Growing Strong STEMs
Reflections of a Beginning Teacher's Preservice Program

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The decline in the number of Americans pursuing advanced degrees in science, technology, engineering, and mathematics (STEM)[1] fields is well documented (Darling-Hammond, 2010; President's Council of Advisor on Science and Technology, 2010). Two few American high school seniors perform at proficient levels in mathematics and science (U.S. Department of Education, 2014), preventing them from entering college in STEM areas of study. Yet, we know how to fix the problem. Darling-Hammond (2010) has said, "We cannot just bail ourselves out of this crisis. We must teach our way out" (p. 3), and this teaching must begin at the elementary level in order to prepare students to take advantage of later advanced study in STEM fields (American Association of Colleges for Teacher Education [AACTE], 2007; National Academies of Science, 2006; National Research Council [NRC], 2006). National and international assessments continue to illustrate that our country is not providing rigorous STEM preparation in K-12 schools.

Yet, there is not just a lack of proficiency in STEM-related subjects on international assessments but also a lack of interest, particularly with women and students of color (The President's Council of Advisors on Science and Technology, 2010). Both the STEM interest and achievement gaps in the U.S. make African American, Hispanic, Native American

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and female students underrepresented in STEM fields (The President's Council of Advisors on Science and Technology, 2010).

Some policies have attempted to enhance educational programs to ensure proficiency in mathematics and science, including No Child Left Behind and the Common Core State Standards (Hanushek, Peterson, & Woessmann, 2014). Due to the alarming statistics in international test scores in mathematics and science, President Obama also devised the "Educate to Innovate" initiative in which designates goals and resources to improve K-12 STEM and STEM in higher education (Washington, D.C., 2011). Further, many states have taken up the STEM call by creating STEM centers for learning in K-12 schools and higher education. Why is it so important? The strength of the American economy is inseparably connected to the strength of its education system (Washington, D.C., 2011). It is notably explained in the literature that capitalistic notions drive the emphasis on education or more specifically STEM education (Au, 2009). In order for students to compete in this global market, it is imperative that they possess the skills needed to do so. Yet, despite the attention, policies, and programs, progress in increasing America's STEM abilities and capacities has been slow.

It may be that exposure to STEM concepts and skills does not begin early enough. Indeed, most programs target middle school students and older. Given the high demand for STEM workers, and the projected growth of STEM fields (Washington, D.C., 2011), it is increasingly important to expose students to STEM education beginning as early as elementary school. Beginning in middle and high school may be too late. If students are not exposed to STEM related activities and instruction in their early elementary years, they may never have the opportunity to gain skills and interest that allow them to be successful later. If teachers are able to expose students to STEM related curriculum as early as elementary school, this exposure could potentially have the ability to spark a greater interest for math and science in students while also motivating them to continue to seek STEM-related opportunities.

Clearly, part of the problem is in teacher education. Some elementary programs are not preparing young children adequately for STEM content or skills, especially in the area of engineering (DiFrancesca, Lee & McIntyre, 2014). Thus, while there is a noticeable disconnect between interest in STEM careers and early exposure to STEM education (Drew, 2015), few studies have explored how preservice STEM programs impact students' motivation to pursue STEM careers. The purpose of this study is to examine one teacher's (the author of this article) preparation and classroom instruction, specifically on the teacher's ability to both integrate STEM curriculum into classroom instruction and exhibit STEM pedagogical specific knowledge in a classroom setting.

The remainder of this article has been divided into four sections. Section one will review the literature on engaged pedagogy, the theoretical grounding of the study and my classroom teaching. The second section will describe the method of data collection utilized in this study; retrospective critical reflection. Then, I analyze narrative excerpts from my perspective as a beginning teacher and critically reflect on my professional experiences in my preservice STEM preparation program. The last section will provide recommendations on qualities STEM preservice programs might consider adopting in an effort to increase their preservice teachers' effectiveness for promoting student interest and competence in STEM.

Pedagogy Matters

Effective educators not only know the content they teach, but know how to teach their content through the use of engaging lessons that require critical thinking in action (McEwan & Bull, 1991). As Hooks (2014) explains, engaged pedagogy is a way to make the learning process easier for our students. We should not look at teaching as a way to share information but to foster our students' intellectual curiosity. There has been a specific focus on how pedagogy can best be utilized in mathematics, science and other STEM related subjects. Hansen and Gonzalez (2104) describe fundamental characteristics of STEM teaching and learning; (1) Base lessons on project-based learning, (2) infuse technology into everyday learning, (3) span learning both inside and outside the scope of STEM disciplines, and (4) relate content to genuine and real-world applications. These four principles heighten engagement and can be linked to motivation and student achievement. Students who are engaged have proven to be successful in many aspects of school (Wang & Holcome, 2010).

If these principles of pedagogy were readily used, one would hypothesize that student achievement would increase in STEM subjects. According to *The Program for International Student Assessment* (2012), or PISA, students in the United States ranked below average in mathematics among the world's most-developed countries, and close to average in science and reading. The National Science Board's (NSB) national action plan for STEM restates these concerns:

> The United States possesses the most innovative, technologically capable economy in the world, and yet its science, technology, engineering, and mathematics (STEM) education system is failing to ensure that

> all American students receive the skills and knowledge required for success in the 21st century workforce. (NSB, 2007, p. 1)

According to Langdon et al. (2011), "In 2010, 7.6 million people or 1 in 18 workers held STEM jobs. Although STEM employment currently makes up only a small fraction of total U.S. employment, STEM employment grew rapidly from 2000 to 2010, increasing 7.9 percent" (p. 2). It has therefore been an increasing concern of educators and policymakers across the United States as to how to teach more students the skills needed to obtain jobs in STEM-related fields and infuse them with the interest and motivation to pursue such careers throughout their early schooling (Atkinson & Mayo, 2010). This is where elementary and secondary pre-service teacher STEM-programs can make a difference by preparing effective and knowledgeable STEM educators.

There are undergraduate STEM education programs for teachers in secondary and middle grades education, as well as a few focused on the preparation of elementary teachers. However, there is still a paucity of STEM education programs in elementary education. STEM education programs are popular when in graduate or doctoral programs, but it is important to expose teachers to STEM education in their undergraduate years, in order for beginning teachers to feel comfortable implementing STEM topics in their classrooms. Perhaps one reason so few STEM-focused elementary education programs exist is the lack of deep program descriptions other universities might use to develop their own programs. Thus below I provide a deep description from the perspective of a former teacher candidate and as a former teacher and alumni of the program. How can we, as educators, motivate students in the classroom to engage in STEM careers when we ourselves are not educated in best practices in STEM education?

Program Description

The STEM-focused elementary teacher preparation program I experienced as an undergraduate student and the goals of this program are described by DiFrancesca, Lee, & McIntyre (2014). This program that I was exposed to as an undergraduate not only consisted of the traditional preservice classes that would be vital to a teacher educator, but also contained an engineering design process methods class, two mathematics methods courses and two science methods courses (DiFrancesca, Lee & McIntyre 2014).

General Education Program for STEM Elementary Teachers

The program required 27 hours of STEM coursework[2] including

Calculus for Elementary Teachers, Conceptual Physics for Elementary Teachers, Materials in Engineering or Design Thinking and Biology, Chemistry and more.

Methodology Classes for STEM Elementary Teachers

The program required students to take two methods courses, each in mathematics and science. The focus was on grade-level content and methodology, and was divided into two semesters of learning, one semester in which the focus was grades K-2, and the other semester in which the focus was grades 3-5 (DiFrancesca, Lee & McIntyre 2014). In these methodology classes the focus was on pedagogy. The coursework also included a strong literacy foundation that includes two courses focusing on reading and one on language arts, engineering methods focused on children's designs and inventions, courses in diversity, special education, and arts, social studies, and two courses that integrate STEM with other curricula as teachers plan lessons and units.

Clinical Observation Hours/Student Teaching

Field placements were an important part of pre-service teachers' training in this particular program, beginning sophomore year and becoming more rigorous throughout the length of the program. For example, during sophomore year an undergraduate student is required to observe the classroom they are assigned to a few times a year. The junior year was carefully planned so that candidates observed excellent mathematics and science instruction. Candidates are required to visit the classrooms for four weeks twice during the semester, and were required to teach lessons for each of their methods courses. During senior year, candidates spend the entire year in the same classroom with fall term consisting of occasional teaching lessons and spring term full-time teaching of a class for 12-15 weeks, while the other weeks are spent teaching specific subject areas or observing.

Reflecting on Goals of the Program

There were explicit goals that were outlined for this particular STEM Prep Program (DiFrancesca, Lee & McIntyre 2014). The three primary goals of the program consisted of, first, designing the program to assist preservice teachers in linking mathematics methodology and science methodology with engineering design. Second, this program targets STEM integration in mathematics and science lessons. Third, the STEM Prep Program aims to improve preservice teachers' attitudes towards STEM and their willingness to expose their future students to STEM (DiFrancesca, Lee & McIntyre, 2014).

Since taking on the role of an educator in my own classroom, I have discovered how important the four underlying principles of STEM teaching can be as addressed by Hansen and Gonzalez (2014) in STEM Learning Principles and Student Achievement. Reflecting from my experiences as a beginning teacher has naturally led to reflection on how prepared I felt graduating from my STEM-focused Elementary Program. Throughout my stories I will intertwine my experiences with my reflection on my preservice education program.

Methodology

In this study, a form of retrospective critical analysis is used to present my findings. I critically analyze what I have learned throughout my beginning teaching experience and relate it to my past, recent experience in my STEM Prep Program. By analyzing the needs of a beginning teacher implementing integrated STEM experiences coupled with active learning, and reflecting on what I was able to gain from my STEM Prep Program, I was able to identify potential solutions to gaps in STEM preservice education and provide recommendations for addressing these gaps.

The STEM Prep Program: Creating Links from Methodologies to Engineering

One of the primary goals of the STEM preparation program was to link methodologies and practices to engineering design (DiFrancesca, Lee, & McIntyre, 2014). The engineering design process enables students to use their knowledge across curriculums to solve problems (DiFrancesca, Lee, & McIntyre, 2014). As part of our engineering design methods course, we learned how to plan our lessons using the Elementary is Engineering (EIE) design process. The EIE design process consists of five ongoing steps as Ask, Imagine, Plan, Create and Improve (Cunningham & Hester, 2007).

As an undergraduate student, I was exposed to an engineering design class in the STEM preparation program. "The course emphasizes the relationship among science, technology, engineering, and mathematics by engaging students in analyses of educational standards in these fields and the creation of integrated, standards-based learning activities" (DiFrancesca, Lee, & McIntyre, 2014, p. 54). This engineering design methods course allowed us to experience STEM-focused projects and lessons with certain curriculums in mind.

For example, in a STEM project focused on creating space crafts to fly a certain distance, my students had to use the EIE process. They were given a list of parameters and through trial and error, had to decide on the best materials to use that would be the most efficient to fly their aircraft but had to stay within the cost parameters of the project. This is where the “Ask” of the EIE process was developed. After students asked themselves what materials they thought would best be suited for the task, they engaged in trial and error process to “Imagine” or envision what materials could complete the job using the parameters. Then they made a “Plan” on how this could be done. How many sheets of materials did they need? What would be the cost? Did they have enough money? What about the number of launches? Each launch was tied to a certain gas price based on the materials used. If they used more than one material, they had to average the gas prices of the materials together. After having a set plan, they students then built the rockets or “Created” their plans. They then had to create linear equations for their rockets and compared their cost and efficiency to other groups. This is where the “Reflect” was relevant. After viewing other groups rockets, materials used, cost and equations, they then had to reflect on how they could make the launch more efficient as well as less costly.

The STEM Prep Program:
Project-Based Instruction and Practice of Integrating Subjects

As a beginning teacher I was motivated to create my first STEM project and to engage my students in active learning. Active learning is defined as any instructional approach that requires students to engage in the learning process, commonly referred to as an instructional activity coupled with reflection (Prince, 2004). I attribute this interest to my experience in a STEM-focused Elementary Education program. I had a plethora of ideas swirling in my head as to how to incorporate the Common Core standards in Geometry into a thoughtful STEM project. As I sat down at my desk one day after school, to begin the planning of my STEM project, I came to my most profound realization as a beginning teacher; “Do I really know how to implement my curriculum within STEM-focused projects?” The answer, unfortunately, was no. What I quickly learned through being a beginning teacher is that the idea of integrating Science, Technology, Engineering and Mathematics was more complex than what I had experienced in my teacher program. As a beginning teacher the lack of authentic STEM experiences1 discouraged me from implementing STEM projects in my first year of teaching—not because of my lack of interest, but because I did not know where to start. As a new teacher, I felt as though I had more important issues to focus on such as IEP paperwork, communicating with parents, enforcing classroom management, and learning my new grade-level curriculum.

The idea of implementing a STEM project or STEM learning experiences based upon my curriculum felt overwhelming. Even though I had an abundance of mathematics and science methodology classes my junior and senior years as an undergraduate, as well as an engineering design methods class, I was not able to design integrated STEM lessons and experience active learning in an actual classroom setting. Teaching is an art, and what better way to practice my craft than through authentic experiences where I was able to test our theories, make triumphs or poor decisions, and reflect upon them.

Preservice teachers need experience with designing, implementing, testing, reflecting and revising their STEM-based projects and theories utilizing authentic work spaces such as the K-12 classroom or STEM camps. Teachers should use the same engineering process, Elementary is Engineering (Cunningham & Hester, 2007), in the planning of integrated lessons and STEM projects in their preservice education, as their future students will use in solving problems. Lecture and planning within class should be coupled with immersing pre-service teaching and experiences outside of the classroom, well before a preservice teacher's senior year. Without these experiences the attitudes of preservice teachers will not change and K-12 students will not be exposed to STEM-related curriculum due to the fact that preservice teachers will not be confident and comfortable with implementing such projects.

The STEM Prep Program: Practice of Reflective Thinking

As I became more comfortable with procedures and policies in my school as well as my curriculum, STEM-based projects became a priority and I started to research different STEM projects that could be implemented through my curriculum. I may not have had the motivation to do STEM-based projects if it had not been for my experience in a STEM Prep Program where my curiosity and interest in STEM infused lessons was heightened. Preparation for my first STEM project was a lengthier process than I had expected. Since it was not something that I had practiced and had experience with implementing in a K-12 setting continuously, it was not an aspect of teaching that I was confident with. I have learned through implementation of STEM projects with students is that it is a learning process; not just for your students but for you as well. Reflective thinking is often lost in translation in the teaching profession; however, reflection is what makes a beginning teacher a more confident and effective teacher. Reflective thinking relies on the idea to think abstractly and is not an innate ability but rather a skill that becomes refined with practice (Fischer & Pruyne, 2003). Without an abundance of authentic STEM experiences in the preservice STEM education program, reflection was minimal.

Discussion

The Qualities of Effective STEM Educators

From my reflection and experiences as a beginning teacher, as well as graduating from a STEM-focused program, I have compiled a list of qualities that I believe create an experienced and thoughtful STEM educator. Infusing these qualities into STEM-focused preservice programs will allow preservice teachers to embody a STEM-focused curriculum when implementing projects and lessons in their classrooms.

Understanding Content and Pedagogy

There have been an increasing number of policymakers and politicians across the country that have argued that individuals in the classroom would be better equipped to teach STEM-related fields if they major in a content or STEM area; not necessarily education (Ball & Bass, 2000). For example, the Obama administration has argued that taking professionals in STEM related fields and introducing these individuals to the classroom would allow for students to acquire authentic STEM experiences (Washington, D.C., 2011). It is important for teachers to understand subject-specific content, but that is not all they need to understand; they need to know how to teach, what types of questions to ask, and be equipped to teach in diverse settings to a variety of learners using a variety of methods (Ball & Bass, 2000). This is why pedagogy matters. I have taught with lateral entry teachers who were brilliant in their field of study. However, after explaining a lesson they became dumbfounded when their students did not truly understand the concept. Due to their lack of pedagogical training, they did not know how to counteract the confusion. For example, research shows that in mathematics, there is a clear difference between knowing what to teach, and understanding how to teach it (Ball & Bass, 2000). I find this to be true in all fields of education. It is important for individuals to not only be exposed to their content but the pedagogy associated with their content; which is learned through a background in education. Therefore, it is a key component to any STEM-focused preservice education program, to have STEM-related content coupled with pedagogy.

Authentic STEM Experiences to Practice Craft

Authentic STEM experiences in which preservice teachers have the opportunity to plan and implement their own projects with a group of students is vital to the success of beginning teachers. I have talked a great deal about the importance of pedagogy throughout this article and how the STEM Prep Program enhanced my skill to teach a diverse group of students and a variety of learners using an assortment of methods. However, it is also important for preservice teachers to understand the content that they are teaching. Most preservice education programs accomplish this through the use of strict content courses. Coming from an Elementary Education STEM-focused program, content was not the center of discussion. However, for secondary teachers it is important for preservice education programs to heighten their content ability as well. What better way to do this then provide preservice teachers with the ability and means to create authentic STEM experiences for students? Through the use of STEM projects, teachers will understand and learn their content. I am not suggesting that content is not a large part of what makes a great teacher, however, preservice educators would benefit from being able to learn the content and apply that content to the design and implementation of STEM projects that they could continuously reflect upon.

In the STEM Prep Program, EIE (Cunningham & Hester, 2007) was the basis for our engineering design methods class. As described in previous sections EIE consists of 5 constant steps; Ask, Imagine, Plan, Create and Improve (Cunningham & Hester, 2007). Not only are these engineering design methods imperative for preservice teachers to know in order to replicate them in the classroom, they are also imperative for preservice teachers to use themselves. Continuous planning, creating and implementing of STEM projects with students would provide feedback that is much needed for STEM preservice teachers. This feedback would allow students to reflect and improve upon their STEM integrated lessons, and, in turn, create more powerful, insightful lessons in the future. Being able to use a set of curricula across subject matters, and infuse it into a STEM project that students would enjoy as well as learn from, is a tedious task. It is perfected with practice. Without the abundance of genuine STEM experiences in preservice education, it is difficult for teachers to be prepared to perform these tasks as beginning teachers in their own classroom.

Reflective Thinking

The largest underrated component to most professions, especially the teaching profession, is reflective thinking. Without reflective thinking, it is impossible to become a more effective and seasoned teacher. For example, after teaching a mathematics lesson if you do not think about the pros and cons to the lesson, what went well and what did not, what reason would you have for changing the lesson? Change does not come first without reflection and as teachers we are often not given the time or practice to reflect. Infusing the habit of reflection into preservice education is essential for all preservice programs, not just STEM-focused programs. This habit is a quality that all great teachers possess; allowing continuous reflection will force teachers to become experts at their craft.

Reflections STEM-ing from Experiences

Not only has the STEM Prep Program made me an effective classroom teacher, but it has allowed me to teach beyond the scope of my preservice education. As a senior first experiencing Elementary Education in my field work, I realized that I was specifically interested in teaching math, and therefore finished my field work in a 5th grade mathematics classroom. From there, I received a job as an 8th grade mathematics teacher, and have been teaching a combination of Common Core Math 8, Math I and Math II since. As I compare my knowledge to those of my colleagues in the workforce, I have realized that the way I explain concepts and teach is much different than that of my counterparts. It is a not a discredit to secondary teachers, but simply a realization through professional development and discussing content and lessons with my colleagues, that pedagogy was not always a "hot topic" in secondary preservice education. It has made me thankful that I was able to obtain this level of pedagogical knowledge through my Elementary Education STEM preservice program.

Intertwining the engineering design process with mathematics and science practices is a skill that I felt as though I needed more practice with as a beginning teacher. There is no such thing as "too much" exposure to the students, or authentic teaching experiences as an undergraduate. For example, it is helpful to craft STEM projects using the engineering design process as well as science and mathematics practices, give your project to your professor and fellow students for feedback, but then what? In my opinion, it is crucial to then take this "finished" STEM project and implement it in the field. Why? Because feedback is critical from already practicing teachers as well as the students. It is important to reflect as a preservice teacher, but you cannot reflect without something to think about. In my efforts to reflect on my experience as a beginning teacher educated through a STEM Prep Program, my goal is to not talk negatively about the STEM Prep Program I went through, but as an educator in today's classrooms, reflect on what helped me in this particular STEM Prep Program and topics I needed additional support with.

Conclusion

There is an obvious need for strong STEM preservice teacher programs. The criticism of teachers entering the classroom without a willingness to intertwine STEM-focused projects and learning into their curriculum is not entirely the burden of the beginning teacher. Without preservice education on how to implement STEM-focused projects with a given set of curriculum, educators will not be comfortable with STEM education and will be less willing for it to be a key instructional piece in their classrooms. Without fixing the root of the problem beginning teachers will not be able to branch out and implement STEM-focused curriculum, hindering the United States' ability to grown strong STEMs.

Notes

[1] Authentic STEM experiences are defined as interactions involving STEM experiences where the students' diverse learning needs are met, outside the typical teacher-students setting (i.e., project based learning) (Watagodakumbura, 2013).

[2] This information was found on the STEM Prep Program's website. In order to preserve the integrity of this particular University's program, they will remain anonymous in this article, and the pseudonym STEM Prep Program will be used.

References

American Association of Colleges for Teacher Education. (2007). *Preparing STEM teachers: The key to global competitiveness. Selected profiles of teacher preparation programs*. Washington, DC: Author.

Association for Career and Technical Education. (2010). *Up to the challenge: The role of career and technical education and 21st century skills in college and career readiness*. Alexandria, VA: Author. Retrieved from: http://www.p21.org/storage/documents/CTE_Oct2010.pdf

Atkinson, R. D., & Mayo, M. J. (2010). *Refueling the US innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education*. The Information Technology & Innovation Foundation, Forthcoming.

Au, W. (2010). *Unequal by design: High-stakes testing and the standardization of inequality*. New York, NY: Routledge.

Ball, D. L., & Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), *Multiple perspectives on the teaching and learning of mathematics* (pp, 83-104). Retrieved from http://www-personal.umich.edu/~dball/chapters/BallBassInterweavingContent.pdf

Bybee, R. W. (2010). What is STEM education? *Science, 329*(5995), 996-996.

Cunningham, C. M., & Hester, K. (2007). *Engineering is elementary: An engineer-*

ing and technology curriculum for children. Paper presented at the ASEE Annual Conference and Exposition, Honolulu, HI.

Darling-Hammond, L. (2010). *The flat world and education: How America's commitment to equity will determine our future*. New York, NY: Teachers College Press.

DiFrancesca, D., Lee, C., & McIntyre, E. (2014). Where is the" E" in STEM for young children? Engineering design education in an elementary teacher preparation program. *Issues in Teacher Education, 23*(1), 49.

Drew, D. E. (2015). *STEM the tide: Reforming science, technology, engineering, and math education in America*. Baltimore, MD: Johns Hopkins University Press.

Fischer, K. W., & Pruyne, E. (2003). Reflective thinking in adulthood. In *Handbook of adult development* (pp. 169-198). New York, NY: Springer.

Hansen, M., & Gonzalez, T. (2014). Investigating the relationship between STEM learning principles and student achievement in math and science. *American Journal of Education, 120*(2), 139-171.

Hanushek, E. A., Peterson, P. E., & Woessmann, L.(2014). *Not just the problems of other people's children*. Cambridge, MA: Harvard University Kennedy School.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: American Association of University Women.

Hooks, B. (2014). *Teaching to transgress*. New York, NY: Routledge.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). STEM: Good jobs now and for the future. *ESA Issue Brief# 03-11*. Washington, DC: U.S. Department of Commerce.

McEwan, H., & Bull, B. (1991). The pedagogic nature of subject matter knowledge. *American Educational Research Journal, 28*(2), 316-334.

McIntyre, E., Walkowiak, T., Thomson, M., Carrier, S., Lee, C., Greive, E., DiFrancesca, D. (2013). A STEM-focused elementary teacher preparation program: Candidate and alumni perceptions. *Teacher Education and Practice, 26*(4), 670-687.

National Academies of Science (2006). Rising above the gathering storm: energizing and employing America for a brighter economic future. Washington, DC: Author.

National Center for Education Statistics. (2012). *Program for international assessment*. Washington, DC: Institute of Education Sciences, U.S. Department of Education.

National Research Council. (1996). *National science education standards*. Washington, DC: The National Academies Press.

National Research Council (US). Committee on highly successful schools or programs for K-12 STEM education. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.

National Science Board. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system*, NSB-070114. Retrieved from http://www.nsf.gov/nsb/edu_com/

draft_stem_report.pdf
Pollard, A. (ed.) (2010) *Professionalism and Pedagogy: A contemporary opportunity. A Commentary by TLRP and GTCE*. London, UK: TLRP.
Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223-232.
Sanders, M. E. (2009). Stem, STEM education, stemmania. *The Technoology Teacher*, 20-27.
Sanders, M. E. (2013). *Integrative STEM education defined*. Blacksburg, VA: Virginia Tech University.
Southall, M. K. (1959). How do children learn? *Childhood Education, 36*(4), 151-152.
Teitelbaum, M. S. (2014). *Falling behind?: Boom, bust, and the global race for scientific talent*. Princeton, NJ: Princeton University Press.
The President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering and math (STEM) for America's future* (prepublication version). Washington, DC: Author.
U.S. Department of Education. (2014). *Science, technology, engineering, and math: Education for global leadership*. Retrieved from http://www.oecd.org/pisa/keyfindings/PISA-2012-results-US.pdf.
Wang, M. T., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal, 47*(3), 633-662.
Wang, X. (2013). Why students choose STEM majors motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, 0002831213488622.
Washington, D.C. (2011). *Educate to innovate*. Accessed June 2015.
Watagodakumbura, C. (2013). The need for a deeper perspective of education to make way for an authentic learning experience. *Journal of Education and Learning, 2*(4), 31.