▲	1.6	570	▲	2.6	586	▲	2.3	Japan
524	▲	5.2	539	▲	3.6	538	▲	4.7	Russian Federation
—		†	487	▼	4.2	528		5.3	Kazakhstan
519	▲	4.9	—		†	523		2.7	Ireland
492		**4.9**	**509**		**2.7**	**518**		**3.1**	**United States[3]**
498		3.0	507		5.6	518		4.2	England-GBR
494		2.9	505		2.2	516		2.1	Slovenia
527	▲	3.2	505		3.5	514		3.8	Hungary
472	▼	4.1	502		2.5	512		2.9	Lithuania[2]
—		†	516		4.1	511		4.1	Israel[4]
509	▲	3.7	505		5.2	505	▼	3.1	Australia
540	▲	4.3	484	▼	1.9	501	▼	2.8	Sweden
—		†	498	▼	2.3	494	▼	2.5	Italy[2]
501		4.7	488	▼	5.4	493	▼	3.4	New Zealand[3]
498		2.2	475	▼	2.5	487	▼	2.0	Norway (8)[5]
—		†	440	▼	5.5	465	▼	3.6	Malaysia
—		†	456	▼	2.1	465	▼	2.0	United Arab Emirates
—		†	452	▼	4.0	458	▼	4.7	Turkey
—		†	409	▼	1.9	454	▼	1.4	Bahrain
—		†	431	▼	3.7	453	▼	3.4	Georgia[2, 6]
—		†	449	▼	3.9	442	▼	3.6	Lebanon
—		†	410	▼	3.1	437	▼	3.0	Qatar[7]
418	▼	3.9	415	▼	4.3	436	▼	4.6	Iran, Islamic Republic of[7]
—		†	427	▼	4.4	431	▼	4.8	Thailand
—		†	416	▼	2.7	427	▼	3.2	Chile[7]
—		†	366	▼	2.9	403	▼	2.4	Oman[7]
—		†	406	▼	3.9	386	▼	3.2	Jordan[8]
—		†	371	▼	2.0	384	▼	2.3	Morocco[8]
—		†	394	▼	4.7	368	▼	4.6	Saudi Arabia[8]

Average score 1995		s.e.	2011		s.e.	2015		s.e.	Education system
590	▲	4.5	606	▲	3.2	618	▲	3.8	Singapore[2]
557	▲	4.0	602	▲	3.4	615	▲	2.9	Hong Kong-CHN[3]
581	▲	1.8	605	▲	1.9	608	▲	2.2	Korea, Republic of
—		†	591	▲	2.0	597	▲	1.9	Chinese Taipei-CHN
567	▲	1.9	585	▲	1.7	593	▲	2.0	Japan
—		†	562	▲	2.8	570	▲	2.9	Northern Ireland-GBR[4]
—		†	542		3.7	564	▲	3.4	Russian Federation
523		3.5	527	▼	2.6	547	▲	2.1	Ireland
484	▼	3.3	542		3.5	546		2.8	England-GBR
—		†	549	▲	1.9	546	▲	2.1	Belgium (Flemish)-BEL[3]
—		†	501	▼	4.5	544		4.5	Kazakhstan
442	▼	4.0	532	▼	3.3	541		2.2	Portugal[2]
518		**2.9**	**541**		**1.9**	**539**		**2.3**	**United States[2, 3]**
—		†	537		2.6	539		2.7	Denmark[2, 3]
—		†	534	▼	2.4	536		2.7	Lithuania[2]
—		†	545		2.4	535		2.0	Finland
549	▲	3.0	540		1.6	530	▼	1.7	Netherlands[3]
521		3.5	515	▼	3.4	529	▼	3.2	Hungary
541	▲	3.0	511	▼	2.5	528	▼	2.2	Czech Republic
475	▼	3.2	—		†	523	▼	2.7	Cyprus
—		†	528	▼	2.2	522	▼	2.0	Germany
462	▼	3.2	513	▼	2.1	520	▼	1.9	Slovenia
—		†	504	▼	2.1	519	▼	2.8	Sweden[2]
—		†	516	▼	3.0	518	▼	3.5	Serbia[3]
495	▼	3.5	516	▼	3.0	517	▼	3.1	Australia
—		†	508	▼	2.6	507	▼	2.6	Italy[2]
—		†	482	▼	2.8	505	▼	2.5	Spain[2]
—		†	490	▼	1.9	502	▼	1.8	Croatia
—		†	507	▼	3.7	498	▼	2.5	Slovak Republic
476	▼	3.0	495	▼	2.8	493	▼	2.3	Norway (4)[6]
469	▼	4.4	486	▼	2.6	491	▼	2.3	New Zealand
—		†	469	▼	4.7	483	▼	3.1	Turkey
—		†	450	▼	3.7	463	▼	3.6	Georgia[7]
—		†	462	▼	2.3	459	▼	2.4	Chile
—		†	434	▼	2.0	452	▼	2.4	United Arab Emirates
—		†	436	▼	3.2	451	▼	1.6	Bahrain[2]
—		†	413	▼	3.4	439	▼	3.4	Qatar
387	▼	4.9	431	▼	3.5	431	▼	3.2	Iran, Islamic Republic of
—		†	385	▼	2.9	425	▼	2.5	Oman
—		†	410	▼	5.2	383	▼	4.1	Saudi Arabia[8]
—		†	335	▼	4.0	377	▼	3.4	Morocco
—		†	342	▼	3.6	327	▼	3.2	Kuwait[8]

▲ Average score is higher than U.S. average score at the .05 level of statistical significance.
▼ Average score is lower than U.S. average score at the .05 level of statistical significance..
— Not available.
† Not applicable.
# Rounds to zero.
*$p<.05$. Change in average scores is significant at the .05 level of statistical significance.
[1] The change in average score is calculated by subtracting the 1995 or 2011 estimate, respectively, from the 2015 estimate using unrounded numbers.
[2] National Defined Population covers 90 to 95 percent of the National Target Population in 2015.
[3] Met guidelines for sample participation rates only after replacement schools were included in 2015.
[4] National Defined Population covers less than 90 percent of the National Target Population (but at least 77 percent) in 2015.
[5] The number in parentheses indicates years of school not grade in schooling.
[6] National Target Population does not include all of the International Target Population in 2015.
[7] Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 15 percent but does not exceed 25 percent in 2015.
[8] Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 25 percent in 2015.
[9] Did not satisfy guidelines for sample participation rates in 2015.
SOURCE: https://nces.ed.gov/timss/timss2015/timss2015

APPENDIX C

TIMSS average science scores of grades 8 and 4 by educational system: 1995-2015

Average score									
1995		s.e.	2011		s.e.	2015		s.e.	**Education system**
580	▲	5.6	590	▲	4.3	**597**	▲	3.2	Singapore[2]
554	▲	1.8	558	▲	2.4	571	▲	1.8	Japan
—		†	564	▲	2.3	569	▲	2.1	Chinese Taipei-CHN
546	▲	2.1	560	▲	2.0	556	▲	2.2	Korea, Republic of
514		2.8	543	▲	2.6	551	▲	2.4	Slovenia
510		5.9	535	▲	3.4	546	▲	3.9	Hong Kong-CHN
523		4.4	542	▲	3.3	544	▲	4.2	Russian Federation
533	▲	3.5	533		4.9	537		3.8	England-GBR
—		†	490	▼	4.2	533		4.4	Kazakhstan
518		5.1	—		†	530		2.8	Ireland
513		**5.5**	**525**		**2.4**	**530**		**2.8**	**United States[3]**
537	▲	3.2	522		3.1	527		3.4	Hungary
553	▲	4.3	509	▼	2.6	522		3.4	Sweden
464	▼	4.0	514	▼	2.5	522	▼	3.0	Lithuania[2]
511		4.9	512	▼	4.6	513	▼	3.1	New Zealand[3]
514		3.9	519		4.7	512	▼	2.7	Australia
—		†	516		4.0	507	▼	3.9	Israel[4]
—		†	501	▼	2.4	499	▼	2.4	Italy[2]
—		†	483	▼	3.4	493	▼	4.0	Turkey
514		2.4	494	▼	2.6	489	▼	2.4	Norway (8)[5]
—		†	465	▼	2.4	477	▼	2.3	United Arab Emirates
—		†	426	▼	6.2	471	▼	4.1	Malaysia
—		†	452	▼	1.9	466	▼	2.2	Bahrain
—		†	419	▼	3.2	457	▼	3.0	Qatar
463	▼	3.7	474	▼	4.0	456	▼	4.0	Iran, Islamic Republic of
—		†	451	▼	4.0	456	▼	4.2	Thailand
—		†	420	▼	3.2	455	▼	2.7	Oman
—		†	461	▼	2.5	454	▼	3.1	Chile
—		†	420	▼	3.0	443	▼	3.1	Georgia[2, 6]
—		†	449	▼	4.1	426	▼	3.4	Jordan
—		†	406	▼	5.0	398	▼	5.3	Lebanon
—		†	436	▼	3.8	396	▼	4.5	Saudi Arabia
—		†	376	▼	2.2	393	▼	2.5	Morocco

Average score									
1995		s.e.	2011		s.e.	2015		s.e.	**Education system**
523	▼	4.8	583	▲	**3.4**	**590**	▲	3.7	Singapore[2]
576	▲	2.1	587	▲	2.1	589	▲	2.0	Korea, Republic of
553	▲	1.7	559	▲	1.9	569	▲	1.8	Japan
—		†	552	▲	3.4	567	▲	3.2	Russian Federation
508	▼	3.4	535	▼	3.7	557	▲	2.9	Hong Kong-CHN[3]
—		†	552	▲	2.2	555	▲	1.8	Chinese Taipei-CHN
—		†	570	▲	2.6	554	▲	2.3	Finland
—		†	495	▼	5.1	550			Kazakhstan
542		**3.4**	**544**		**2.1**	**546**		**2.2**	**United States[2, 3]**
464	▼	3.1	520	▼	2.6	543		2.4	Slovenia
508	▼	3.4	534	▼	3.7	542		3.3	Hungary
—		†	533	▼	2.8	540		3.6	Sweden[2]
528	▼	3.2	529	▼	3.0	536	▼	2.4	England-GBR
532	▼	3.1	536	▼	2.5	534	▼	2.4	Czech Republic
—		†	516	▼	2.2	533	▼	2.1	Croatia
—		†	515	▼	2.4	530	▼	2.7	Lithuania[2]
515	▼	3.5	516	▼	3.3	529	▼	2.8	Ireland
—		†	528	▼	2.9	528	▼	2.4	Germany
—		†	528	▼	2.8	527	▼	2.1	Denmark[2, 3]
—		†	516	▼	3.1	525	▼	3.7	Serbia[4]
521	▼	3.7	516	▼	2.9	524	▼	2.9	Australia
—		†	532	▼	**3.7**	**520**	▼	2.6	Slovak Republic
—		†	517	▼	2.5	520	▼	2.2	Northern Ireland-GBR[5]
—		†	505	▼	3.1	518	▼	2.6	Spain[2]
530	▼	3.2	531	▼	2.2	517	▼	2.7	Netherlands[3]
—		†	524	▼	2.7	516	▼	2.6	Italy[2]
—		†	509	▼	2.0	512	▼	2.3	Belgium (Flemish)-BEL[3]
452	▼	4.1	522	▼	3.8	508	▼	2.2	Portugal[2]
505	▼	5.4	497	▼	2.4	506	▼	2.7	New Zealand
504	▼	3.7	494	▼	2.5	493	▼	2.2	Norway (4)[6]
—		†	463	▼	4.7	483	▼	3.3	Turkey
450	▼	3.4	—		†	481	▼	2.6	Cyprus
—		†	480	▼	2.5	478	▼	2.7	Chile
—		†	449	▼	3.5	459	▼	2.6	Bahrain[2]
—		†	455	▼	3.9	451	▼	3.7	Georgia[7]
—		†	428	▼	2.5	451	▼	2.8	United Arab Emirates
—		†	394	▼	4.3	436	▼	4.1	Qatar
—		†	377	▼	4.3	431	▼	3.1	Oman
380	▼	4.6	453	▼	3.8	421	▼	4.0	Iran, Islamic Republic of
—		†	429	▼	5.5	390	▼	5.0	Saudi Arabia
—		†	264	▼	4.4	352	▼	4.4	Morocco[8]
—		†	347	▼	4.8	315	▼	5.1	Kuwait[8]

▲ Average score is higher than U.S. average score at the .05 level of statistical significance.
▼ Average score is lower than U.S. average score at the .05 level of statistical significance.
— Not available.
† Not applicable.
*p<.05. Change in average scores is significant at the .05 level of statistical significance.
1 The change in average score is calculated by subtracting the 1995 or 2011 estimate, respectively, from the 2015 estimate using unrounded numbers.
2 National Defined Population covers 90 to 95 percent of the National Target Population in 2015.
3 Met guidelines for sample participation rates only after replacement schools were included in 2015.
4 National Defined Population covers less than 90 percent of the National Target Population (but at least 77 percent) in 2015.
5 The number in parentheses indicates years of school not grade in schooling.
6 National Target Population does not include all of the International Target Population in 2015.
7 Did not satisfy guidelines for sample participation rates in 2015.
8 Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 15 percent but does not exceed 25 percent in 2015.
9 Did not satisfy guidelines for sample participation rates in 2015.
SOURCE: https://nces.ed.gov/timss/timss2015

APPENDIX D

PISA average scores in mathematics, by education system: 2015

Education system	Average score	s.e.	Education system	Average score	s.e.
OECD average	490 ▲	0.4	Israel	470	3.6
Singapore	564 ▲	1.5	**United States**	**470**	3.2
Hong Kong (China)	548 ▲	3.0	*Croatia*	464	2.8
Macau (China)	544 ▲	1.1	*Buenos Aires (Argentina)*	456	6.9
Chinese Taipei	542 ▲	3.0	Greece	454 ▼	3.8
Japan	532 ▲	3.0	*Romania*	444 ▼	3.8
B-S-J-G (China)	531 ▲	4.9	*Bulgaria*	441 ▼	4.0
Korea, Republic of	524 ▲	3.7	*Cyprus*	437 ▼	1.7
Switzerland	521 ▲	2.9	*United Arab Emirates*	427 ▼	2.4
Estonia	520 ▲	2.0	Chile	423 ▼	2.5
Canada	516 ▲	2.3	Turkey	420 ▼	4.1
Netherlands	512 ▲	2.2	*Moldova, Republic of*	420 ▼	2.5
Denmark	511 ▲	2.2	*Uruguay*	418 ▼	2.5
Finland	511 ▲	2.3	*Montenegro, Republic of*	418 ▼	1.5
Slovenia	510 ▲	1.3	*Trinidad and Tobago*	417 ▼	1.4
Belgium	507 ▲	2.4	*Thailand*	415 ▼	3.0
Germany	506 ▲	2.9	*Albania*	413 ▼	3.4
Poland	504 ▲	2.4	Mexico	408 ▼	2.2
Ireland	504 ▲	2.1	*Georgia*	404 ▼	2.8
Norway	502 ▲	2.2	*Qatar*	402 ▼	1.3
Austria	497 ▲	2.9	*Costa Rica*	400 ▼	2.5
New Zealand	495 ▲	2.3	*Lebanon*	396 ▼	3.7
Vietnam	495 ▲	4.5	*Colombia*	390 ▼	2.3
Russian Federation	494 ▲	3.1	*Peru*	387 ▼	2.7
Sweden	494 ▲	3.2	*Indonesia*	386 ▼	3.1
Australia	494 ▲	1.6	*Jordan*	380 ▼	2.7
France	493 ▲	2.1	*Brazil*	377 ▼	2.9
United Kingdom	492 ▲	2.5	*Macedonia, Republic of*	371 ▼	1.3
Czech Republic	492 ▲	2.4	*Tunisia*	367 ▼	3.0
Portugal	492 ▲	2.5	*Kosovo*	362 ▼	1.6
Italy	490 ▲	2.8	*Algeria*	360 ▼	3.0
Iceland	488 ▲	2.0	*Dominican Republic*	328 ▼	2.7
Spain	486 ▲	2.2			
Luxembourg	486 ▲	1.3			
Latvia	482 ▲	1.9			
Malta	479 ▲	1.7	**U.S. states and territories**		
Lithuania	478 ▲	2.3	*Massachusetts*	500 ▲	5.5
Hungary	477	2.5	*North Carolina*	471	4.4
Slovak Republic	475	2.7	*Puerto Rico*	378 ▼	5.6

▲ Average score is higher than U.S. average score at the .05 level of statistical significance.

▼ Average score is lower than U.S. average score at the .05 level of statistical significance.

NOTE: Education systems are ordered by 2015 average score. The OECD average is the average of the national averages of the OECD member countries, with each country weighted equally. Scores are reported on a scale from 0 to 1,000. Standard error is noted by *s.e*. Italics indicate non-OECD countries and education systems. B-S-J-G (China) refers to the four PISA participating China provinces: Beijing, Shanghai, Jiangsu, and Guangdong. Results for Massachusetts and North Carolina are for public school students only. Although Argentina, Malaysia, and Kazakhstan participated in PISA 2015, technical problems with their samples prevent results from being discussed in this report. This table corresponds to table 3 in *Performance of U.S. 15-Year-Old Students in Science, Mathematics, and Reading Literacy in an International Context* (NCES 2017-048).

SOURCE: https://nces.ed.gov/surveys/pisa/pisa2015/pisa2015highlights_5a_1.asp

APPENDIX E

Average scores and changes in average scores of U.S. students on PISA science, mathematics, and reading; 2000, 2003, 2006, 2009, 2012, and 2015

	2000		2003		2006		2009		2012		2015						
Subject	Average score	s.e.	Average score	s.e.	Average score	s.e.	Average score	s.e.	Average score	s.e.	Average score	s.e.	2015–2000	2015–2003	2015–2006	2015–2009	2015–2012
Science literacy	†	†	†	†	489	4.2	502	3.6	497	3.8	496	3.2		†	○	○	○
Reading literacy	504	7.0	495	3.2	—	†	500	3.7	498	3.7	497	3.4	○	○	—	○	○
Mathematics literacy	†	†	483	2.9	474	4.0	487	3.6	481	3.6	470	3.2		○	○	▼	▼

○ Average score in 2015 is not measurably different than in comparison year at the .05 level of statistical significance.
▼ Average score in 2015 is lower than in comparison year at the .05 level of statistical significance.
— Not available. PISA 2006 reading literacy results are not reported for the **United States** because of an error in printing the test booklets making comparisons not possible.
† Not applicable. Although science was assessed in 2000 and 2003, because the science framework was revised for 2006, it is possible to look at changes in science only from 2006 forward. Similarly, although mathematics was assessed in 2000, because the mathematics framework was revised for PISA 2003, it is possible to look at changes in mathematics only from 2003 forward.
NOTE: All average scores reported as higher or lower than the comparison year are different at the .05 level of statistical significance. Standard error is noted by *s.e.* This table corresponds to table 4 in *Performance of U.S. 15-Year-Old Students in Science, Mathematics, and Reading Literacy in an International Context* (NCES 2017-048).
SOURCE: Organization for Economic Cooperation and Development (OECD), Program for International Student Assessment (PISA), 2000, 2003, 2006, 2009, 2012, and 2015.

APPENDIX F

PISA average scores in science, by education system: 2015

Education	Average score	*s.e.*	Education system	Average score	*s.e.*
OECD average	493	*0.4*	Iceland	473 ▼	*1.7*
Singapore	556 ▲	*1.2*	Israel	467 ▼	*3.4*
Japan	538 ▲	*3.0*	*Malta*	465 ▼	*1.6*
Estonia	534 ▲	*2.1*	Slovak Republic	461 ▼	*2.6*
Chinese Taipei	532 ▲	*2.7*	Greece	455 ▼	*3.9*
Finland	531 ▲	*2.4*	Chile	447 ▼	*2.4*
Macau (China)	529 ▲	*1.1*	*Bulgaria*	446 ▼	*4.4*
Canada	528 ▲	*2.1*	*United Arab Emirates*	437 ▼	*2.4*
Vietnam	525 ▲	*3.9*	*Uruguay*	435 ▼	*2.2*
Hong Kong (China)	523 ▲	*2.5*	*Romania*	435 ▼	*3.2*
B-S-J-G (China)	518 ▲	*4.6*	*Cyprus*	433 ▼	*1.4*
Korea, Republic of	516 ▲	*3.1*	*Moldova, Republic of*	428 ▼	*2.0*
New Zealand	513 ▲	*2.4*	*Albania*	427 ▼	*3.3*
Slovenia	513 ▲	*1.3*	Turkey	425 ▼	*3.9*
Australia	510 ▲	*1.5*	*Trinidad and Tobago*	425 ▼	*1.4*
United Kingdom	509 ▲	*2.6*	*Thailand*	421 ▼	*2.8*
Germany	509 ▲	*2.7*	*Costa Rica*	420 ▼	*2.1*
Netherlands	509 ▲	*2.3*	*Qatar*	418 ▼	*1.0*
Switzerland	506 ▲	*2.9*	*Colombia*	416 ▼	*2.4*
Ireland	503	*2.4*	Mexico	416 ▼	*2.1*
Belgium	502	*2.3*	*Montenegro, Republic of*	411 ▼	*1.0*
Denmark	502	*2.4*	*Georgia*	411 ▼	*2.4*
Poland	501	*2.5*	*Jordan*	409 ▼	*2.7*
Portugal	501	*2.4*	*Indonesia*	403 ▼	*2.6*
Norway	498	*2.3*	*Brazil*	401 ▼	*2.3*
United States	**496**	*3.2*	*Peru*	397 ▼	*2.4*
Austria	495	*2.4*	*Lebanon*	386 ▼	*3.4*
France	495	*2.1*	*Tunisia*	386 ▼	*2.1*
Sweden	493	*3.6*	*Macedonia, Republic of*	384 ▼	*1.2*
Czech Republic	493	*2.3*	*Kosovo*	378 ▼	*1.7*
Spain	493	*2.1*	*Algeria*	376 ▼	*2.6*
Latvia	490	*1.6*	*Dominican Republic*	332 ▼	*2.6*
Russian Federation	487 ▼	*2.9*			
Luxembourg	483 ▼	*1.1*			
Italy	481 ▼	*2.5*			
Hungary	477 ▼	*2.4*	**U.S. states and territories**		
Lithuania	475 ▼	*2.7*	*Massachusetts*	529 ▲	*6.6*
Croatia	475 ▼	*2.5*	*North Carolina*	502	*4.9*
Buenos Aires (Argentina)	475 ▼	*6.3*	*Puerto Rico*	403 ▼	*6.1*

▲ Average score is higher than U.S. average score at the .05 level of statistical significance.

▼ Average score is lower than U.S. average score at the .05 level of statistical significance.

NOTE: Education systems are ordered by 2015 average score. The OECD average is the average of the national averages of the OECD member countries, with each country weighted equally. Scores are reported on a scale from 0 to 1,000. All average scores reported as higher or lower than the U.S. average score are different at the .05 level of statistical significance. Italics indicate non-OECD countries and education systems. B-S-J-G (China) refers to the four PISA participating China provinces: Beijing, Shanghai, Jiangsu, and Guangdong. Results for Massachusetts and North Carolina are for public school students only. Although Argentina, Malaysia, and Kazakhstan participated in PISA 2015, technical problems with their samples prevent results from being discussed in this report. This table corresponds to table 1 in *Performance of U.S. 15-Year-Old Students in Science, Mathematics, and Reading Literacy in an International Context* (NCES 2017-048).

SOURCE: https://nces.ed.gov/surveys/pisa/pisa2015/pisa2015highlights_3.asp

APPENDIX G

Number of departmentalized public middle grades teachers who reported a particular main assignment and the percentage of teachers who taught various percentages of classes within that main assignment, by subject of main assignment: 2011–12

Selected main assignment	Number of teachers	Percent with a major in main assignment: Total	Percent with a major in main assignment: Certified	Percent with a major in main assignment: Not certified	Percent with no major in main assignment: Total	Percent with no major in main assignment: Certified	Percent with no major in main assignment: Not certified	Total certified
English	139,100	46.1	36.3	9.8	53.9	20.4	33.4	56.7
Mathematics	116,100	28.1	21.9	6.3	71.9	31.0	40.9	52.9
Science	86,400	44.9	33.1	11.7	55.1	23.7	31.5	56.8
Biology/life sciences	12,100	44.7	22.5	22.2	55.3	10.7	44.6	33.2
Physical science	25,700	16.6	7.3	9.4	83.4	13.9	69.5	21.2
Earth sciences	9,100	18.0	6.2!	11.8!	82.0	14.0	68.0	20.2
Social science	79,200	51.6	40.4	11.3	48.4	22.1	26.2	62.5
Geography	5,200	‡	#	‡	98.7	11.5	87.2	11.5
Government/civics	2,200	‡	‡	‡	95.8	‡	78.8	‡
History	29,500	33.0	17.3	15.8	67.0	15.1	51.8	32.4
French	3,600	84.8	76.2	‡	15.2!	‡	‡	88.6
German	500	72.1	55.3!	‡	‡	‡	#	83.2
Spanish	10,900	65.7	56.1	9.6!	34.3	26.5	7.8!	82.6
Art/arts and crafts	12,700	80.0	72.2	7.8	20.0	11.1!	8.9!	83.3
Music	24,900	95.6	87.9	7.7!	4.4!	3.5!	‡	91.4
Dance/drama or theater	2,500	32.1!	28.2!	‡	67.9	40.1	27.8!	68.3
Health education	38,600	79.7	72.9	6.9	20.3	15.0	5.3	87.8
General elementary education	61,300	77.2	51.4	25.8	22.8	11.9	10.9!	63.3

Rounds to zero.

! Interpret data with caution. The standard error for this estimate is equal to 30 percent or more of the estimate's value.

‡ Reporting standards not met. The standard error for this estimate is equal to 50 percent or more of the estimate's value.

NOTE: Teachers include traditional public school and public charter school teachers who taught departmentalized classes to students in any of grades 5–8, and no grades lower than 5 or higher than 9. Often a main assignment includes several subfields. Under science and social science, several subfields are examined in detail. These subfields are not inclusive of all subfields in the subject and, therefore, do not add to the broad field total. Majors are included regardless of whether they were held within or outside the school/college of education. Majors in main assignment are credited if they were held at the bachelor's degree level or higher. A certification is credited if it is a regular or standard state certificate or a probationary certification in- subject and includes any grades 6 through 8. Detail may not sum to totals because of rounding and because some data are not shown. Not all apparent differences shown in the table are statistically significant.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2011–12.

Source: Baldi, S., Warner-Griffin, C., & Tadler, C. (2015). Education and Certification Qualifications of Public Middle Grades Teachers of Selected Subjects: Evidence from the 2011-12 Schools and Staffing Survey. NCES 2015-815. *National Center for Education*

APPENDIX H

Number of departmentalized public high grades teachers who reported a particular main assignment and the percentage of teachers who taught various percentages of classes within that main assignment, by subject of main assignment: 2011–12

Selected main assignment	Number of teachers	Percent with a major in main assignment			Percent with no major in main assignment			Total certified
		Total	Certified	Not certified	Total	Certified	Not certified	
English	152,400	79.4	69.4	9.9	20.6	12.7	8.0	82.1
Mathematics	144,800	70.1	61.5	8.7	29.9	19.4	10.4	80.9
Science	126,300	79.7	72.3	7.3	20.3	13.4	7.0	85.7
Biology/life sciences	51,900	74.4	64.7	9.7	25.6	15.3	10.3	80.0
Physical science	64,600	46.0	38.0	8.0	54.0	29.5	24.5	67.4
Chemistry	24,200	45.9	34.2	11.8	54.1	35.6	18.4	69.8
Earth sciences	12,400	37.9	31.8	‡	62.1	30.8	31.3	62.5
Physics	13,300	50.4	36.7	13.7!	49.6	24.1	25.5	60.8
Social science	120,800	78.9	67.5	11.4	21.1	15.4	5.7	82.9
Economics	8,900	‡	‡	‡	89.1	18.0!	71.1	21.7!
Geography	7,300	‡	‡	‡	98.8	11.0!	87.9	11.9!
Government/civics	15,600	6.8!	‡	5.2!	93.2	19.8	73.4	21.4!
History	60,300	54.8	26.0	28.8	45.2	10.9	34.4	36.9
French	11,900	80.1	71.1	9.1	19.9	10.8	9.0!	81.9
German	3,300	85.9	73.3	‡	14.1!	‡	‡	83.7
Latin	1,400	54.4!	48.8!	‡	45.6!	43.9!	‡	92.8
Spanish	50,500	73.7	63.3	10.4	26.3	20.7	5.6	84.0
Art/arts and crafts	33,400	81.9	72.3	9.6!	18.1	10.2	7.9	82.5
Music	38,500	93.4	87.3	6.1	6.6	4.5!	2.2!	91.8
Dance/drama or theater	10,000	73.1	52.2	‡	26.9!	19.2!	7.7!	71.5

! Interpret data with caution. The standard error for this estimate is between 30 percent and 50 percent of the estimate's value.

‡ Reporting standards not met. The standard error for this estimate is 50 percent more of the estimate's value.

NOTE: Teachers include traditional public school and public charter school teachers who taught departmentalized classes to students in any of grades 10–12 or grade 9 and no grade lower. Each main assignment includes several subfields. Under science and social science, several subfields are examined in detail. These subfields are not inclusive of all subfields in the subject and, therefore, do not add to the broad field total. Majors are included regardless of whether they were held within or outside the school/college of education. Majors in main assignment are credited if they were held at the bachelor's degree level or higher. A certification is credited if it is a regular or standard state certificate or a probationary in-subject certification and at the secondary level. Detail may not sum to totals because of rounding and because some data are not shown. Not all apparent differences are significant.

Source: Hill, J., & Stearns, C. (2015). Education and Certification Qualifications of Departmentalized Public High School-Level Teachers of Selected Subjects: Evidence from the 2011-12 Schools and Staffing Survey. NCES 2015-814. *National Center for Education Statistics*.