Global Perspectives on STEM Education

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Introduction

This literature review is intended to examine the global perspectives on Science, Technology, Engineering, and Mathematics (STEM) education. In the United States, education has seen recent emphasis on STEM with a push to prepare students for a plethora of future jobs in these fields. While some studies have shown the United States to be falling behind other countries in STEM, another interpretation is that other countries have caught up to the U.S. or surpassed its long-time lead (Ossola, 2014). There are many facets to this focus on STEM, including global comparisons with regards to pedagogy and curricula in both K-12 and higher education, women and minorities in STEM, and the future reality of the labor markets in these fields.

What is STEM education?

Tsupros (2009) provides a definition of STEM (as cited by Gerlach, 2012) stating:

> ...an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy.

The Graduate Research Fellowship Program (2012) of the National Science Foundation (NSF) provides a more specific definition by outlining the disciplines that fall under STEM. These include: chemistry, computer and information science and engineering, engineering, geosciences, life sciences, materials research, mathematical sciences, physics and astronomy, psychology, social sciences, and STEM education and learning research.

The term “STEM” is believed to have been first coined in 2001 by Judith Ramaley, Assistant Director for Education and Human Resources at the National Science Foundation (Ossola, 2014). Originally termed “SMET”, the format “STEM” was a more popular and pleasing way to order the acronym. Much earlier, there was an initial movement in STEM which occurred during the time of the Space Race, in the late 1950’s. Due to the competitive spirit of the United States, and a push from President Eisenhower, the country emerged as a leader in technology and engineering (Woodruff, 2013). The U.S. feared falling behind, but after years of education reforms and standards implementation, the U.S. now “struggles to maintain an edge” according to Woodruff (2013). The philosophy of STEM education began to take off in 2008 and was reinforced in 2009 during President Obama’s State of the Union Address which placed importance on the country’s “commitment to scientific research and innovation” (Heitin, 2015; Woodruff, 2013). President Obama made reference to the Space Race in his speech and encouraged the country to exceed what was achieved at that time.

Currently, the United States is seeing a new education reform with the implementation of the Next Generation Science Standards (NGSS) and the Common Core State Standards (CCSS). According to Woodruff (2013), both the NGSS and CCSS place emphasis on integrating STEM subject areas and evidence-based reasoning. Additionally, engineering is afforded the spotlight in the new NGSS standards. In my personal experience as a science educator, science courses in the past have mainly been taught as a separate entity. With the need to meet previous state standards and high-stakes testing in New York, teachers have felt a need to teach to the test. Teachers also often feel rushed to complete the curriculum in time. Hopefully, the NGSS will provide the opportunity for educators to truly integrate the different fields of STEM. With engineering a central focus, the NGSS will encourage teachers to incorporate engineering ideals into their Biology or Algebra curriculum.

The need for STEM

The U.S. Department of Education ("Science, Technology, Engineering and Math: Education for Global Leadership," n.d.) has projected that there will be significant percentage increases in STEM careers between the years 2010 and 2020. While all occupations could see a 14% increase, STEM-specific jobs could increase between 16 and 36% and as much as 62%, as projected specifically with Biomedical Engineering. Though there are projected to be plenty of future STEM jobs, only 16% of American high school seniors have shown to be proficient in math and actually plan to pursue a STEM career. Even of those who do major in STEM subjects, only half end up working in a related career.

The U.S. News/Raytheon STEM Index (2016) has recently shown an increase in STEM degrees, but still a shortage of STEM workers. From 2014-2015, there were 30,835 additional STEM graduates and 230,246 additional STEM jobs. U.S. News editor and chief content officer, Brian Kelly stated that "our universities are producing more STEM graduates", but "many of the students are foreigners on temporary visas." What this ultimately means is that the U.S. is still not creating the STEM workforce needed to fill future STEM-related jobs.

The U.S. has a clear need for its people to pursue STEM careers, but other countries may be feeling the same pressure. The European Union (EU), predicts a large demand for STEM-skilled labor as many current STEM workers are reaching retirement age according to the Directorate General for Internal Policies (Caprile, Palmen, Sanz & Dente, 2015). In a comparison study from 2006 to 2011, the Rising STEMs publication from the European Centre for the Development of Vocational Training (2014) showed that there has been a general decline of STEM graduates. In order to fill the void, some countries seek outside workers. Katsomitros of The Observatory on Borderless Higher Education (2013) showed that for the EU, in particular, finding workers could be an issue with only 3% of scientists in the EU coming from non-EU countries. Stricter immigration laws play a large role in letting in outside talent.

China, on the other hand, has shown a significant increase in the output of STEM graduates than any other country ("Science & Engineering Indicators," 2016). In 2011, the Accenture Institute for High Performance (as cited by Katsomitros, 2013) reported that 41% of all degrees awarded in China were in STEM fields. This is a big difference to the United States' measly 13 percent. Since the economic crisis of 2008, China made a commitment to restructure its economy by shifting the focus from an export-oriented model to one that is domestically driven (Katsomitros, 2013). China has put much effort into innovation being the second largest research and development investor in the world.

The Middle East and North Africa (MENA) region also has its set of STEM concerns. According to The World Bank in 2008 p. 22 (as cited by Arnove, Torres & Franz, 2013), 70% of students in many MENA countries graduate with degrees in the humanities and social science, while only 22.6% of MENA students pursue STEM in college (Ezzine, 2009 as cited by Arnove, Torres & Franz, 2013). While other nations in the MENA region have lower numbers of students seeking and obtaining STEM degrees and an overall lower quality of scientific research and education, Iran and Turkey have made significant gains, especially in the area of engineering.

In general, the rest of the world is catching up to those countries who do well in STEM disciplines. This is one of the reasons we see the U.S. appear to be lagging. In a blog post written by May (2013), she provides an overview of Andreas Schleicher's TED Talk. In his talk, he discusses how, according to the scores from PISA (the Programme for International Student Assessment), we see not a decline in the educational performance of the U.S., but rather an increase in the levels of education in other countries. In the 1960's the U.S. was the world leader of high school graduates, but by the 1990's, the United States became 13th in the world ranking. Many other countries had raised their educational standards. One such country was Korea, that went from 27th to number one.

STEM Education

Education in both K-12 and higher education environments have responded to the push for STEM education. This has happened both in the United States and abroad since many countries are seeing STEM workforce shortages. In order to prepare students to be successful in STEM disciplines, there is consensus that better preparation and training of teachers is also needed ("Science, Technology, Engineering and Math: Education for Global Leadership," n.d.; Corlu, Capraro & Capraro, 2014).

K-12 STEM Education

In response to the need for and improvement of STEM education, in the U.S., new K-12 education standards have recently emerged that will support this pedagogy. The NGSS was constructed with collaborative help from the American Association for the Advancement of Science (AAAS), National Academy of Sciences, and National Science Teachers Association, the National Academy of Engineering, and the Achieve organization (Sanders, 2012). The NGSS takes an integrative approach by working to fully merging engineering and technology with the existing structure of science education. The NGSS is not asking for there to be standalone engineering and technology classes, but that these ideals be incorporated into existing science and math education. In addition to the integrative nature of the new standards, much emphasis is being placed on students' abilities to problem-solve, engage in practice- and inquiry-based learning, and, in general, improve their overall scientific literacy. Even though there is a need for STEM workers and new standards, some states still don't put an emphasis on encouraging or requiring students to engage in STEM. For example, New York State currently only requires three years of science in high school, as opposed to four years each of English and Social Studies (Regents Requirements, n.d.). A change to show how truly important STEM is should be on both a state and federal level.

In its effort to become a candidate country for EU membership, Turkey is currently experiencing education reform with one purpose being the improvement of their STEM education (Corlu et al., 2014). Successful testing decides where students attend school, and only the ablest attend elite upper secondary and higher education schools according to the Turkish Education Association (2008, 2010 as cited by Corlu et al., 2014). Only students funneled into specialized schools end up accessing quality STEM education. In a study by Baran, Bilici, Mesutoglu & Ocak (2015) use a model to provide STEM education to disadvantaged students. Students part of this study engaged in an out-of-school STEM education program and participated in activities like Egg-drop, creating a scaled model of the solar system, inventing mobile apps, designing a wind turbine, and others. Ultimately, these STEM programs are ensuring student access to "hands-on, collaborative, design-based, and inquiry oriented" activities that can improve their ability to problem-solve (Baran et al., 2015).

A comparative study by Swain, Monk & Johnson (2010) looked at science education in Egypt, Korea, and the UK. Conditions in which the secondary science educators work was discussed and found to be vastly different. Egyptian teachers had few to no resources, using primarily a standard curriculum and textbook. Both students and teachers in this country do not get to actually experience the phenomena taught. The Egyptian science curriculum is taught to large classes with little opportunity for practical and hands-on experiences. Korean teachers actually had access to well-resourced laboratories and teach a standard curriculum that includes inquiry, student-centered activities, and practical work. In the UK, science teachers have well-equipped schools and laboratories and practical activities make up a large portion of class time. While teachers from all three countries aim for practical work, their work conditions can hinder the achievement of these goals. To see how countries truly stack up comparatively with regard to their education, international test scores can provide a ranking of participating countries. PISA includes mathematics, reading, and science. The 2012 report from the Organisation for Economic Co-operation and Development (OECD) on the PISA results show that both Korea and the UK are above the OECD average, while the United States and Turkey are below the average (UNITED STATES - Country Note - Results from PISA, 2012). Egypt did not participate in PISA.

STEM in Higher Education

Colleges and universities worldwide have also been impacted by the STEM movement. The most recent report on Science & Engineering Indicators from the National Science Board in 2016 shows an overall increasing trend with regard to the number of STEM degrees awarded from U.S. higher education institutions. Institutions have been charged with the need to increase the "number, diversity, and quality of STEM graduates" according to the American Society for Engineering Education (2009, 2012 as cited by Borrego & Henderson, 2014). At research universities, Anderson et al. (2011) suggest initiatives to encourage "science faculty to be equally committed to their teaching and research missions." The researchers believe institutions should reward, recognize, and support their faculty who are excellent teachers in addition to researchers. One major direction in postsecondary STEM education is to include greater interdisciplinarity (Atkinson & Mayo, 2010). Because many work environments are actually considered interdisciplinary or multidisciplinary, the academic systems should take this into consideration.

A study in Taiwan by Tseng, Chang, Lou & Chen (2013) looked at how project-based learning (PjBL) influenced the attitudes of engineering students towards STEM. Taiwanese college freshmen engaged in a PjBL activity and gave positive feedback, noting that scientific expertise would be useful in their daily lives and that their response to engineering was higher than the other STEM subjects. Students in the study suggested that engineering skills and knowledge were the most useful and practical of the four STEM disciplines.

In many countries, there is an overarching government agenda to support satisfying a demand for labor. In order to achieve this, countries are investing heavily in STEM, and quite a significant amount of support is going to higher education institutions. According to the ICEF Monitor ("Demand for STEM programming," 2012), the King Abdullah Scholarship Programme in Saudi Arabia pays for 125,000 students to pursue undergraduate and graduate degrees in primarily STEM-related disciplines. Peru, too, is investing millions of dollars to create thousands of new science and technology postgraduate fellowships and scholarships.

Women in STEM

In shifts towards better STEM education and preparing students for the STEM workforce, a common theme seen in many countries is the challenge of encouraging females in STEM disciplines. According to Modi, Schoenberg & Salmond (2012), young girls tend to lose interest in science and math during their middle school and high school years. In general, interest in STEM subjects is low for girls in comparison to that of boys. One possible theory is the impact of the portrayal and representation of females in these fields, which can prevent girls and women from entering them. This may account for the fact that even though women fill almost half of all jobs in the U.S., less than 25% of STEM jobs are actually filled by women (Beede et al., 2011). Modi et al. found that, more recently, girls expressed that they are interested in STEM, but it may not be a top choice for a career. The perception that STEM careers are not typical for females, that girls do not like the idea of being the only one of their gender in a STEM-related course, and knowing that they may have to work harder in a STEM career than men are additional barriers associated with female interest and involvement in STEM. A report by Hill, Corbett & St. Rose (2010) provides several recommendations to combat the problem of few women entering and staying in the STEM workforce. Suggestions include cultivating girls achievement and interest in STEM disciplines, creating college environments that support females in STEM, and counteracting bias.

Other countries also see similar issues. In a report by Marginson, Tytler, Freeman & Roberts (2013), they found that a "consistent and broader policy setting is needed" in order to encourage women's participation in STEM. France's National Ministry of Education focused on guiding young females towards STEM fields through enacting equality legislation. This encouraged the diversification of the career choices made by girls. In Canada, however, federal policy has not focused on the underrepresentation of women in STEM. Due to this, the country has not seen much improvement in this area. In some countries in Asia, like Cambodia, young women still have trouble accessing higher education (Salmon, 2015). Countries like Malaysia, Mongolia, and the Republic of Korea do see female enrollment in STEM disciplines, but they still remain the minority. While this particular report provides an overview of the situation at hand in Asia, it does not mention how to overcome this global issue of gender gap in STEM, except that women "must be ensured the equal opportunity to learn in all areas, including STEM."

Critiques on the focus of STEM

The push for STEM education has created both challenges and opportunities. While there is evidence that there will be a global need for STEM workers, others feel that this is a myth. Charette (2013) argues that there are reports suggesting supply and demand issues with more students graduating with STEM degrees and experience than there are jobs. A 2012 study by Costa found that in the U.S. wages for employees in computer and math fields have stagnated since the year 2000.

Zakaria (2015), warns that focusing too much on STEM could mean less emphasis on broad-based learning and liberal arts. He also points out that if the U.S. tries to mimic the education styles of Asia, which, for years, have been oriented around memorization and testing, we will lose some of our strengths-- creative and critical thinking and problem solving. An article by Ossola (2014) also supports the idea that "if students spend more time on math then they're spending less time on something else."

Even within the realm of STEM itself, there are concerns that emphasis on one field will supplant the other. Evans (2016), the NSTA Executive Director, shares that California Governor, Jerry Brown, signed into law that computer science will be required in every grade in the state's public schools. Evans disagrees with this new law, as well as states who allow computer science to count as a math or science course. The suggestion is that schools should teach computer science basics through regular K-8 courses and offer computer science electives in high school. Evans cites the United States' poor scores on assessments like Trends in International Mathematics and Science Study (TIMSS) and PISA.

Conclusion

A recent focus on STEM education is evident throughout the world. With an expected dearth of STEM workers in the near future, both K-12 and higher education are paying attention to and making changes to include more and increase the quality of STEM education. Many countries have also become conscious that there is a problem with women engaging in and entering STEM fields. Ultimately, there is more of an argument for the emphasis on STEM education than not. If implemented with an interdisciplinary approach, learners will experience and use inquiry, problem solving, creativity, and critical thinking. These are skills that everyone can benefit from at all stages of schooling and beyond.

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