STEM Professional Development Policies in the United States: Trends and Issues

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Introduction

In this chapter, an overview of policies regarding professional development for science, technology, engineering and mathematics (STEM) education in the United States, as well as associated trends and issues, are presented and discussed. The historical outcomes of the education system in the United States has altered legislation which has, in turn, impacted specific subjects and professional development. The progression of education and the pieces of legislative policies that advanced education in the United States have shed light on the creation of professional development for STEM.

Professional Development Policies

In order to understand STEM education, one cannot overlook professional development policies' historical context. Education in the United States progressed slowly until the mid to late 1800s. As the United States entered its industrial revolution period (1860-1890), the role of schooling in society, in terms of curriculum and methodology, changed (Del Giorno, 1967). The Nation's welfare depended on the proper education of its citizens; this created great concern for the future (Mackenzie, 1894). Concerns for the Nation's education prompted the leading educational organization, National Education Association, to form the Committee of Ten in 1892. The Committee of Ten appointed conference committees for nine subjects: 1. Latin; 2. Greek; 3. English; 4. Other Modern Languages; 5. Mathematics; 6. Physics, Astronomy and Chemistry; 7. Natural History (included Biology, botany, zoology, and physiology); 8. History, Civil Government and Political Economy; and 9. Geography (National Education Association, 1894).

Organizing the subjects resulted in an increase in students taking science courses, as well as the inclusion of labs for science whenever possible. Likewise, it gave rise to the formation of a curriculum structure with defined subjects (Del Giorno, 1967).The Committee of Ten also established the introduction of certain subjects early on in a child's education, and the provisions for instruction in all subjects for both college-bound and non-college-bound students (National Education Association, 1894, 1918;

Weidner, 2004). These changes created opportunities and a need for teachers to receive professional development.

In the latter part of the 19th century, professional development became a great concern with the emergence of textbooks that questioned teaching methodology. These textbooks addressed specific teaching methods, such as not using the textbook alone, and allowing the student to discover things on his or her own (Del Giorno, 1967). During this time, teachers received professional development by reading magazines (such as *Science)*, books, and letters (like the *Preston Papers*), field experience, and/or trainings (such as those the Industrial Education Association offered to manual arts instructors). This created unstructured professional development, or professional development that occurred without financial assistance from the federal government.

To describe professional development, one must combine several definitions: First, professional development is a teacher's ongoing learning experience (Luft & Hewson, 2014). Christopher Day's (1999) definition of professional development includes all-natural learning experiences and planned activities intended to provide a direct or indirect benefit to the individual or school. Through these activities, teachers "renew and extend their commitment as change agents" (Day, 1999, p. 18). Summarizing these definitions, one could operationally define professional development as a continuous learning experience that has a direct and indirect impact on the teacher and the teacher's commitment as a change agent in his or her classroom.

There are implications for this definition in legislations at the state and federal levels. At the state level, for example, in Milwaukee, WI, 1893, Dr. Lorenzo Dow Harvey organized classes for teachers and principals. They were to meet every other Saturday to "stimulate teachers' professional reading and thought on the application of psychological principles to the everyday situations of the schoolroom" (Bawden, 1950, p. 90). At the federal level, professional development is first addressed informally in the Morrill Act of 1862, and first addressed formally (funds allotted for professional development) in the 1978 amendments of Elementary and Secondary Education Act.

One must view the history of professional development -- whether for science, technology, engineering, mathematics, or other subjects -- through the lens of educational policy, curriculum, and tools for education. Taking this approach makes it easier for one to see professional development's transition from unstructured (which still takes place today) to structured (mandated by federal and state policies).

A Brief Overview of STEM Professional Development Policies Past

From the mid 1800s to the early 1950s, science, technology, engineering, and mathematics education took slightly different paths. This led the federal government to pass legislation that directly impacted each subject differently. Teachers received professional development for each subject in the 1800s and early 1900s mainly through journal articles and books. By the mid 1900s, professional development for science, technology, engineering, and mathematics educators had expanded to include preparatory courses and some formally structured programs (Del Giorno, 1967; Hurd, 1961). As the nation entered the 1950s, the federal government had enriched itself with science, technology, engineering, and mathematics education policy. Educational policies from this point forward included rhetoric related specifically to these subjects.

Much of the federal education policy in the 1990s and 2000s concentrated on standards, assessment, and accountability (Hurst, Tan, Meek, & Sellers, 2003). States were under federal mandates to create standards and assessments that required teachers to be trained and educated on updates for each state's educational directives. States had to review and revamp many of the professional development programs that already existed to accommodate these federal mandates. Moving into the 2000s, the federal government embedded itself further into science, technology, engineering, and mathematics education, as well as teacher professional development, with a major educational reform act: No Child Left Behind.

STEM Education Professional Development Policies Present

The chief educational policies passed from 1950 to 1999 facilitated the transition of professional development from solely unstructured, to both unstructured and structured, providing trainings for science, technology, engineering, and mathematics teachers. The policies also offered much support and funding for the development of curriculum for K-12 science and mathematics. Engineering and technology K-12 curriculum did not receive as many provisions as mathematics and science, but would eventually receive attention in the 2000s. Along with funding and support came mandates on the programs for research, placing science, technology, engineering, and mathematics education and its professional development under much scrutiny. STEM – a buzzword/term used in reference to science, technology, engineering, and mathematics, and professional development and education related to these subjects -- began to emerge among policy writers and education professionals.

The National Science Foundation coined STEM (science, technology, engineering, and mathematics) some time in the early 1990s (Dugger, 2016a). Even though the acronym included engineering and technology, when used, it most often referred to mathematics and science. This could be because past federal policy stated that science included engineering and technology; in many instances, engineering and technology were described as tools used in education, rather than subjects in their own right. It was not until 2010 that the term, STEM appeared in a federal policy and was defined as “the academic and professional disciplines of science, technology, engineering, and mathematics” (America COMPETES Reauthorization Act, 2011, §2). Just like the unclear use of the acronym, STEM, the realm of professional development was murky. In turn, it received criticism.

Progress Through the Teacher Pipeline: 1992–93 College Graduates and Elementary/ Secondary School Teaching as of 1997 acknowledged research that indicated K-12 teacher professional development was “viewed as inadequate by many scholars and policymakers, and initiatives to improve [were abundant]” (Henke, Chen, & Geis, 2000, p. 2). A core argument was that formal professional development would not have lasting effects unless it was connected to the classroom (Fullen, 1991). The National Center for Education Statistics (2001) found that only 18 percent of public school teachers felt that professional development was connected to other programs at their schools.

It was also suggested that teachers were more likely to participate in professional development that focused on state or district curriculum and performance standards (80 percent), while 74 percent preferred integration of educational technology trainings, and 72 percent preferred an “in-depth study of the subject area of the main teaching assignment” (Parsad, Lewis, Farris, & Westat, 2001, p. 4). A study for mathematics and science education indicated that instruction around use of technology in the classroom was teachers’ most highly perceived need within professional development. Content knowledge was teachers’ second most highly perceived need (mathematics and science content for elementary teachers and science content only for middle school teachers; high school teachers were not concerned with content knowledge) (Weiss, Banilower, McMahon, & Smith, 2001). The findings in these studies, as well as with several others, prompted policy writers to include provisions for professional development in the rewrite of the Elementary and Secondary Education Act, No Child Left Behind.

The No Child Left Behind Act of 2001 (NCLB) included not only improvements for professional development and stipulations for stronger accountability, but also initiatives to help revitalize STEM education (United States Department of Education, 2012). The NCLB allowed funds to be combined from Title II of this Act (“preparing, training, and recruiting high quality teachers and principals”), other Acts, and other sources for professional development (No Child Left Behind, 2002, §1119).

It also specified that there should be a

> “(2) focus on the education of mathematics and science teachers… [that development] continuously stimulate teachers’ intellectual growth and upgrade teachers’ knowledge and skills… (3) bring mathematics and science teachers… together with scientists, mathematicians, and engineers to increase the subject matter knowledge of mathematics and science teachers… (5) [and] improve and

> expand training of mathematics and science teachers… in effective integration of technology (§2201)."

The NCLB focused strongly on professional development in science and mathematics. Engineering was encompassed in science, and technology education was viewed as it had been in previous educational policies: a tool to enhance education.

The focus on professional development within mathematics and science education was further established in NCLB through provisions to grow partnerships with mathematics and science educational agencies outside of the classroom.

The Mathematics and Science Partnerships (MSPs) had a goal to improve students' academic achievement in mathematics and science through quality instruction. The MSPs' purpose was to encourage higher institutes to improve teacher education for mathematics and science teachers by "focus[ing] on the education of mathematics and science teachers as a career-long process that continuously stimulates teachers' intellectual growth and upgrades teachers' knowledge and skills" (No Child Left Behind, 2002, §2201). The MSPs were to bring together educators and other professionals in mathematics and sciences to improve teaching skills by exposing teachers to sophisticated laboratory equipment and other resources. The creators of MSPs hoped that teachers would be able to develop curriculum that aligned with the state's standards, and that teachers would enforce the "standards expected for postsecondary study in engineering, mathematics, and science" in classrooms (No Child Left Behind, 2002, §2201). To fulfill NCLB requirements, states were mandated to create assessments and curriculum that aligned with standards. The assessments would show the long-term trend in reading and mathematics for students, and create an avenue for improving professional development.

By 2004, all states had professional development requirements for license renewal that varied in criteria from superintendent recommendations to 150 hours of professional development (Cavell, Blank, Toye, & Williams, 2004). 37 states had funds specifically for professional development programs, 24 states established policies that aligned professional development with state content standards, and 35 had standards in place for professional development (Cavell, Blank, Toye, & Williams, 2004; Skinner, 2005).

States' initiatives for professional development created an increase in teacher participation, but "most teachers' professional development experiences were not of high quality" (National Science Board, 2006, p. 1-41). In 2007, Rising Above the Gathering Storm stated that teachers were the key to improving student performance, which influenced the government to place a stronger emphasis on STEM education in the next federal policy.

In Rising Above the Gathering Storm (2007), a committee formed by the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine, voiced their concerns on the erosion of the scientific and technological building blocks that were needed to maintain the United States' economic leadership. The report identified two key challenges connected to STEM skills: the creation of high-quality jobs for Americans, and the nation's need for affordable, clean, and reliable energy. The committee recommended four actions to focus on helping the country to overcome these challenges; one of the actions called for changes in K-12 education. This action step was referred to as 10,000 Teachers, 10 Million Minds and would recruit 10,000 science and mathematics teachers annually, educating 10 million minds. Rising Above the Gathering Storm (2007) acknowledged the teacher shortage. Likewise, it acknowledged that students had only a 40 percent chance of having a teacher for chemistry who had majored in the subject. If the subject were English, however, that possibility rose to 80 percent (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007). Rising Above the Gathering Storm (2007) specified a need for professional development opportunities that were high-quality, focused on content, had a significant effect on student performance, included year-long mentoring, contained pedagogical strategies, and provided high-quality curricular materials. To tackle the goal of 10,000 Teachers, 10 Million Minds, federal policymakers drafted a bill to provide resources for the enhancement of STEM education and professional development.

The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act of 2007, or America COMPETES Act, was "an Act to invest in innovation through research and development, and to improve the competitiveness of the United States" (intro.). The America COMPETES Act Title VI was devoted to education, and allotted grants for teachers to earn master's degrees in science, technology, engineering, and mathematics education. The America COMPETES Act authorized programs for teachers to experience research, and created other professional development opportunities to enhance teachers' science, technology, engineering, and mathematics content knowledge. The "National Panel on Promising Practices in K-12 STEM Teaching and Learning" was tasked with "identifying promising practices for improving teaching and student achievement in science, technology, engineering, and mathematics" (§6131).

Technology and engineering, for what seemed like the first time in a federal educational policy, were treated as separate subjects, and the acronym, STEM was used. It was not until the Act was reauthorized in 2010 as the America COMPETES Reauthorization Act that STEM was defined. In December 2007, America's economy began to show signs of instability. The federal government signed the American Recovery and Reinvestment Act of 2009 (ARRA) to avert education cuts (United States Department of Education,2009a).

The ARRA allotted $4.35 billion in funds for a competitive grant program called *Race to the Top*. A criterion on the application required states to include a plan for high-quality professional development, and the government gave priority to STEM-focused applications (United States Department of Education, 2009b). The monetary investments from ARRA and *Race to the Top* provided education the means to continue to move forward. According to the Nation's Report Card 1990-2007 and the Trends in International Mathematics and Science Study or TIMSS 1995 and 2007 reports, overall, the nation was making progress. In 2010, the America COMPETES Act was reauthorized to continue the growth of STEM education.

In America COMPETES Reauthorization Act, there were many provisions for improvement in education and professional development for science, technology, engineering, and mathematics. The Office of Science and Technology Policy established a committee – CoSTEM -- to coordinate Federal STEM education and STEM programs (§101). CoSTEM was tasked with creating a five-year strategic plan that pledged money for recruiting high-quality STEM teachers, producing high-quality professional development, strengthening the infrastructure for supporting STEM instruction and engagement, and providing STEM resources and equipment (National Science and Technology Council Committee on STEM Education, 2011). In America COMPETES Reauthorization Act, each letter in the acronym, STEM was used liberally throughout the policy as an abbreviation for its associated subject -- not to describe an integration of the subjects.

The America COMPETES Reauthorization Act of 2010 brought about more changes to STEM education. A section entitled *Science, Technology, Engineering, and Mathematics Support Programs*, which housed the National Science Foundation Authorization Act of 2010, reflected many advances. This act made available $9.3785 billion to be used for education and human resources at the National Science Foundation (§503).

This allotment of funds to the National Science Foundation (NSF) was important to STEM education because in 2012, an analysis of federal funds suggested that the majority of STEM education funding and professional development came from the NSF. This analysis stated that the NSF was a "key component of the federal STEM education effort" (Gonzalez, 2012, p. 1).

A 2010 report by the Committee on Standards for K–12 Engineering Education emphasized the lack of attention that the "T" and "E" in STEM had historically received. The America COMPETES Act of 2007 and America COMPETES Reauthorization Act of 2010 seemed to be the first federal education policies to pull technology and engineering out from under the umbrella of science. Though it was not very clear in the policies, the "T" in STEM was addressed in education as a tool to help improve or enhance the curriculum of other subjects.

For technology education to take a stand among the major subjects, a clear definition – in addition to standards – was necessary. The first standards written for technology education were the 2000 *Standards for Technological Literacy: Content for the Study of Technology* (2000/2002/2007). Within these standards, technology and technology education were defined.

> "Technology is the innovation, change, or modification of the natural world or environment to satisfy perceived human wants and needs…Technology education is [further] a study of technology, which provides an opportunity for students to learn about the process and knowledge related to technology that are needed to solve problems and extend human capabilities" (International Technology Education Association, 2007, p. 242).

Having a clear definition of technology, technology education, and standards provided the "T" in STEM with the foundation to become its own entity during the 2015 Elementary and Secondary Education rewrite debates.

In the same 2010 report, The Committee on Standards for K-12 Engineering Education provided several reasons as to why engineering had yet to create K-12 standards. The Committee stated that engineering education was strongly connected to science, mathematics, and technology. The standards for engineering education were the same as the standards for these subjects. Thus, engineering education did not need its own. Another rationale was that K-12 engineering was still in its infancy, making it difficult for engineering education to stand on its own (Committee on Standards for K–12 Engineering Education, 2010). However, engineering education was not without some guidelines. The Accreditation Board for Engineering and Technology (ABET) adopted Engineering Criteria (EC) 2000 in 1996.

The criteria that EC2000 and later amendments set were directed toward post-secondary education programs. This did not prevent K-12 educators from using the EC2000's criteria to create curriculum for the "E" in STEM. From 2010 to 2015, STEM education and professional development for each of these content areas experienced growth. The federal government's focused on creating integrated curriculum for STEM, and on recruiting highly qualified STEM teachers.

In order to practice the integration of STEM, educators fashioned curriculum by using the standards that the "National Council of Teachers of Mathematics' *Principles and Standards for School Mathematics* (2000) , the National Research Council's *National Science Education Standards* (1996) , *Standards for Technological Literacy* (2000), the Accreditation Board for Engineering and Technology's *Engineering Criteria 2000* (1997), and the *Common Core State Standards Initiative for Mathematics* (2011)" (Asunda, 2012, p. par. 18) had set forth.

The government debated STEM-specific standards, but had not yet set federal mandates. Though still on rocky ground, curriculum for STEM education was advancing. Teachers for STEM education, on the other hand, were in short supply, and many teachers were expected to retire over the next several years. These issues prompted the White House to run a campaign to recruit more STEM educators.

In 2011, President Obama set out to obtain 100,000 well-qualified mathematics and science teachers in ten years. The *100Kin10* was launched through the efforts of the Carnegie Corporation of New York and Opportunity Equation, to meet the President's goal. The *100Kin10*'s objective was to help train and retain STEM teachers by bringing together various sectors (i.e. federal, corporate, universities, and nonprofits). By August 2013, *100Kin10* had raised over $53 million, and was committed to training 40,000 teachers by 2016 (National Science Board, 2014). The debate over criteria and plans for reaching the President's goal and stalling ESEA's reauthorization made it necessary for President Obama to provide waivers for stipulations in the No Child Left Behind Act.

The NCLB included a deadline: all students needed to be proficient in math and reading by 2014. The waiver provided states with the flexibility to create their own plans for failing schools, as well as student-achievement goals (McNeil & Klein, 2011). The requirements for states to utilize the waiver included the creation of standards that focused on college and career readiness, and the development of teacher evaluations based on students' performance. The exchange over the flexibility of NCLB's mandates caused a shift in the theme of teacher professional development, from primarily content-focused to standards-based instruction emphasis. The National Survey of Science and Mathematics Education (2012) reported that 64 percent of science and 76 percent of mathematics teachers had participated in professional development directed toward states' science and mathematics standards (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013).

These findings countered those in 2000, when most science and mathematics teachers indicated that professional development was content-focused (Weiss, Banilower, McMahon, & Smith, 2001).

In 2015, after much debate and many amendments, the Elementary and Secondary Education Act was reauthorized as Every Student Succeeds Act (ESSA). The Nation's commitment to equal opportunity for all students was renewed. The ESSA included STEM education and professional development, but not to the extent proposed in the first drafts. It required the integration of engineering design skills and practices into the states' science assessments (§1201). In addition, states were expected to carry out programs that provided alternative routes for state certification, "especially for teachers of… science, technology, engineering, mathematics" (§2101).

The ESSA made states and local agencies responsible for developing and providing professional development for teachers to promote high-quality instruction in science, technology, engineer, ing, mathematics, and computer science (§2101, §2103). The ESSA allotted grants for STEM partnerships, which would replace the MSPs that were no longer receiving funding, and mandated that teachers with professional development instruction regarding the use of technology to enhance student achievement in STEM areas, including computer science (§4109). The ESSA used the acronym STEM to refer to science, technology, engineering, and mathematics which under the section, "well-rounded educational opportunities." The ESSA provided local education agencies with funds to create opportunities such as programs and activities for STEM (§4107). The ESSA contained a section for "STEM Master Teacher Corps," which were "State-led effort[s] to elevate the status of the science, technology, engineering, and mathematics teaching profession" (§2245). Another use of the acronym described what a "STEM-focused Specialty School" was:

> "a school, or dedicated program within a school that engages students in rigorous, relevant, and integrated learning experiences focused on science, technology, engineering, and mathematics, including computer science, which include authentic schoolwide research" (§4102).

The ESSA used the term, "integration" in conjunction with STEM, though it provided no further clarification on what this integration should have been for curriculum or standards development. Under the current federal educational policy – ESSA -- each subject (science, technology, engineering, and mathematics) has been addressed in some fashion. The policy still favors science and mathematics education, but it also tackles technology and engineering. In ESSA, the integration of STEM emerges, and professional development for STEM teachers is created or enhanced to include integration.

Discussion

The following discussion will identify any trends and issues in STEM education professional development policies

Trends

Based on the information stated above, it is obvious that professional development in STEM subjects (science, technology, engineering and mathematics) has varied widely in the past, but is progressing in similar ways in the present. In the past, professional development for STEM lacked structure, policy, and adequate curriculum materials and other resources. The emphasis on individual subjects such as science, technology, engineering and mathematics was high, and there was competition among these subjects for prominence and attention. This inspired individuals, groups, and organizations to create, offer, and participate in professional development depending on the STEM subject.

At the beginning of the twenty-first century, legislation impacted educational programs for students, as well as professional development workshops that science, technology, engineering, and mathematics teachers attended. The federal government passed several policies that had major ramifications for these subjects' curriculum, standards, and professional development. The "T" and "E" in STEM began to assert themselves and create their own identities, separate from mathematics and science.

The NCLB was a comprehensive bill that brought accountability to education and stressed the need for interactions between America's STEM businesses and STEM education. The America COMPETES Act placed heavy emphasis on STEM education and teacher recruitment for these subjects. Both the America COMPETES Act and the America COMPETES Reauthorization Act stipulated provisions to strengthen teaching and learning in the primary and secondary levels of STEM education. Both policies provided funding to the National Science Foundation for professional growth trainings, program and curriculum development, and standards geared toward the integration of science, technology, engineering, and mathematics.

President Obama's goal of 100,000 teachers for STEM is well on its way to being achieved. The 100Kin10 program has trained more than 40,000 STEM teachers, and has received tens of thousands of dollars to improve teachers' skills and provide support to help keep STEM educators in the classroom longer (100Kin10, 2016).

The ESSA has delivered a foundation for STEM education and its integration. The "T" in STEM has become stronger. Technology is an elective area in most states; over 28,000 men and women teach it (Dugger, 2016b). Technology education is now well-defined; and standards for the subject are in place.

The "E" in STEM is slowly progressing; some promising things are developing in the field. In Framework for Quality K-12 Engineering Education (2014) authors Moore, Glancy, Tank, Kersten, Smith, and Stohlmann proposed a clear definition for K-12 engineering education programs. These advances will help guide policy makers and educators in the creation of curriculum and standards for engineering, and in the integration of engineering in STEM (Moore, Glancy, Tank, Kersten, Smith, & Stohlmann, 2014).

STEM no longer places emphasis on science and/or mathematics alone. Each content area in the acronym is now addressed individually. In addition, the National Engineering Council and the National Research Council of the National Academies considers the integration of these subjects vital to the success of the nation's sustainability in innovation and foundation for successful employment. Even though the most recent federal educational policy – ESSA -- did not define STEM in terms of curriculum and standard-integration, it did contain provisions to form STEM-based programs and professional development models. STEM education continues to advance, and STEM educators will receive the training and support they need to help nurture the nation's aspiring scientists, technologists, engineers, and mathematicians: the future "STEMists."

Issues

As noted earlier, there is an expectation that teachers develop curriculum that aligns with standards and complies with NCLB's requirements. The NCLB's increased accountability mandates to states to create assessments in reading and mathematics opened up opportunities for professional development through Math Science Partnerships (No Child Left Behind, 2002). However, as Trivedi (2014) pointed out, a lack of adequate accountability measures continues to haunt professional development in STEM education. Considering the integrated nature of a set of distinct disciplines, establishing a set of unified assessments is not an easy task. Additionally, gender and socioeconomic achievement gaps, accessibility gaps, and poor teacher quality continue to add more challenges to STEM professional development.

Massimo (2015) and Hademenos (2017) observed similar issues, and suggested strategies -- such as revising structured, traditional, compartmentalized curriculum into integrated STEM curriculum, and developing suitable STEM teaching methods, as well as motivational learning activities and assessments – to overcoming these challenges. In context, teacher expertise is crucial. Considering the present state of the teaching force in science, technology, engineering and mathematics -- the limited teacher expertise and experience, especially in the elementary grades -- it is difficult for teachers to fully integrate these disciples into successful STEM lessons. On the other hand, forcing teachers at the secondary level with well-structured, discipline-based expertise to accommodate other disciplines in the name of STEM education is not without issues. As a case in point Kumar, Thomas, Morris, Tobias, Baker and Jermanovich (2011a, 2011b) noticed elementary teachers benefited significantly more than secondary teachers in a science professional development effort. This reflected the need for more science in elementary teacher development. University faculty from science, technology, engineering and mathematics could successfully partner with teachers to make STEM integration more meaningful in teacher professional development. See Kumar and Altschuld (2008) for an example of how such a partnership was behind a successful, NSF-funded teacher preparation project in science.

As Marder (2013) stated, though integrating science, technology, engineering and mathematics under STEM is a worthy undertaking, "we—the scientists, mathematicians, and engineers who will be asked to help implement the new standards—do not ourselves always possess the full set of skills that STEM education will ask of our students" (p. 150). Morever, in an overcrowded curriculum, pressuring teachers to find time for cross-disciplinary themes and activities in STEM is a complicated matter that needs carefully thought-out professional development efforts, regardless of elementary, middle or secondary level. Since school districts evaluate teacher performance, they must be involved in professional development so that teachers are not set up to fail -- asked to do one thing, and then evaluated on something else.

Limitation of appropriate contexts where multiple competencies from the STEM disciplines can overlap poses an obstacle to successful STEM implementation (Massimo, 2015). Not every concept cuts across science, technology, engineering and mathematics. This leaves teachers with the task of hunting for overlapping contexts, limiting successful implementation of STEM in schools.

When it comes to funding STEM professional development with public (e.g., NSF) and private funds, STEM education is not without its critics. For example, according to Zakaria (2015) "consider America's vast entertainment industry, built around stories, songs, design and creativity. All of this requires skills far beyond the offerings of a narrow STEM curriculum" (n.p.). There is no simple response to such criticisms. As Zakaria (2015) continued, "America overcomes its disadvantage — a less-technically-trained workforce — with other advantages such as creativity, critical thinking and an optimistic outlook.

A country like Japan, by contrast, can't do as much with its well-trained workers because it lacks many of the factors that produce continuous innovation" (n.p.). The STEM education community should take such criticisms into account, seriously reflecting on the advantages and disadvantages of STEM education. It should approach STEM professional development with caution, especially where public funds, such as systemic educational reforms, are involved. Program evaluation plays a key role in this.

As Anderson (2002) pointed out, "the nature of systemic reform is complex and no one evaluation study has sufficient resources and time to fully investigate the breath and depth of all the components of restructuring education systems. Systemic reform involves the simultaneous restructuring of many components of the education system in order to improve simultaneously the academic performance of all students at all levels of the K-12 system" (p. 72). STEM education professional development is a complex systemic reform. Therefore, more comprehensive evaluation (Kumar & Altschuld, 2002) and needs assessment ought to be employed to determine "what is (the current status or state) and "what should be (the desired status or state)" (Altschuld & Kumar, 2010, p. 3) and to guide effective policies leading to successful classroom practices in science, technology, engineering and mathematics.

Final Note

On a final note, it is extremely important that developers of STEM professional education policies build these policies on foundations of sound, evidence-based research. If not, "policymakers are often left with no choice but to base decisions affecting science [technology, engineering and mathematics] education on the face value of what are often not-so-well-informed research and development efforts, project findings of limited scope, and personal opinions of politicians" (Kumar & Altschuld, 2003, p. 561). Likewise, contributions from fields such as the Learning Sciences in improving our understanding of learning should not be overlooked in developing effective STEM professional development policies (Kumar, 2017). STEM professional development remains a fertile field for research and development in K-12 education in the United States, and developing policies that facilitate successful STEM professional development will be critical from here on out.

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