

THE FEDERAL SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS K-12
EDUCATION INITIATIVE: RETURN ON INVESTMENT

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THE FEDERAL SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS K-12
EDUCATION INITIATIVE: RETURN ON INVESTMENT

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Abstract

THE FEDERAL SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS K-12 EDUCATION INITIATIVE: RETURN ON INVESTMENT

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Over the past 8-10 years, Science, Technology, Engineering, and Mathematics education initiatives have been created to fill the gap in American primary and secondary (K-12) students' knowledge and skills in the areas of Science, Technology, Engineering, and Math. This has led to educational resources being funneled toward STEM education and other STEM-related initiatives, from national government programs, to state and local STEM committees, and after-school programs.

This study provides an overview of the federal support efforts directed at the American K-12 STEM education movement as it pertains to the *America COMPETES Act* of 2007 and subsequent years, as well as the known outcomes of the movement thus far. Conclusions regarding the efficacy of the federal STEM education effort to date and insights for future support efforts are included.

ACKNOWLEDGEMENTS

For my wife, Abby and my son, Edward.

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Chapter One

Introduction

The movement toward integrating Science, Technology, Engineering, and Mathematics- or STEM- concepts into modern curriculum has permeated state and national educational ideology, as well as world educational ideology in the span of roughly 10 years. The momentum of this movement has been fueled by the ever-changing landscape of technology, economic markets, and global competition.

A clear definition of “STEM” is difficult to identify, as the acronym has been applied to everything from sustainable uses of natural resources to matters of national security and prosperity. “STEM education” is also not immune to issues of ambiguity. This is best summed up in Rodger W. Bybee’s book, The Case for STEM Education: Challenges and Opportunities (2013).

As STEM education has continued to expand and develop, the use of the acronym has been applied to advertisements, classrooms, competitions, conferences, curriculum, resources, presentations, workshops, summer experiences, and videos, just to name a few examples. (Bybee, 2013, p. x)

Amidst this ambiguity, both state and national governments and organizations have integrated sets of STEM standards into existing educational standards. These large steps toward STEM integration are a testament to the perceived link between STEM education and national prosperity, global climate change, and the future of human advancement. In short, STEM is engineering and innovation which creates a highly-valued niche in the global economy. STEM and STEM concepts, as they apply to education, are used to help students make connections between traditional educational disciplines and their application to modern technology, innovation, and the global physical and economic climates (Bybee, 2013).

The purpose of this study is to provide the reader with a short history of federal STEM

education support efforts, and the efficacy of these efforts on the American K-12 student. This is done through an exploration of the “America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act” (*America COMPETES Act, 2007*) as well as the supporting documents related to the National Science and Technology Counsel’s (NSTC, 2011) Committee on STEM Education’s (CoSTEM) *Federal 5-Year Strategic Plan for Science Technology, Engineering, and Mathematics (STEM) Education* (NSTC, 2013). The effects of this federal effort were undoubtedly manifold, however the prime mover for the STEM support effort was advancing American students ahead of those from other nations. Thus, the outcomes of these support efforts were then explored through a review of the Programme for International Student Assessment (PISA) test scores and other related metrics.

Finally, the intent of this study is to provide the reader with additional insights into STEM literacy, American standardized test scores, and a host of other topics that could also warrant further study. This was done with the hope that the knowledge gleaned would lead the reader to a better understanding of the current state of American K-12 STEM education and inspire future inquiry into the topic.

Background

STEM education has had a rather ambiguous identity. Beginning in the 1990s, the National Science Foundation (NSF) began using the acronym “SMET” and then rearranged the acronym to its current form, “STEM” (Bybee, 2013). STEM’s growing popularity has recently given birth to another component, the addition of the “A,” representing Art and Design, to create “S.T.E.A.M.”. STEAM education, however, has not yet gained the same recognition as STEM. This is evidenced most notably in both state and federal policy (*STEM Education Act, 2015*).

STEM initiatives come in many different shapes and sizes. Some are informative in nature, some involve the development of curriculum materials, and still others aim to form public policy. STEM supporters likewise include local, state, and federal government entities, along with private sector partners. These supporters and their forms of support also have different beginning and end points in the history of STEM education support. This study was intended to explore support measures at the federal level and their measurable effects on American K-12 students throughout the *Federal 5-Year Strategic Plan for STEM Education*.

Statement of the Problem

What is the motive and mission of the Federal STEM Education initiative? How has the federal government supported American K-12 STEM education initiatives? What are the quantitative and qualitative results of the American K-12 STEM education effort? Are these efforts making a positive impact on American K-12 Education and American ideals? If so, what is the magnitude?

Purpose of the Study

The purpose of this project is to explore federal support efforts of the American K-12 STEM education initiative. This study is not intended to be a catalog of federal STEM supporters, but rather a synthesis of the methods and forms of support as well as the measurable outcomes of support. Additionally, the aim of this study is to provide the reader with a synthesis of the data reported during the *Federal 5-Year Strategic Plan for STEM Education* reported by the Committee on STEM Education (CoSTEM) and the National Science and Technology Council (NATC). Finally, the justification for federal support toward American K-12 STEM education

initiatives will be discussed along with the outcome data available during this study.

Significance of the Study

This study is important to the American system of education, economic markets, and future generations because it can be used as a synopsis of the federal STEM support and its outcomes. This study can be used to aid current and future accountability of federal education reform and spending measures and can also be used as a synoptic history of the American STEM Education initiative.

Definition of Terms

K-12: Refers to Kindergarten through 12th grade levels of education.

Outcomes: For the purposes of this research, “outcomes” will include both quantitative and qualitative data.

STEAM: Science, Technology, Engineering, Arts and Mathematics. This definition is pertinent as it is often used interchangeably with STEM, but is not sited in current legislative documents (Bybee, 2013).

STEM: Science, Technology, Engineering, and Mathematics. However, the STEM acronym as a slogan can refer to many different areas including products, careers, ideals, lessons, or approaches, related to STEM Subjects (Bybee, 2013).

STEM Education: An innovative approach to Science, Technology, Engineering, and Mathematics to unlock creativity and problem-solving in learners of all ages. Through discovery, modeling, and contextual learning, students realize their potential and excel in active learning environ-

ments. STEM partnerships demonstrate the potential to unlock growth in education and workforce training by integrating the knowledge of Science, Technology, Engineering, and Mathematics in ways that expand college and career choices for students (Bybee, 2013).

Support: For the purposes of this research, “support” will include aid of STEM education through monetary funds, training, philosophical backing/alignment/approval, promotional materials, etc.

Delimitation of Research

The research for this project was conducted through internet resources, publications, papers, and periodicals pertaining to STEM & STEAM Education via the Karmann Library at the University of Wisconsin-Platteville. The EBSCO host online search engine was also utilized for key searches and citations. Material from the US Department of Education webpage, as well as other federal and state web sources were also included. Finally, this paper includes reference to conversations with experts in the STEM education field recorded in March of 2017.

Examples of local and state level standards, benchmarks, initiatives, results, and/or support may be exclusive to the state of Wisconsin Department of Public Instruction, its schools, and/or STEM-specific organizations. For this study, examples of support from the private sector will be limited to those partnered with, or resourced by, state and federal entities. All research materials were accessed between August 2016 and May 2017.

The outcomes of the STEM support initiative have also been limited to government partners and governmental reports with an emphasis on large sample sizes.

Method of Approach

The review of literature included accessing the online library resources via the UW-Platteville library page. This included Karmann Library at the University of Wisconsin-Platteville resources, OECD, ProQuest, and EBSCO Host. From these peer-reviewed journal articles, books, and government documents, and their reference materials, further resources were identified, increasing the base of resources used in this study. Aid for this research also came in the form of correspondence with the Karmann Library at the University of Wisconsin-Platteville and inter-library loan system, government publications, and reports. Government publications cited several useful private sector and nonprofit resources which also enriched the resources for this study.

Initial searches were focused on federal support of American K-12 STEM education. This led to several comprehensive articles and books related to STEM education and STEM outcomes. These comprehensive resources were then used to find more specific information regarding support and efficacy measures.

Finally, both the support and outcome data were synthesized to provide the reader with an adequate history of STEM education support, and a snapshot of its effects on American K-12 students. Additionally, sources of literature and commentary regarding the outcomes of the STEM Education initiative, and speculation about the future of American K-12 STEM Education are included in the conclusion section of this paper.

Chapter Two: Review of Related Literature

Introduction

The focus of this review of literature is to share with the reader a path for understanding the material available on the topic of American K-12 STEM education, specifically the historical issues surrounding federal support for American K-12 STEM education and outcomes. The story of STEM education and/or reform can be traced back to the 1950s when multiple new educational programs emerged around chemistry, physics, and other disciplines related to science and mathematics. These programs attempted to add to the knowledge and curriculum base of the time. These programs were met with resistance that naturally occurs when the status quo is changed or challenged (Bybee, 2013).

However, when the “Sputnik moment,” as it is referred to, occurred in 1957 with the launch of the Soviet spacecraft, things began to change. The Sputnik moment spurred national interest in education reform, which ultimately included the *National Defense Education Act (NDEA)* in 1958. This, in turn, sparked further educational reforms in subsequent administrations. Eventually, the enthusiasm and collective vision of the technological advancement gave birth to the space race and the Apollo missions (Bybee, 2013).

President Barack Obama mentioned the Sputnik moment as a rallying point for education reform in his 2011 State of the Union address (Office of the Press Secretary, 2011). This reference to the Sputnik moment and a need for change by President Obama was important for several reasons. First, American students had fallen behind the rest of the world in math and science. This is evidenced by the Programme for International Student Assessments (PISA) data which consisted of standardized test scores from up to 75 developed nations (OECD, 2010). In 2009, PISA ranked American 15-year olds 31st in mathematics and 23rd in science (OECD,

2010). Additionally, the American workforce needed to adopt 21st-century skills to stay competitive in the global economy. Some of these skills included adaptability, complex communications, non-routine problem solving, self-management, and systems thinking (Bybee, 2013). Still other reasons for the president's call to action included the mounting global focus on the environment, natural resources, and the weakening of national security. Could a federal education initiative boost the nation's interest in STEM and STEM fields? Could this newfound interest in STEM translate into American students climbing the PISA rankings in math and science?

Ultimately, the US federal government heeded the call for STEM education support, and in 2007 passed the America COMPETES Act. The authors of the act stated that "a well-educated population is essential to retaining America's competitiveness in the global economy" (H.R. 2272, 2007, SEC. 6001-1). The authors of this act highlighted STEM education best practices, teacher training, and the general focusing or condensing of federal resources. Then in 2010, the Office of Science and Technology Policy (OSTP), a member of the National Science and Technology Council (NSTC), was charged with the creation of a *Federal 5-Year Strategic Plan for STEM Education* by 2012 under the *America COMPETES Reauthorization Act of 2010* (H.R. 5116, 2010). The *Federal 5-Year Strategic Plan for STEM Education* and the reports that supported it were the base for this study's federal support efforts toward K-12 STEM education.

It is also important to note that, along with a host of other co-chairs, task force members, and committee members from all the CoSTEM partner agencies, there was one point person. Mr. John P. Holdren, Assistant to the President for Science and Technology, and Director of OSTP, authored an introductory letter to the Members of Congress, in each one of the subsequent *Federal 5-Year Strategic Plan for STEM Education* documents. This is significant be-

cause the NSTC and the OSTP are cabinet-level positions, thus making them sensitive to presidential elections and the appointment of White House staff. Mr. Holdren's letters to congress are significant because in these letters Holdren laid out the Obama administration's initial and continuing goals, practices, and findings for each report. The information in these reports are helpful to better understand the progress of the STEM initiative, considering the issues present at the time the reports were written (NSTC, 2013).

Federal Support of K-12 STEM Education

The *Federal 5-Year Strategic Plan for STEM Education* was created to help increase the "coordination and efficiency" of the federal investments in STEM education (NSTC, 2012 p. iv). The *America COMPETES Reauthorization Act of 2010* called for the formation of a National committee on STEM Education referred to as CoSTEM (H.R. 5116, 2010). CoSTEM was then charged with the task of developing the *Federal 5-Year Strategic Plan for STEM Education*. One of the first tasks of CoSTEM was to create an inventory of all Federal STEM education support efforts. CoSTEM also created goals and objectives to guide each participating agency's support efforts.

Between the 2010 *America COMPETES Reauthorization Act* and the 2013 release of the *Federal 5-Year Strategic Plan for STEM Education*, CoSTEM addressed the need for a condensing of federal STEM support efforts by creating *The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio* (NSTC, 2011 p. iii) The purpose of this report was to provide an inventory of all the agencies associated with CoSTEM and to identify any "duplication, overlap, and fragmentation" of their programs (NSTC, 2011 p. iii). *The Federal STEM Education Portfolio* also included a list of areas where support efforts overlapped, and included

measures for program effectiveness. This portfolio also provided a breakdown of the \$3.4 billion federal spending over 252 programs. Finally, the authors of this report highlighted the effectiveness of programs by type and interagency goals (NSTC, 2011).

From a political standpoint, this report seemed to serve as a primer or a justification for CoSTEM's role in STEM Education reform and its priority level for subsequent fiscal budgets. However, the authors of the report clearly stated that "the primary issue is how to strategically focus the limited federal dollars available so they will have a more significant impact in areas of national priority" (NSTC, 2011 p. xi).

The *Coordinating of Federal Science, Technology, Engineering, and Mathematics (STEM) Education Investments: Progress Report* was published in February of 2012 to satisfy a requirement for annual reporting as outlined in the America COMPETES Reauthorization Act of 2010 (NTSC, 2012). The authors of this report provided an overview of the development of the *Federal 5-Year Strategic Plan for STEM Education*, and reiterated much of what was contained in *The Federal STEM Education Portfolio* (NSTC, 2012). The delivery date of this report and its content seemed to suggest lack of coordination amongst the CoSTEM members. Why would a report about the progress of *Federal 5-Year Strategic Plan for STEM Education* such as this be delivered just prior to the actual expected due date of the *Federal 5-Year Strategic Plan for STEM Education* itself?

It is important to note at this point that all the subsequent documents regarding the *Federal 5-Year Strategic Plan for STEM Education* had an explicit due date for its release of spring of 2012 (NCTC, 2012). This was most explicitly stated in Mr. Holdren's letter to the Members of Congress in the *Coordinating of Federal Science, Technology, Engineering, and Mathematics (STEM) Education Investments: Progress Report*: "The strategic plan will be completed in

Spring 2012” (NSTC, 2012 p. iv).

The *Federal 5-Year Strategic Plan for STEM Education*, submitted in May of 2013, began with Mr. Holdren’s letter to the Members of Congress. Holdren cited President Obama’s sentiments about an “all hands on deck” approach toward STEM Education (NSTC, 2013 p. iii). These words were borrowed from the 2011 State of the Union address. This sentiment was echoed in the *Federal 5-Year Strategic Plan for STEM Education* document in a multitude of ways. The authors of the plan outlined the Committee on STEM (CoSTEM), agency partners, and various quantitative goals, some of which had already been supported. For example, the Department of Education allotted \$4.3 billion in Race to the Top funds. They also set a goal to train 100,000 excellent STEM teachers within the subsequent ten years known as the “100Kin10” effort. This goal is in alignment with the *America COMPETES Act of 2007 and 2010* which called for teachers to be trained with “best practices” regarding STEM education (H.R. 5116, 2010). This emphasis on best practices in STEM education is predictable rhetoric for any educational initiative. Is it wise to use such an ambiguous title for a measurable data point, especially when regarding a field as ambiguous and dynamic as STEM education?

The next section of the plan described an effort to increase funding by 6% by the fiscal year 2014 (FY2014) while reducing or condensing the number of programs receiving funding. This was justified in the plan by applying funds to programs that showed “positive growth,” or to new “programs of promise” (NSTC, 2013). These actions were taken to condense the focus of federal STEM education programs and spending as mentioned in subsequent documents. This component of the plan was mandated in the *America COMPETES Act of 2007 and 2010* (H.R. 5116, 2010). The intended prudence of this component is obvious, but is it possible to measure the success of a program over the course of one fiscal year? Perhaps some programs require

more time to reach their full potential or desired population. Additionally, is it possible that some programs are not ambitious enough in their efforts, but meet their growth targets easily?

Next, the plan established the roles of The Department of Education (ED), the National Science Foundation (NSF), and The Smithsonian Institute. The plan put K-12 education partnerships, 100Kin10 teacher training, and oversight of all CoSTEM partners under the care of the ED. The NSF was to head all undergraduate level efforts, and leaders at the Smithsonian Institute were to oversee informal educational experiences in conjunction with a host of other federal agencies including NASA, USDA, and others. It is important to note that The Smithsonian Institute did not have the ability to issue grant monies unlike its subordinate agencies under the hierarchy laid out in the plan. What was the motivation for moving The Smithsonian Institute to this position when it seems incapable of fulfilling the role assigned to it?

The plan then set forth goals for the FY2014:

- It would help federal STEM efforts reach more students and more teachers more effectively by reorienting federal policy to meet the needs of those who were delivering STEM education, specifically: school districts, states, colleges, and universities. It would help to reorganize efforts and to redirect resources around more clearly-defined priorities, with accountable lead agencies.
- It would enable rigorous evaluation and evidence-building strategies for federal STEM education programs.
- It would increase the impact of federal investments in important areas such as graduate education by expanding resources for a limited number of programs, while recognizing and supporting key disciplines and professions in a state of shortage.

- It would provide additional resources to meet specific national goals, such as preparing and recruiting 100,000 high-quality K-12 STEM teachers, recognizing and rewarding excellence in STEM instruction, strengthening the infrastructure for supporting STEM instruction and engagement, increasing the number of undergraduates with a STEM degree by one million over the next decade, and broadening participation in STEM fields by underrepresented groups. (NSTC, 2013)

The plan continued with more specific goals and courses of action for each of the following sections:

- Federal Role in STEM Education
- Strategic Priorities and Coordination Strategies
- Implementing the *Federal 5-Year Strategic Plan for STEM Education*

(NSTC, 2013)

Authors of the plan extensively justified the position and rationale for each of its goals and actions within each of the above sections. They also emphasized the need for accountability and the value of good data throughout each section (NSTC, 2013). One of the major challenges this movement faced was using good or applicable data. This was admitted in *The Federal STEM Education Portfolio* under the “Limiting Factors” heading: “Challenges associated with collecting and sharing student data can limit STEM education program evaluation strategies” (NSTC, 2011 p. 12). It might have been difficult for CoSTEM partners to create best practices, or make wise financial decisions if the measurable data was not accurate or not applicable to the given scenario.

The implementation section of the plan was the most extensive. Here the authors laid out the “Strategic Priorities and Coordinated Strategies” (NSTC, 2013 p. 8). Under this section, the

“Priority STEM Education Investment Areas” were expressed along with a rationale for each. Below are the priority investment areas that pertained to the topic of this paper.

- Improve STEM Instruction: *Prepare 100,000 excellent new STEM teachers by 2020, and support the existing STEM teacher workforce.*
- Increase and sustain youth in public engagement in STEM: *Support a 50% increase in the number of US youth who have an effective, authentic STEM experience each year before completing high school.*

(NSTC, 2013).

The authors also laid out near-, mid-, and long-term actions. Each action was accompanied by desired outcomes and metrics/milestones (NSTC, 2013). These initial priorities were significant because they showed how the 5-year plan authors and practitioners approached solving the concerns and directives communicated in the *America COMPETES Act*. The plan states:

Research shows that top-performing teachers can make dramatic differences in student achievement and suggests that the impact of assigning students to top-performing teachers each year can significantly narrow achievement gaps. Thus, the need to focus on improving STEM teaching is clear (NSTC, 2013, p. 17).

This statement, and others like it, show the legislators’ emphasis on teacher education. Hence, the CoSTEM partners emphasized supporting teacher training programs in the 5-year plan (NSTC, 2013). These points of emphases caused the researcher to raise the following questions. How long does it take to become a top-performing STEM teacher, and is it possible to do so in the time frame proposed in the 5-year plan? Is it possible to replicate excellent teaching on a national scale? Finally, what other resources, beyond STEM training, might an excellent STEM teacher need to effectively bridge the achievement gap?

The plan continued with a road map for support within the body of the document and, more specifically, in Appendix B. Here the authors organized priorities for general investment design principles, design principles by objective, and investments serving underrepresented groups (NSTC, 2013). Some general design principles expressed were expected and elementary, like a detailed budget, or alignment with evidence-based practices. Still others carried the main “all hands on deck” theme, with principles such as planning for the sharing of ideas, partner cost sharing, staff training, and other accountability measures (NSTC, 2013).

Another design component of interest was the deliberate consolidation effort. In this design component, the total number of programs that received support would be reduced while programs of growth would receive additional funding. A parallel design component channeled support toward new programs introduced during the given support year (NSTC, 2013). Again, it is unclear if the accountability measures and investment strategies stated in the plan translated into the outcomes desired (e.g.: excellent teachers, effective programs, etc.).

The major overarching goal for K-12 education in the 5-year plan was best expressed within the Executive Summary section of the plan where the authors stated:

Investing in STEM education is critical to the nation and its economic future for a number of reasons:

Our K-12 system is “middle of the pack” in international comparisons: Among 33 Organization for Economic Cooperation and Development (OECD) countries that participated in a recent Programme for International Student Assessment (PISA) study, which measures students’ ability to apply what they have learned in reading, mathematics, and science, and has been designed to assess whether students can use their knowledge in real-life situations, 12 countries had higher scores than did the United States in science

and 17 had higher scores in mathematics.

(NSTC, 2013, p. vi-vii)

This direct reference to standardized test scores and national rankings should not go unnoticed. Beyond all the other metrics/measurables highlighted in other sections of the plan, this point is one that deserves extra attention. The 5-year plan could have been a very successful endeavor and still be viewed so because of the performance of a very narrow population of American students on an international assessment. The international assessments, such as PISA, attract global attention whenever they are released. It appears as if the federal STEM efforts were aligned to both STEM education reform and dominance on international assessments. These two goals are not necessarily achieved using the same means, and could in fact be opposed to each other.

In conclusion, the 5-year strategic plan for STEM education was the most ambitious education reform effort related specifically to STEM education in federal history. This can be said because it was designed to synthesize all the federal STEM support efforts into one initiative (NSTC, 2013). With approximately \$3 billion in funding for each of the subsequent 5 years, the expectations for American K-12 STEM education advancement were very high.

As noted earlier, the *Federal 5-Year Strategic Plan for STEM Education* was to be submitted in the spring of 2012. However, the completed plan was not submitted to Congress until the spring of 2013. This fact and others will be discussed in later sections of this work.

The following section will include an outline of the first outcomes of the *Federal 5-Year Strategic Plan for STEM Education* and the changes made to the structure of the plan over time.

Initial Outcomes and Evolution Support

The *Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education* for the 2014 fiscal year was submitted on March 24, 2014. In Mr. Holdren's letter to the Members of Congress section, he restated some "key strategies" the President has focused on in the past (NSTC, 2014, p.ii).

Setting ambitious national goals: These goals include moving American kids from middle to top of the pack of international rankings in science and math, preparing 100,000 excellent STEM teachers...

(NSTC, 2014, p. ii).

The authors of the report showed the initial outcomes from the first year of the *Federal 5-Year Strategic Plan for STEM Education*. These outcomes were largely based on building networks, training teachers, and exploring research. Other expected outcomes from the first year were the consolidation efforts in each agency. The report clearly outlined the funding that was allocated, reallocated, and budgeted for the next year's programs.

One program highlighted for K-12 education was the "redesigning of high schools to teach real-world skills" (NSTC, 2014, p.3). Other programs included STEAM teacher training and research to develop new STEM education practices. Many of the efforts highlighted in the 2014 report emphasized further study and the collection of fresh data. As noted in earlier commentary, the time frame for some of the programs that received support seemed to be rather ambitious. The programs that received support needed to show positive results in a short amount of time, only two or three years in some cases. Other programs may have even shown positive results that were not enough to warrant further funding.

The 2014 Progress Report included descriptions of some new areas of program support.

For instance, the redesigned high schools were referred to as “Next Gen High Schools” (NSTC, 2014 p. 2), and advancements in STEM curriculum research began to include more types of course offerings to more students. Other endeavors included media and entertainment industry education, cyber security, computing partners, and a “maker” movement (creativity/construction of hands-on projects), just to name a few (NSTC, 2014).

The consolidation of programs also continued in 2014, showing a reduction from 138 total programs in 2013 to 111 in 2014 (NSTC, 2014). Again, the current programs and new programs were all well-documented in the later sections of the report. Further accountability measures were shown as goal completions, via the tables on near-, mid-, and long-term goals, outcomes, and metrics and milestones. Most milestones and metrics were completed or were on-track, with a small number being missed or pending. The accountability measures presented in the report were thorough and were well-communicated. But, they were more aligned to the management of the system and monies allotted than the outcomes focused on in the beginning of the report (NSTC, 2014). This could prove problematic as programs may have needed more development time so progress could be made toward bridging the STEM literacy and skills gap.

The *Progress Report on Coordinating Federal STEM Education* for the 2015 fiscal year was submitted on March 25, 2015. In the report, underrepresented students were highlighted along with descriptions of continued research into best practices for hands-on STEM learning and leverage efforts for the use of participating federal agencies’ physical assets. Physical assets included the use of educational space, tools, and even National Oceanic and Atmospheric Administration (NOAA) vessels that were made available. Other emerging themes included a greater emphasis on computer science (NSTC, 2015). The report included the fact that President Obama became the first president to ever write a line of computer code as a part of an “Hour of

Code” (NSTC, 2015, p. iii). Still, others included greater emphasis on bio-medical fields.

The authors of the 2015 report also showed the 2013-15 consolidation efforts by stating that “over the past two years, the overall number of STEM programs has been reduced by 40%” (NSTC, 2015, p. 11). Programs like the Maker Movement, Next Generation high schools and access to 21st century STEM curricula were all highlighted, as in earlier reports, along with the expansion plans for 2016.

The third and final *Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education* for the 2016 fiscal year was submitted on March 31, 2016. In Mr. Holdren’s letter to the Members of Congress for the 2016 report there was, as in preceding years, an emphasis on “setting and working to achieve ambitious national goals” (NSTC, 2016, p. ii). Earlier documents in this same section of Mr. Holdren’s letter referenced a need to move American students from the middle of the pack to the top in international rankings, namely the PISA rankings. In this 2016 letter there was no mention of advancing American students up the international rankings. Mr. Holdren did report however that the 100Kin10 movement had reached the halfway point in the completion of this goal (NSTC, 2016, p. ii). A possible reason for this omission of national ranking as a goal and the half way milestone of the 100Kin10 movement will be discussed the conclusion section of this paper.

The 2016 report included highlighted initiatives from previous reports. One subject that was particularly highlighted in the 2016 report was the area of computer science. The report noted that, “by some estimates, just one quarter of all K-12 schools in the United States offer computer science with programming and coding” (NSTC, 2016, p. 2). The authors of the report also described the new “computer science for all” initiative and its addition to the 2017 fiscal budget (NSTC, 2016, p. 2).

Overall, the 2016 report, although formatted differently, proved to be the most extensive of the three reports. The authors took care to expound on each topic, as well as show more evidence and detail in each section.

As mentioned earlier this was the last progress report submitted to congress regarding the 5-year plan. The outcome of the 2016 presidential election most likely had a profound effect on the future of the 5-year plan, its authors, and the federal money allocated for its implementation. Mr. Holdren's and other positions were cabinet-level appointments, and with any administrative change in the White House, a new set of cabinet appointments and other subsequent changes are often made.

Earlier in 2015, some other changes occurred to the educational landscape that led to further STEM support outside of the 5-year plan efforts. The *Every Student Succeeds Act of 2015* is one example of STEM support funneled through an additional avenue. This law contained provisions for advancements in STEM education and other similar initiatives (Gamoran, 2016).

In the spring of 2015 the 114th Congress passed the *America COMPETES Reauthorization Act of 2015* (H.R. 1806, 2015). It is important to remind the reader at this point that the *America COMPETES Reauthorization Act of 2015*, and the acts of Congress that preceded it, were the laws that mandated and directed the 5-year plan initiative. Within the 2015 act it was stated that “‘STEM education’ means education in the subjects of STEM, including computer science” (H.R. 1806, 2015, sec 2, 2). In addition to the emphasis on computer science, the authors of the act also stated the following regarding STEM outcomes:

SEC. 201. FINDINGS; SENSE OF CONGRESS.

(a) FINDINGS.—Congress finds the following:

(2) According to the Program for International Student Assessment 2012

results, America lags behind many other nations in STEM education.

American students rank 21st in science and 26th in mathematics.

(b) SENSE OF CONGRESS.—It is the sense of Congress that—

(1) more effective coordination and adoption of performance measurement based on objective outcomes for federally supported STEM programs is needed.

(H.R. 1806, 2015)

In September of 2015, the 114th Congress passed the *STEM Education Act of 2015*. This act placed special emphasis on computer science in STEM education, and mandated grant pathways for teachers (H.R. 1020, 2015). It can be seen over the evolution of these documents that the field of, and very definition of STEM has changed over time. This specific adaptation made sense as Computer Science is, in fact, a science. However, these types of emphatic mandates could possibly overemphasize one component of STEM to the detriment of the others. This could also cause future support to be given toward fields that are not necessarily STEM-related, but carry the required titling. Perhaps more targeted investments would have been more appropriate to reach the goal of improving PISA scores rather than investing in a wide range of “STEM” initiatives.

As stated earlier, the STEM support efforts and outcomes listed above are merely an overview of federal support efforts initiated by the *Federal 5-Year Strategic Plan for STEM Education* and other government actions. The following section includes more quantitative data regarding K-12 STEM education outcomes over this first phase of reforms.

Measures of Success

As discussed earlier in this work, STEM stands for Science, Technology, Engineering, and Mathematics. An ongoing challenge for policymakers and those who studied STEM education is the so-called “STEM measurement data,” which often only included either science and/or math outcomes (ACT, 2016). As stated earlier in this work the federal documents repeatedly referred to only the international Math and Science test scores or rankings as a priority metric.

Other metrics like the 100Kin10 effort are measurable outcomes, but might not be outcomes directly aligned to student achievement on international assessments. This is perhaps more forgivable since there were few standardized testing metrics for the technology or engineering components of STEM education. Again, the generally-accepted definition of STEM education, or STEM literacy, is the ability to apply mathematics and science to solve problems (engineering) while using modern technology. The lack of such comprehensive assessment leaves the efficacy of the STEM support efforts ambiguous.

Furthermore, if an assessment were created it would still have limitations due to the broad definition of STEM. For example, a student could theoretically possess strong computer science skills, but not perform well on a test oriented toward biomedical or applied physics components. Is this student’s STEM literacy still at an acceptable level?

Results and Outcomes

The results presented in this section are provided because they represented some of the most applicable sources of data, as well as some of the most current data available regarding the topic of STEM education. Also comprised here are the qualitative and quantitative outcomes

available during the *America COMPETES Act* and the duration of the *Federal 5-Year Strategic Plan for STEM Education*.

As noted earlier in this work, both the *America COMPETES Act* and the *Federal 5-Year Strategic Plan for STEM Education* included goals and priorities focused on improving the American K-12 student achievement level on the Programme for International Student Assessments (PISA) (NSTC, 2014). Therefore, to measure the ultimate outcome of these initiatives, the PISA rankings for American K-12 students served as the primary measure of success.

(PISA) is a triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students.

In 2015, over half a million students, representing 28 million 15-year-olds in 72 countries and economies, took the internationally agreed two-hour test. Students were assessed in science, mathematics, reading, collaborative problem solving and financial literacy. The results of the 2015 assessment were published on 6th December 2016.

(OECD, 2017, p. About)

As noted earlier, according to the *Programme for International Student Assessment 2012* results, America lagged behind many other nations in STEM education. American students ranked 21st in science and 26th in mathematics (H.R. 1806, 2015). In the 2015 PISA publication, American students ranked 25th in science and 39th in mathematics (OECD, 2016). This data did not show that the federal investments in STEM education had a positive effect on America's international rankings. Moreover, the American students tested in 2015 fell lower in the rankings than American students tested in 2012.

The PISA score, as stated above, is only administered to 15-year-old students. Thus, it was not representative of the entire K-12 population. It is possible that the *America COMPETES*

Act and the *Federal 5-Year Strategic Plan for STEM Education* had a positive effect on K-12 students both younger and older than 15. Perhaps the following data points provide a clearer picture of the success of the STEM education initiative among the other age groups that fell within K-12 education.

The federal government had its own extensive measures for all areas of K-12 education in the National Center for Educational Statistics (NCES). This agency's data is used to form public policy and is often cited in papers such as the *Federal 5-Year Strategic Plan for STEM Education*. The 2015 national report card section of the National Assessment of Educational Progress (NAEP) of the NCES provided information about the national STEM picture in the following ways:

- In 2015, the national science scores for 4th and 8th grade students increased from 2009 data. However, the 2015 science scores for 12th graders remained unchanged from 2009 (NAEP 2015 Science, 2015).
- For 2015, 12th grade students' math scores dropped from 2013 (NAEP 2015 Math, 2015).
- The NAEP also began measuring technology and engineering literacy scores in 2014.

Eighth-grade students were presented real-world scenarios involving technology and engineering challenges. Students were asked to respond to questions aimed at assessing their knowledge and skill in understanding technological principles, solving technology and engineering-related problems, and using technology to communicate and collaborate. Students were also surveyed on their opportunities to learn about technology and engineering in and out of school.

(NAEP Technology, 2014 p. 1)

This “Technology & Engineering Literacy (TEL)” report seemed to have the most applicable STEM data of the NCES publications (NAEP, 2014). The authors of this report put an emphasis on students’ ability to apply technology and problem-solving skills along with a host of other metrics beyond math and science scores. Additionally, the data in this report was organized into several different sub-demographics related to gender, socioeconomic status, and other valuable data points.

The data collected in this first round of testing was then used as a baseline for future comparisons. Some specifics from the initial round of testing included the following: on average, female students scored 3 points higher than male students; students without school lunch support scored 28 points higher than their peers who were supported by school lunch programs; and 50% of all students reported using a computer to create, edit, or organize digital media at least once a month in school (NAEP, 2014).

Another source of comprehensive national testing is the ACT. However, though not directly affiliated with the federal government, ACT data is still included in this work as the ACT test has become one of the most popular college-readiness tests used in the United States. ACT has provided proprietary survey data on many different subjects, namely English, science reasoning, mathematics, and reading comprehension. However, the ACT test also provided STEM interest survey data along with the four other data points to provide a STEM benchmark score in a publication titled “The Condition of STEM.” This showed STEM interest survey data alongside the four main data points. The report also showed other demographic data points such as ethnic and gender information. This report was significant for all the aforementioned reasons and ACT provided very timely information. The ACT data is available much sooner than the NAEP data,

making it a valued data point for this research (ACT, 2016).

Some of the data points from the 2016 *Condition of STEM Report* included that over 1 million students demonstrated an interest in STEM areas. Forty-eight percent of students showed an interest in STEM majors. Only 20% of students who took the ACT in 2016 were ready for first year STEM college courses. There was also a 3% increase in interest in computer science over the previous five years (ACT, 2016). It should be noted that the ACT data is a compilation of mathematics and science testing. It does not directly measure the test taker's ability to use modern technology in conjunction with math and science to solve real world problems. Again, it seems that the means of measurement does not test topics that match the accepted definition of STEM.

In conclusion, this literature review included an overview of the historical and contemporary documents that identified the means of federal K-12 STEM support. Outcomes provided in government documents as evidence of federal K-12 STEM support, as well as supplemental works that aided this research, were synthesized. The study of this subject has raised questions about the availability, motives, and presentation of federal K-12 STEM support and outcomes. Additionally, emerging trends were identified that may shape future federal K-12 STEM support and outcomes. The next section of this work will attempt to draw conclusions about these themes and the overall efficacy of federal K-12 STEM support.

Chapter Three: Conclusions and Recommendations

For this study, many sources related to federal support of K-12 STEM education and its outcomes were cited. The best sources of literature proved to be government documents and government-partnered agencies. The chronology and context of the sources should also not be overlooked. These facts along with the outcomes presented earlier led to the following conclusions and questions about K-12 STEM education support and outcomes:

Conclusions

The motive and mission of the Federal STEM Education initiative were inherently flawed. As noted often in this study and in the resources that supported it, one of the clearest goals of the federal STEM initiative was to move American K-12 students upward in the PISA rankings. Additionally, the documents often included the goal for students to acquire 21st century skills and abilities to meet the challenges of future scientific, economic, geopolitical problems. It seems that the measure of the federal STEM initiative, PISA rankings, and the goal of arming American K-12 students with the skills and abilities to be competitive in the global STEM arena were not well aligned with each other. STEM encompasses much more than the knowledge of math and science. It includes the student's ability to use math, science, and modern technology to solve problems. Perhaps this mismatch was caused by the STEM initiative focus on an unclear target due to the somewhat subjective nature of the STEM definition.

STEM education lacked a clear and widely-accepted definition. This fact led to ambiguity in planning, goal setting, measurement, and practice. The federal government, through acts

of Congress, even took measures to write certain components of STEM education into law. The measure which the federal government repeatedly cited as a high priority- to improve PISA rankings, only incorporated two components of STEM, namely science and mathematics. Thus, it is difficult to assess the efficacy of an endeavor such as the *Federal 5-Year Strategic Plan for STEM Education* when the original intended outcome is so unclear. Perhaps a more comprehensive measure like the NAEP *Technology & Engineering Literacy (TEL)* would have been better suited to measure the growth of the American K-12 students' STEM knowledge, skills, and abilities.

What is clear is how the federal government supported American K-12 STEM education initiatives. Additional points that are very clear include how much was spent by the federal government on STEM education and what programs did with the monies. This is best evidenced by the existence of *The Federal Science, Technology, and Mathematics (STEM) Education Portfolio*. It is also clear that the federal government's investments, consolidations, and accountability measures have produced a catalog of STEM programs with measurable outcomes in addition to new avenues for STEM education that show promise.

Other areas of clarity include the data produced during the life span of the *America COMPETES Act* and the *Federal 5-Year Strategic Plan for STEM Education*. Through the review of these data-points the researcher created an image of the STEM initiative's outcomes. The PISA Scores of American students did not advance them in the international rankings, moreover they fell backward in the international rankings. Again, it is important for researchers to understand the context and content of these international rankings when assigning judgment to the federal STEM education initiative. The support given to 5-year plan helped to educate over 50,000 STEM teachers (NAEP, 2014). The program practitioners supported by the 5-year plan

helped to create new models and modes of STEM education. New data was also collected and qualified to aid future STEM initiatives. The 5-year plan also gave countless STEM experiences to students both in and outside of school. The fruits of these efforts most likely won't be fully realized within 5 years of the initial efforts most of those effected were within the primary school ages. However, if these outcomes, both positive and negative, are taken out of proper context, or incorrectly applied to support or challenge STEM initiatives, the potential for further fragmentation and the wasting of federal resources remains a likely possibility.

The inherent outcomes of the federal STEM education initiative are likely yet to be seen in their full magnitude. Like the outcomes attributed to the “Sputnik Moment” of the late 20th century, the outcomes of the STEM education initiative on the beginning of the 21st need time to come to fruition. As the younger generation of American K-12 students enter the world of higher education, teachers trained in STEM concepts enter the workforce, and as the global economy grows and changes, the research community will be better equipped to judge the ultimate magnitude of the federal STEM education initiative. At the time of the research conducted for this study, there was a great lack of quality scholarly resources directly related to the topic of K-12 STEM education regarding macro federal support efforts and the *Federal 5-Year Strategic Plan for STEM Education* and the outcomes thereof.

Insights

It should not be overlooked that politics and political strategies played a part in the STEM education initiative. This is best evidenced by the Congressional Committee on Science, Space, and Technology regarding the *Federal 5-Year Strategic Plan for STEM Education* and its proposed reorganization of federal funding of STEM Education under the fiscal year 2014

budget proposal. In this hearing, Mr. Holdren and other CoSTEM representatives fielded questions about the *Federal 5-Year Strategic Plan for STEM Education*, mostly concerning the tardiness of its publication, concerns over the cuts proposed to NASA, the position of the Smithsonian Institute, and the general haste with which the plan was put together. It was obvious that the hearing was very well attended and several Members of Congress wanted to weigh in on the *Federal 5-Year Strategic Plan for STEM Education* (Committee on Science, Space, and Technology, 2013).

STEM and STEAM education had become popular buzz words in both political and educational circles at the time of this legislation. Neither political stakeholders nor educational stakeholders wanted to be viewed as resistant to technology and innovation. But many lacked an adequate understanding of what STEM is, and what it is not. As discussed earlier, it can be problematic, if STEM taglines are used arbitrarily. STEM titles and measures of STEM programs can and do form policy, and lead to the application of valuable resources. The ambiguity of STEM and the popularity of STEM could be used by policymakers and organizations to leverage support for programs or initiatives merely including STEM in their title.

Further evidence of political influence on the *Federal 5-Year Strategic Plan for STEM Education* is evidenced by the lack of a 2017 progress report. As mentioned earlier in this work, the OSTP is sensitive to national election results. Due to the presidential election results of 2016, it is likely that the OSTP director position, along with many other positions, changed. At the time of this research, no reports or further *Federal 5-Year Strategic Plan for STEM Education* documents could be obtained beyond the March 2016 report.

Further research into STEM outcomes could lead to a better understanding of the state of American K-12 students' STEM literacy, interest, and aptitude. Perhaps measuring applicable

STEM concepts could be measured in entry-level military testing such as the Armed Services Vocational Aptitude Battery (ASVAB) assessment. Or, perhaps more STEM specific components could be included into the ACT and other similar assessments. Additionally, a clear picture of the labor market data related to STEM literacy could help form future policy decisions regarding investments toward STEM initiatives.

Questions

Where does the STEM education initiative go from here? One literary source that provided an answer to this question was Surr, Loney, Goldston, Rasmussen, and Anderson's *Myths and Motives behind STEM*. In this study, the authors quantified qualitative data from a variety of federal and state agencies in an effort to uncover emerging themes in STEM education. Some examples of this study's findings are listed below:

- Notions of STEM are currently evolving to reflect a more integrated and inclusive meaning and purpose.
- Evolving notions of STEM education have not been consistently articulated within the STEM education community, leaving room for varying interpretations.
- Emerging trends have not been fully embraced within the STEM education community, and some members indicated reservations or resistance to some of these changing notions.
- The notions of STEM reflected in the Department of Public Instruction website closely align with emerging views of STEM within the STEM education community.

(Surr, W., Loney, E., Goldston, C., Rasmussen, J., & Anderson, K., 2016, p. 14)

Is it too soon to tell what the effects of the STEM education initiative will be? The students tested in the 2015 PISA assessment had only two or three years' worth of STEM education investments, which were during the early stages of implementation of the *Federal 5-Year Strategic Plan for STEM Education*. The American K-12 students whom this initiative focused upon will continue to be measured even after the completion of the *Federal 5-Year Strategic Plan for STEM Education* implementation. Additionally, students included in the PISA scores from 2015 will have two more years of concentrated educational investments that could positively affect their STEM-readiness as they exit the K-12 system. Furthermore, it is difficult to measure the direct relationship between the teachers who were educated in the 100Kin10 movement and others like it over just a few years' worth of training and practice. Perhaps they will become better STEM teachers over time? Perhaps they need continued support to be effective?

Was the federal investment big enough to cause real change? The federal government spends roughly \$1.1 trillion on education. The STEM education initiative, as cited earlier, only makes up around \$3 billion of those funds (NSTC, 2011). It is possible that programs like the Next Generation high school projects and others like it may require a more substantial federal investment to be successful.

If standardized test scores are not an accurate measurement of the effectiveness of the STEM education initiative, then what is? National expert on STEM and STEM education Dr. Alan Gomez, Chief Academic Officer and Co-Founder of STEM Academy, had the following to say in an interview at the 2017 Wisconsin Technology and Education Association in March of 2017.

Just because a student is in science classes or science testing doesn't ensure that they are going to be successful in the STEM arena, or the application of that. The idea is to not

only get to the base-line science, but get them the opportunity to apply that, so that we can measure what that success actually is. Then they will be productive citizens in our workforce, not just because of testing.

(Gomez, 2017)

Dr. Gomez also noted that American students are very creative and good at innovating, while students in other countries excel in academic testing. He asserted that it would be detrimental if our students lost their ability to innovate to improve their rank on international test scores. Perhaps what is not being measured is what matters most, and instead of answering the right question with the wrong measure, the research community, through diligent study, could one day know the true measure of the STEM education initiative.

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