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Strategic Future Directions for Developing STEM Education in Higher Education in Egypt as a Driver of Innovation Economy

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Abstract
STEM (Science, Technology, Engineering and Mathematics) education has been achieving growing international attention. As the world economy is becoming more diversified and dependent on innovation, Science, Technology, Engineering, and Math (STEM) skills and expertise are progressively more needed for competition and development. Egyptian students are less competitive with other countries in STEM fields. With this new movement in education to focus more on STEM, Egyptian policymakers need to develop strategic future directions for developing STEM education in higher education in Egypt as a driver of innovation economy. The main objective of this paper is to propose strategic future directions for developing STEM education in higher education in Egypt as a driver of innovation economy, to achieve this objective the paper starts by outlining historical perspective regarding the roots of STEM education, and then followed up with the attempt to conceptualize and define the basic terms of the paper. It then outlined the features of STEM education as a national priority, since it is a driver of innovation economy. The contemporary current status of STEM education efforts in Egypt was analyzed by utilizing SWOT analysis. Finally, strategic future directions for developing STEM education in higher education in Egypt were proposed.
Keywords: STEM education, Innovation Economy.

1. Introduction

Science, Technology, Engineering and Mathematics (STEM) Education has become an international issue of consideration over the past decade. This is stimulated by the dynamic global economy and workforce needs that demonstrate there will be a lack of STEM qualified workers and educators around the world.

As the world moving with unprecedented speed into a high-tech future of the globalized, technology-driven age there is intense concentration on the importance of (STEM) education and how it impacts on a nation's growth and ability to have a skilled and educated manpower to drive their nation forward with economic expansion. Many see the education of current generations in the areas of STEM, as the key to shifting the world's population towards having a greater understanding of the importance of achieving economic growth, environmental conservation and sustainable development (Langdon, et al., 2011).

Institutions of higher education have a significant responsibility in STEM education by means of providing undergraduate education, running teacher training programs, and presenting in-service training for K–12 teachers. STEM capacities prepare students to be critical thinkers, to communicate and collaborate across actual obstacles, and to solve complex and ever-changing problems in a progressively technological and complex global community. Egyptians students with these capacities will drive innovations and fuel the global increasingly STEM-based economy. Additionally, a 2014 report of the National Network of Business and Industry Associations reveals that contained within the skills all employees need, regardless where they work, are the ability to apply knowledge in Mathematics, Science, Technology, and critical thinking (National Network of Business and Industry Associations, 2014).

STEM education, as an initiative, has been only recently introduced into Egyptian institutions of K-12 and not yet in higher education. However, the absence of strategic future directions to introduce, and expand STEM education in higher education ,and make it available for all students is obstructing Egypt's ability to develop a powerful national talent pipeline needed for an innovation economy. Hence Egypt must develop a strategic roadmap to STEM education that will nurture the pipeline of STEM students and graduates to ensure that Egypt has sufficient talent to meet the requirements of its economic development.

If developing STEM education in higher education in Egypt is not seriously taken into consideration now, Egypt will be at risk of failing current and future generations, and Egyptian higher education system will not be able to produce the next generation of brilliant innovators.

2. Statement of the problem

In the speedily expanding field of STEM education, much of the related published academic literature focuses upon pedagogical methods and good practices instead of long-term strategic directions and future directions of STEM education as a driver of innovation economy.

Innovation is an essential driver of a nation prosperity.A considerable ratio of economic growth has been ascribed to improved productivity resulting in part from innovation. Innovation economy requires not only STEM graduates, but also STEM graduates who have many different kinds of skills. These graduates are called"

the Deep Divers", who exceed the boundaries of a given discipline or field. STEM graduates also are called "**Interdisciplinary Connectors**", who tries to create new products via the integration of two or more disciplines (Atkinson, and Mayo, 2010).

Although there is a growing need for STEM professionals, however there is not a clear strategic future directions for how Egypt intends to educate them. Egypt cannot meet the STEM jobs challenge with its current educational policies and systems. It must have comprehensive STEM agenda that link students and programs to labor market opportunities. It is time for Egypt to exploit the innovations already in place across the country and provoke economic growth encouraging STEM opportunities. Accordingly Egypt needs a high quality and stable source of STEM jobs for the future supported by the development of strategic future directions of STEM education to direct the national efforts to introduce the best possible STEM education in postsecondary arena for all the Egyptian.

In the light of what has been mentioned ,this paper seeks to propose strategic future directions of STEM education in higher education in Egypt as a driver of innovation economy, to achieve this objective the study will answer the following questions:-

The main research question in this paper is:-

What are the proposed strategic future directions for developing STEM education in higher education in Egypt as a driver of innovation economy?

This question is broken down as follows:-

1. What is the historical context of STEM education?
2. How the concept of STEM education and its related concepts are defined?
3. What is the role of STEM education as a driver of innovation economy?
4. What are the determinants of STEM education?
5. What are the initiatives of some of the most successful countries in STEM education?
6. What is the current status of STEM education efforts in Egypt?
7. What are the proposed strategic future directions for developing STEM education in higher education in Egypt as a driver of innovation economy?

3. Scope and Objectives of the Study

The main objectives of this study is to:-

1. Discuss the historical context of STEM education.
2. Define the concept of STEM education and its related concepts.
3. Provide a characterization of the role of STEM education as a driver of innovation economy.
4. Identify the determinants of STEM education.
5. Analyze the initiatives of the most successful countries in STEM education.
6. Identify the current status of STEM education efforts in Egypt.
7. Propose possible strategic future directions for developing STEM education in higher education in Egypt as a driver of innovation economy.

4. Significance of the study

The following information will be derived from this study:

1. The study will identify the historical context of STEM education and outline its theoretical and applied foundations.
2. The study will help stakeholders gain a common understanding of the role of STEM education as a driver of innovation economy.
3. The study may help Egyptian policymakers to develop strategic roadmap for developing STEM education in higher education.

5- Research methodology

5.1 The Source of Data

A. Secondary data: obtained through related literature.

B. Primary data: collected through:

1. Questionnaire that had been classified into two parts.
   - The first part prepared to collect basic data.
   - The second part contained information about SWOT analysis.
2. A workshop conducted by the researcher with a group of 53 dedicated stakeholders from the Science, Technology, Engineering and Mathematics education community who were asked to develop strategic future directions for STEM education in higher education in Egypt .Participants worked through two sessions:
   - Describing STEM education current reality in Egypt by way of a S.W.O.T. analysis.

- Defining strategic future directions for STEM education in higher education in Egypt.

6-Theoretical Framework Guiding the Study

6-1 STEM Education: Historical context

STEM education was initially named Science, Mathematics, Engineering and Technology (SMET) (Sanders, 2009), and it was a proposal created by the National Science Foundation (NSF). This educational proposal was to provide all students with critical thinking skills that would make them creative problem solvers and eventually more in demand in the labor pool. It is recognized that any student who joins in STEM Education, mainly in the K-12 setting would have a benefit if they chose not to pursue a post-secondary education or would have an even superior benefit if they did join college, specifically in a STEM field (Butz et al., 2004).

The use of STEM was mainly used in engineering firms to produce groundbreaking technologies such as the light bulb, automobiles, tools and machines, etc. Many of the people responsible for these innovations were only somewhat educated and/or were in some sort of apprenticeship. For example, Thomas Edison did not go to college (Beals, 2012), nor did Henry Ford; despite the fact that Ford did work for Thomas Edison for several years. These “geniuses” of innovation used STEM tenets to manufacture some of the most creative technologies in history: however, STEM in education was nearly non-existent (Butz et al., 2004).

STEM education was the outcome of a number of historical events. Most prominent was the Morrill Act of 1862. This Act was responsible for the development of land grant universities that, in the beginning, focused for the most part on agricultural training, but soon engineering based training programs were formed (Butz et al., 2004). For example, The Ohio State University was founded in 1870, but was initially called the Ohio Agricultural and Mechanical College (Background of Ohio State, 2012). As more and more land grant institutions were being established, more and more STEM education training was eventually being taught and in due course integrated into the labor pool. Other factual events drove STEM education to grow and prosper. Two such events were World War II, and the launch of the Soviet Union’s Sputnik.

Since the birth of NASA, the space industry clearly has succeeded and originated several technological victories including putting a man on the moon; nevertheless, NASA has been responsible for many STEM education initiatives. Funding through NASA grants has been accountable for bringing STEM education initiatives to both pre and post-secondary education for the past five decades (NASA, 2012).

6-2 Conceptualizing and defining terms

6-2-1What is STEM?

The National Science Foundation formulated the idea of STEM in the late 1990s in the United States. Originally the acronym was SMET but after discouraging feedback and some re-thinking it developed as STEM (Williams, 2011). The word S.T.E.M. is an acronym for **S**cience, **T**echnology, **E**ngineering and **M**athematics. There are several researches who might use this acronym as the definition of STEM education. Namely, they identify STEM by the separate subjects of which it is composed. Whereas, this account is insufficient (Bybee, 2010). On the contrary, STEM education should be defined as an integrative approach to curriculum and instruction. It is most excellently realized by removing any boundaries between the subjects and imagining them taught as one (Morrison & Bartlett, 2009).

STEM’s recognized potential is to satisfy a student’s learning experience by aiding him or her in the ability to transfer learning (Berry, et al., 2004).Students can propose solutions for new multidimensional problems based upon previously learned principles and basics applied through science, technology and engineering, and mathematics. It is suggested that implementing teaching strategies, such as problem-based learning through a STEM curriculum, may renovate students’ desires to understand the world around them and engage them in classroom instruction (Havice, 2009).

6-2-2What is STEM Education?

“On January 25, 2011, the first sitting President of the United States spoke the words “Science, Technology, Engineering and Math” in his State of the Union Address the President stated”:

> “Let's also remember that after parents, the biggest impact on a child's success comes from the man or woman at the front of the classroom. InSouth Korea, teachers are known as "nation builders." Here in America, it's time we treated the people who educate our children with the same level of respect. (Applause.) We want to reward good teachers and stop making excuses for bad ones. (Applause.) And over the next 10 years, with so many baby boomers retiring from our classrooms, we want to prepare 100,000 new teachers in the fields of science and technology and Engineering and math” (Whitehouse.gov, 2011).

STEM education is not a new concept derived by the White House. STEM education has been around for decades. “The acronym STEM stands for science, technology, engineering and math. In general, STEM includes life sciences (except medical sciences), physical sciences, Mathematics and Statistics, Computer

Science and Engineering. The Department of Commerce also includes certain STEM-related managerial occupations in its definition of STEM, while the Organization for Economic Co-operation and Development (OECD) includes manufacturing and processing, as well as architecture and building". (Klobuchar, 2014)

Barkos et al. (2012), stated:

> "Perhaps for the first time since the launch of Sputnik, educators broadly agree on the value of STEM education for ensuring America's edge in the global economy. Yet teachers, administrators, and policy-makers find themselves confused about what it means to successfully implement STEM programs and initiatives" (p.2).

Although, STEM education is not a new concept as mentioned above, nevertheless many of researchers approach STEM education with doubt because there is no single definition of STEM education exists, and many "do not have an interdisciplinary understanding of STEM" (Breiner, Harkness, Johnson & Koehler, 2012, p. 6). It is obvious that there is a massive need for all stakeholders to reach an agreement of what STEM education is and how it might be introduced in educational settings?

There are two conventional approaches to defining STEM education. The first approach is to include education in any field defined as STEM. This approach combines together four different disciplines on the supposition that their common noteworthy importance advances technological innovation, competitiveness, and long-term national wealth and security (NAS et al. 2007). It does not discuss the question of what constitutes a STEM field.

The second approach is to call attention to logical and conceptual relationships across different STEM fields to treat STEM education as one entity (Honey et al. 2014). This definition demands for curriculum and pedagogical unity across different STEM fields.

Xie & Killewald ,2012; Xie & Shauman ,2003 proposed another approach to overcome the perplexity about the definition of STEM education is to be precise in empirical studies. Many sociological studies take this approach. Namely, a study may be focused on academic achievement or degree attainment in a specific STEM field, e.g., Science or Mathematics. In Pre-higher education, a researcher may be concerned with specific issues such as, achievement in a defined subject, such as Science or Mathematics, and commonly uses measures such as standardized test scores. At the undergraduate and graduate levels, a researcher may be concerned with specific issues such as, participation in specific majors, achievement in specific courses, and attainment of degrees in specific fields considered part of STEM. In this paper, I keep an eye on this practice of being precise each and every time possible.

Morrison called STEM education a meta-discipline or the "creation of a discipline based on the integration of other disciplinary knowledge into a new whole" (Morrison, 2006, p. 4). This definition mentions the use of an integrated approach, which refers to combining subjects rather than teaching them separately.

The theoretical justification of STEM education has stemmed from the curriculum integration theories. Integration of curricula or integrated way of teaching appears crucial for STEM education in terms of dealing with the combined nature of the four disciplines and actual life (Corlu et al. ,2014).

The Colorado Department of Education describes STEM as,

> "An interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering and mathematics in context 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." (Tsupros, Kohler, & Hallinen, 2009)

This definition emphasizes interdisciplinary approach which refers to combining theoretical aspects with real-world applications to develop economy.

STEM education inspires innovation by linking subject areas, which helps students create new relations between disciplines and sometimes helps make totally new ones (Council on Competitiveness, 2005). STEM education generates real life learning opportunities for students. It advances a learning environment for students to, not only learn 21st century skills, but also have the opportunity to craft new skills (Narum, 2008).

These definitions of STEM education emphasize that STEM is more than piecing areas together (S+T+E+M) to teach them on their own or in an integrative way, they also highlight the importance of STEM education as a driver of innovation and acquiring new skills. In addition to, the idea behind STEM education is to produce critical thinkers, innovators and problem-solvers, combine classroom lessons with real-world problems and encourage investigation and cooperative learning.

In my opinion STEM education is more than its essential parts. It is a complex social phenomenon and can be seen as an interdisciplinary complicated field of study that is covering education in the fields of practical and applied sciences that are taught by combining them in an innovative ways of thinking to create entirely new interrelated multi-disciplinary ones to solve complex contextual problems.

6-2-3What is STEM literacy?

STEM literacy is attained when a student can put into operation his or her understanding of how the world works within and across the four interdependent STEM disciplines to promote the social, economic, and environmental conditions of their local and global community (Milliken, D.; Adams, J. ,2010, pp. 13-14).

(Bybee, 2013, p.101) defined STEM literacy as an individual's:

- Knowledge, and skills to classify questions and problems in life situations, explain the world, and depict evidence-based assumptions about STEM-related inquiries.
- Comprehending of the distinguishing characteristics of STEM disciplines as formulas of human knowledge, investigation and design;
- Consciousness of how STEM disciplines form our physical, intellectual, and cultural environments; and
- Readiness to an individual in STEM-related issues.

I think that STEM literacy is one of the purposes of STEM education. It is a process through which an individual is provided with the knowledge and procedural skills fundamental for approaching society's complex contextual problems.

6-2-4What is STEM Job?

The acronym STEM is specified by its nature, it refers to science, technology, engineering and math, however, and there is no agreement on the basic elements of a STEM job. Professional and technical support occupations in the fields of computer science and mathematics, engineering, and life and physical sciences consistently make the lists of STEM occupations. Workers in STEM occupations earn more on average than their counterparts in other jobs, there is a payoff in choosing to pursue a STEM degree (Langdon, David et al., 2011). U.S. Department of Commerce Economics and Statistics Administration made STEM list contains 50 specific occupation codes **(See Appendix: 1: Table 1).**

6-2-5What is STEM College major?

STEM college majors were defined by the National Science Foundation and included subjects in the fields of Chemistry, Computer and Information Technology Science, Engineering, Geosciences, Life Sciences, Mathematical Sciences, Physics and Astronomy, Psychology, Social Sciences, and STEM education and Learning Research (NSF, 2012). (**See Appendix: 1: Table 2)** for a full descriptive list of STEM majors.

6-3 STEM education as a National Priority

In 2009, President Obama declared a "call to action" for improving STEM education as a national priority to encourage endeavors of innovation, creativity, and future job development (Office of the Press Secretary, 2010). The idea of STEM education as a national Priority is not only motivated by a real aspiration of a nation to be globally competitive, but also to work for satisfying labor pool requirements. On the word of a report released by the U.S. Congress Joint Economic Committee in April 2012, "[despite] the clear demand for STEM talent by domestic employers, the U.S. is failing to produce an ample supply of workers to meet the growing needs of both STEM and non-STEM employers…" (The NEA Foundation Report, 2012).

STEM jobs are the jobs of the future. They are fundamental for developing a nation's technological innovation, competitiveness, economic growth, and overall standard of living. (Langdon, David et al. ,2011) Over the past 10 years, growth in STEM jobs was three times as fast as growth in non-STEM jobs. They will grow 1.7 times faster than non-STEM occupations over the period from 2008 - 2018" (Feder, 2012). A recent report by the President's Council of Advisors on Science and Technology (PCAST) approximates that there will be one million lesser STEM college graduates over the next decade than U.S. industries will need. The request for STEM graduates may in point of fact be higher, given that PCAST also estimated that STEM competencies are progressively required for workers both within and outside specific STEM occupations (National Economic Council and Office of Science and Technology Policy,2015).

Accordingly, Egypt needs to have strategic future directions to STEM education as a fundamental pivotal priority to secure its economic growth.

6-4 STEM education as a driver of innovation economy

The target of STEM education is to produce the next scientists, technologists, engineers, and mathematicians who will make new inventions (PCAST, 2010). STEM education makes students ready to have STEM careers like aerospace, architectural, biomedical, chemical, civil, electrical, and network engineers together with biological, chemical, construction management, mapping, simulator maintenance, and survey technicians. (North Dakota Department of Career and Technical Education, 2007). STEM education creates as well new multi-disciplinary occupational fields ―such as nanobiology, network science or bioinformatics (Council on Competitiveness, 2005).

STEM education particularly carries a premium in the global labor market (Rothwell, 2013).STEM has long been fundamental to a nation's power to manufacture superior products, improve and expand health care, advance cleaner and more effectual national energy sources, maintain the environment, preserve national security, and develop the economy. President Barack Obama asserted the importance of STEM education when he said :(National Economic Council and Office of Science and Technology Policy, 2015).

> "We don't want to just increase the number of American students in STEM. We want to make sure everybody is involved. We want to increase the diversity of STEM programs, as well…and that means reaching out to boys and girls, men and women of all races and all backgrounds. Science is for all of us. And we want our classrooms and labs and workplaces and media to reflect that."

President Barack Obama, March 23, 2015, P. 25.

Higher education a key element of the innovation system. It operates as both intellectual capital source and seedbed of new firms in the evolving knowledge economy (Etkowiz, 1999). Intellectual capital and the ability to interpret ideas into innovative technologies, products and services quicker and more excellent than the competition are pillars of the innovation economy. Innovations in the future will not need innovators of just specialization skills, they will need teams of collaborators who can mix together numerous skills and opinions. This collaboration consists of not only combined activities among scientists and engineers, but also with business and industry specialists, including specialists in the services sector. The 21st century STEM knowledge workforce will cover several sectors, including the instructional workforce at the pre K-12 and higher education levels (i.e., teachers and faculty), scientists and engineers, legislators and policy-makers, in addition to a knowledgeable people more broadly (Babco, 2004).

Innovation economy do well with workers and entrepreneurs with creativity and critical thinking skills, who can put into operation knowledge, and who are technically and technologically capable. Due to today's education system may not prepare students well for the future, and traditional educational pathways and degrees may not meet the needs of the innovation economy, so it is a must to search for strategic future directions of STEM education in higher education. (Gulf Coast Community Foundation, 2013). Figure1. Indicates the new skills and the work -force required by innovation economy in Gulf Coast ,U.S.A.

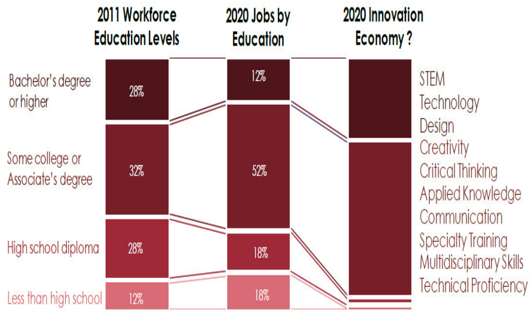

Figure 1. The new skills required by innovation economy.
Source: Gulf Coast Community Foundation, 2013.

National Governors Association (NGA) asserted that investments in K-12 STEM, higher education, and the workforce are considered to be essential support for the innovation economy (Fitzpatrick, 2009), as well as American prosperity has been driven by developments in the STEM fields. Skills in these areas made easy for the country to come first in the space race and the Cold War and it needs them now to move to a technology driven economy. To move to a technology driven economy, President Barack Obama's Council of Advisors on Science and Technology (PCAST) has produced an official report that demands the establishment of a Master Teachers Corps. The report emphasizes two actions: (1) hiring 100,000 new STEM teachers and (2) paying higher salaries to the top 5 percent of STEM teachers. The President stressed the necessity of preparing highly qualified teachers, investment in STEM education programs in terms of its capability to innovate and generate jobs, and it is essential to adopt STEM teaching to prepare students for the future economy (West, 2011).

6-5 The determinants of STEM education

In this section the determinants of STEM education known to affect STEM education is examined. Sociological research on STEM education comes into being at the frontier between the sociology of science and education. On one hand the sociology of science concentrates on science as an important, exceptional social institution. On the other hand, the sociology of education studies concentrates on the attainment of both general knowledge and educational credentials as outcomes of social, familial, and institutional ambient (Hora, M. T., 2010).

6-5-1 Contextual factors

Societal and institutional environments count for STEM education just as they do for general education, but literature on the prominent influential contextual factors for STEM education has concentrated on precise factors expected to influence involvement and achievement in STEM education. Educational institutions are at variance in resources for STEM education, such as teacher quality and laboratories. Many studies suggest that funding and resource obtainability influences the degree of engaging students and surpassing at STEM education (Museus et al., 2011; Wang ,2013). Some studies suggest that the characteristics of institutional context and climate affect students' pursuit of and perseverance in a STEM major (Chang et al. ,2014; Hurtado & Carter 1997; Seymour & Hewitt, 1997).

Discouraging campus climates, extremely competitive classrooms, inadequate instruction, and too much assignments can reduce academic engagement, achievement, and perseverance toward a degree (Cabrera et al., 1999; Chang et al. , 2011, 2014; Seymour & Hewitt ,1997).

Higher education environments in which students find attractive instruction, support from faculty and other students, adequate financial aid and networking opportunities are encouragingly associated with STEM engagement and persistence (Chang et al. , 2011; Graham et al. ,2013, Museus et al. ,2011;Seymour & Hewitt 1997). The chance to work in partnership with faculty on undergraduate research projects may be effective to build up student's self-confidence and recognition of the scientific community (Chang et al., 2011; Graham et al., 2013). More notably, these programmatic investments may advance the persistence of students in STEM college majors.

6-5-2 Family Factors

One prominent explanation posits that the relatively high levels of education and income that characterize middle- and high-SES families enable them to provide their children with the encouragement, support, exposure to science, and access to STEM enrichment experiences necessary to develop and sustain early interest, confidence, and aspirations in STEM (Archer et al. 2012, Dabney et al. 2013, Harackiewicz et al. 2012, Sjaastad 2012, Turner et al. 2004). Some researchers further suggest that middle-class parenting strategies and resources may promote a worldview that enables children to view science as a thinkable/natural career choice (Archer et al., 2012). The family influence on youths' social-psychological orientation may be particularly important for promoting math and science achievement and persistence in the STEM pipeline (Mau 2003, Tai et al. 2006, Wang 2013).

Multivariate analyses show that differences by family socioeconomic background in STEM interest and persistence during postsecondary education disappear when other factors, such as academic achievement, are controlled (Chen & Soldner 2014, Ma 2009, Mau 2003, Xie & Killewald 2012). Thus, recent research suggests that family background plays an influential role in acquiring the academic skills necessary to attain a postsecondary degree but it does not play a direct role in the pursuit and attainment of a STEM degree specifically.

6-5-3 Individual Factors

Achievement in Math and Science courses in postsecondary education and scores on standardized Math and Science tests is strongly correlated with individual cognitive capability, spatial ability, numeracy, and other indicators of basic cognitive functions. Specific individual social-psychological features such as Math and Science self-concept, interest in science, and aspirations for a science-related profession (Wai et al., 2010; Cech et al. ,2011; Maltese & Tai 2011; Wang 2013).

6-6 The initiatives of some of the most successful countries in STEM education

The essential objective of this section is to find out what other countries done to develop STEM education in higher education, and the take-up of STEM in the labor market, and to draw out possible lessons and ideas for proposing strategic future directions for STEM education in higher education in Egypt. Broadly, the countries chosen were referred to in the literature of STEM education as the most successful countries in STEM education. These countries are United States, Israel, The United Kingdom, Korea, Japan, Singapore, and Western Europe (Germany, France, Ireland, the Netherlands, Norway, and Spain).

Numerous countries formulated a national government commitment to STEM agenda in its national policy. National STEM policy commonly emphasizes on the 'pipeline' of school and tertiary STEM education that is stimulated by concerns about the STEM labor force that is considered highly important to economic growth.

United States government have completely hold a STEM agenda. The 2010 Report to the President, Prepare and inspire: K-12 education in science, technology, engineering and maths (STEM) for America's future that put the justification for the United States governments STEM agenda: (President's Council of Advisors on Science and Technology, 2010, p.vii).

> "The success of the United States in the 21st century – its wealth and welfare – will depend on the ideas and skills of its population. These have always been the Nation's most important assets. As the world becomes increasingly technological, the value of these national assets will be determined in no small measure by the effectiveness of science, technology, engineering, and mathematics (STEM) education in the United States. STEM education will determine whether the United

> States will remain a leader among nations and whether we will be able to solve immense challenges in such areas as energy, health, environmental protection, and national security … It will generate the scientists, technologists, engineers, and mathematicians who will create the new ideas, new products, and entirely new industries of the 21st century."

The United States government's commitment to STEM is revealed in federal legislation. Firstly presented in 2007 by President Bush, and reauthorized by President Obama in 2010, the America COMPETES Act (Congress of the United States of America, 2010) denotes a wide-ranging, legislative commitment to STEM education, research and development, and innovation. Regarding education, the America COMPETES Act: granted the grounds for programs increasing the number of STEM teachers; demanded the co-ordination of STEM related efforts crosswise scientific organizations. The Act also called for establishing a committee accountable for matching federal efforts related to STEM, developing and implementing through the participating organizations, and bringing up-to-date once every five years a 5-year STEM education strategic plan, which shall: a. identify and schedule yearly and long-term objectives; b. indicate the joint metrics that will be utilized to evaluate advance toward accomplishing the objectives; c. demonstrate the approaches that will be taken by each participating organization to evaluate the efficiency of its STEM education programs and activities; and d. explain the role of every organization in sustaining programs and activities designed to achieve the objectives. (Congress of the United States of America, 2010).

The transformation of the Israeli economy into a chief player in the global knowledge-economy has been a main draw for STEM professionals into Israeli knowledge- and technology- focused industries. Israel possesses the status as 'Start-Up Nation', enjoying the triumph of its innovation-driven high-tech economy. Much of the praise for today's thriving knowledge economy is given to Israel's education system mainly to Israeli universities and research institutes. Israeli STEM is exceptional in three ways: - (Drori, 2013)

- Like the United States, Israel's STEM pipeline possesses the odd characteristic of weak input and specifically strong output: STEM education in schools finds the middle ground due to not strong infrastructure, high student-to-teacher ratios, and small budgets, yet Israel is among the leading countries in academic research, industrial and military R&D, and high-tech innovation.
- Israel's STEM potential is compromised by the fact that an estimated 15-17% (and rapidly growing) of Israel's population is Ultra-Orthodox and consequently does not join in STEM education and labor pool.
- Parting from the conventional STEM pipeline of schooling into the place of work, Israel's STEM pathway is 'interjected' with compulsory military service for 18-year-olds. This obligation of a minimum of 2 (women) or 3 (men) years of service delays the commencement of higher education, yet also builds-up skills and work culture that translate into innovation and entrepreneurial capabilities.

Two factors, in relation to the organization of Israel's education system, make Israel's STEM education most distinctive. First, the authorized partitioning of Israel's school system into various and separate education systems brings about uneven exposure to STEM education. Most extreme in this regard is the absence of any STEM education in Ultra-Orthodox schools, which leads to some 20% of Israeli children studying in a school that presents no STEM education. Second, owing to the request for obligatory military service, Israeli 18-year-olds do not transition from secondary school into college or university (Drori, 2013).

Considerations over the obtainability of STEM graduates, their position in the labor market and the possibility for STEM professionals to stimulate the economy have been developed over a long period of time in the UK (House of Lords, 2012; Sainsbury, 2007). The House of Lords (2012) report, Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects, obviously connects the demand for a capable supply of high quality STEM graduates to the UK labor markets to economic growth and welfare.

The United Kingdom's long-term policy agenda for STEM is represented by their Science & Innovation Investment Framework 2004-2014, which states:

> "The nations that can thrive in a highly competitive global economy will be those that can compete on high technology and intellectual strength – attracting the highest skilled people and the companies which have the potential to innovate and to turn innovation into commercial opportunity. These are the sources of the new prosperity. This is the opportunity. This framework sets out how Britain will grasp it. It sets out how we will continue to make good past underinvestment in our science base – the bedrock of our economic future. More than that, it sets out not only how we intend to invest in this great British asset – the world-class quality of our scientists, engineers and technologists – but how we will turn this to greater economic advantage by building on the culture change under way in our universities, by promoting far deeper and more widespread engagement and collaboration between businesses and the science base, and by promoting innovation in companies directly. "(DfES 2004, p.1)

Over the past decade, Korean people have intensified their interest in science and technology (KOFAC, 2011; Oh, 2012). The Korean government has revealed impressive attention and emphasis on STEM for its economic development since the 1960s. Its latest projects for Korean higher education, such as BK21 and WCU, have also aimed at focusing more on science and engineering than on the humanities and social sciences. Another example indicating governmental attitudes toward STEM is that of the past Lee, Myung-Bak administration (2008-2013), which established the Ministry of Education and Science Technology (MEST) by combining the Ministry of Education & Human Resources with the Ministry of Science & Technology in 2008.This decision intended to created collaboration by joining primary, secondary, and higher education with R&D in science and technology. These policies for STEM education before the 2000s can be believed as successful, considering that Korea placed 22nd in the IMD World Competitiveness Ranking in 2012. The second plan called attention to educating personnel for a creativity-based economy. For education, its strategies include promoting STEAM education for primary and secondary education and granting a research- approachable environment to improve research competence for tertiary education by reinforcing the World-Class University project, the Global Ph.D. Scholarship, and reinforcing four specialized institutions in science and technology – KAIST, GIST, DGIST, and UNIST as a research hub. The plan also comprise backing-up women in science and technology in cooperation with the Korea Advanced Institute of Supporting Women in Science, Engineering, and Technology (WISET) (Jon and Chung,2013).

The Japanese government has presented a variety of national strategies to enhance STEM. Firstly, national Curriculum Guidelines for compulsory primary and secondary school-level science and mathematics have been developed that amplify hours and content. These guidelines are accompanied by other initiatives that work toward improving science teaching, including disciplinary training of primary school science teachers (Matsushita, 2010). These strategies intend to advance the condition of basic STEM education nationwide. A second strategy encompasses 'elite' education (e.g. Super Science Secondary school program, and the 'science elite track 'from secondary to tertiary education). Thirdly, strategies have been executed which concentrate on shifts between university and career paths. Fourthly, strategies have been developed which precisely tackle the gender differences in STEM education and STEM professions, including initiatives involving public and corporate sector funding (Marginson et al., 2013).

Singapore appreciates the necessity for talent to move forward in STEM related fields. One approach of performing this is by attracting experts. (Lim, 2010). The responsibility of STEM disciplines in both general education and vocational and occupationally-specific programs in education and training was to deliver the human capital engine for economic growth and to generate a sensation of Singaporean identity (OECD, 2010).

Singapore put strategies, policies and programs to improve STEM at all stages of education. A foremost reason in the success of the students is the financial investment in the education system by the leaders and policymakers towards STEM based education. Main strategies to develop and sustain STEM at all levels include: (Idris, et al., 2013)

- All-inclusive visions and planning.
- System arrangement across stakeholder clusters.
- Long-term adherence to a well-developed strategy.
- Combination of content and higher-order thinking skills.
- Researched and skill based curriculum.
- Investment in teachers.

Western Europe, Germany, France, Ireland, the Netherlands, Norway, Spain, and the United Kingdom altogether have national STEM policies or strategies (Eurydice, 2011) that grant a consistent STEM agenda, recurrently connected to wide-ranging educational goals. Commonly, these policies or strategies include: advancement of an unquestionable image of science; intensifying public knowledge of science; refining school based mathematics and science (teaching and learning); and developing interest and partaking in school-based mathematics and science, tertiary STEM disciplines and the STEM workforce. Furthermore, Western European national STEM policies aim at addressing discrepancies (gender and minority groups) in education and work - based STEM, and match graduates skills with employer needs(Marginson et al., 2013). In Slovenia, Austria, Slovak Republic, and Finland the national STEM- exact strategies are any more prioritized as STEM has successfully been mainstreamed (Kearney, 2011).

The most successful countries in STEM have established strategic national STEM policy foundations which permit approving conditions for a variety of actions such as world class university programs, the executive recruiting of foreign science talent and new doctoral groups, decentralized program initiatives and partnerships and engagement that link STEM activities in schools, vocational and higher education with industry, business and the professions, programs, curriculum reform and new teaching standards, Often STEM programs are facilitated or informed by institutes, centers or other agencies that have been exclusively created to develop and resource the shared national STEM agenda.

Though very few international policies and strategic directions can be instantly transferred into the Egyptian context, the STEM strategic directions of other countries provide an illuminating framework through which many possibly useful ideas for proposing strategic future directions for developing STEM education in higher education. The following key findings were the result of the analysis of the commonalities between the countries mentioned before.

6-7 Key findings and lessons for Egypt

Key findings and lessons for Egypt can be summarized as follows:-

1. Formulating a national government commitment to STEM agenda in its national policy.
2. Forming national STEM policy and strategies that emphasizes on the 'pipeline' of school and tertiary STEM education that is stimulated by concerns about the STEM labor force that is considered highly important to economic growth.
3. Extensive legislative and policy framework for STEM overlaying a decentralized, fragmented education system spanning school, community and tertiary sectors.
4. Developing national initiatives to enhance awareness of the nature of STEM professions.
5. Advancing a constructive picture of science and mathematics, and STEM.
6. Expanding public knowledge and awareness of scientific literacy and s method.
7. Strengthening increased student partaking in school-based mathematics and science, higher education level STEM-disciplines, and the STEM trained workers.
8. Sustaining increased accomplishment in school-based mathematics and science, and higher education STEM-disciplines.
9. Tackling under-representation of minority groups and those located in different geographical places.
10. Setting-up procedures for harmonization between STEM-related ministries, agencies, organizations and STEM stakeholders.
11. Creating shared metrics to watch carefully progress in STEM education.
12. Strengthening participation in STEM through branching at secondary school level between STEM and non-STEM paths, and vocational paths leading to important STEM training.
13. Developing STEM-heavy technical and vocational schools and higher education institutes, at the side of academic secondary schools and universities.
14. Establishing strong links between STEM subjects at secondary school level and university entrance/ comprehensive prerequisite requirements for university programs necessitating advanced STEM knowledge, optimizing preparation in the disciplines.
15. Attracting the brightest people into STEM (students, scientists, engineers) from the national and international talent pool.
16. Improving research competency for tertiary education by reinforcing the World-Class University.

6-7 Identifying the current status of STEM education efforts in Egypt

The idea of establishing a STEM school in Egypt was far-fetched during that critical stage of real political, economic and social change in Egypt, but it became a reality on August 2011 and the first Egyptian STEM School opened the doors to the Egyptian gifted students in Mathematics and Sciences irrespective of their gender, social, or economic background. Essentially, the project – based learning environments are not known to many of the educational figures in the ministry of education in Egypt, consequently it is a new experience and learning approach to the Egyptian educational counselors, policy makers, school principals, administrators, teachers, students and their parents. "It was really very hard to start a project that you know nothing about" those words were recurrently heard from the traditional Egyptian teachers who have been chosen to do an burdened job (Abd El Aziz, 2013).

Conversations between the Ministry of Education and USAID grew into a plan to seting-up Science, Technology, Engineering and Math (STEM) Schools, based on the American model advanced by USAID. The STEM schools program was offered in Egypt during the 2011-2012 school year, and there is a necessity for faculty professional development must be on-going. There should be some sort of a link between these STEM schools (Rissmann-Joyce; El Nagdi , 2013).

STEM School for Boys

The STEM School for Boys was established on September 17, 2011 in the Global Village by his Excellency, Dr. Ahmed Gamal El-Deen, the Minister of Education for Egypt. The goals for this STEM school were identified in addition to the school mission as follows (Rissmann-Joyce; El Nagdi , 2013):

GOAL1: Students must show profound understanding of the scientific mathematical and social components of Egypt's distinguished challenges as a country.

GOAL2: Students must display understanding of the content and ways of knowing that demonstrate scientific, mathematical and technological literacy and subject matter competence.

GOAL3: Students must show self-motivation, self-direction and a hunger for nonstop learning.

GOAL4: Students must display the power to think autonomously, creatively and analytically.
GOAL5: Students must demonstrate the ability to question, collaborate and communicate at a high level.
GOAL6: Students must display the capacity to turn out to be socially responsible leaders
GOAL7: Students must put into operation their understanding to improve creativity, innovation and invention with a actual world vision with a consciousness and eye toward a more contemporary Egypt.
GOAL8: Goals 1 – 7 must be implemented and viewed through the lens of a digital platform. Students must become fluid with technology to ensure that they maximize digital methods of data storage and communication

Mission

The school seeks .....

1. Partnerships with universities, research Departments, factories, companies and those who care about education for developing, training and application for student and teacher learning.
2. To be linked with the latest innovations and research issues in a lifelong culture and to work as a team with the students and the teachers.
3. To develop the elements of innovation and creativity as an essential goal and to shed light on the role of science and engineering in the development of Egypt and the world.
4. To provide technical and financial support for the student-based learning focused on inquiry, projects and working as a team.
5. Continuing evaluation of all student and teachers while concentrating on developing the highest skills and self-reliance possible.

STEM School for Girls

The STEM School for Girls commenced its activities a year after the boys' school and has the same goals and mission. Students at both schools are acquiring the 21st Century Skills of communication, creativity, critical thinking and collaboration. It became visible that both STEM schools are tackling every single element of the school mission statement. The American University in Cairo, USAID, and World Learning are teaming up with the STEM schools to improve this innovation.

The Graduate School of Education at the American University in Cairo has founded a STEM Center. This initiative will grant professional development for STEM school educators, conduct action research at STEM schools, and assign graduate students to STEM schools for required fieldwork. As AUC has a signed Memorandum of Understanding (MOU) with the University of Minnesota's STEM Center, cutting edge educational research and practices will be available to boost STEM student achievement in addition to faculty development in inquiry-based teaching and project-based assessment strategies.

Egyptian higher education system has made massive steps in many areas, unluckily, STEM education is not one of the areas in which Egypt has made progress. Egypt has a great opportunity now to nurture the momentum produced by previous efforts, and policy drivers, to review where STEM journey has taken Egypt, and to discover the opportunities for STEM future in Egypt.

7. S.W.O.T. Analysis

This section aims at finding out the strengths, weaknesses, opportunities and threats (S.W.O.T.) in relation to STEM education in higher education in Egypt. The list below indicates the collective agreed upon issues in relation to each category, as stated below.

Strengths

1. Faculty are impressed by innovation in STEM education.
2. There has been some progress in developing pathways in Mathematics, Physics, Engineering, Biology, bioinformatics and Chemistry.
3. There is positive willingness of leaders of higher education to reinforce inter-college cooperation among faculty and deans to advance STEM education.
4. There is great human capital.
5. There is recognition that STEM education matters.

Weaknesses

1. There is no STEM education strategic plan.
2. Engineering programs are difficult to coordinate due to different higher education institutions infrastructures and divergent programs.
3. Scarcity of experienced faculty sufficiently prepared to faculty teach STEM disciplines efficiently.
4. There is no STEM undergraduate or graduate courses across departments in higher education institutions.
5. There is no regulations for developing shared faculty teaching load across interdisciplinary coursework.
6. The instructional technologies needed for STEM courses requires certain logistical infrastructure.
7. Infrastructure to support STEM education is highly expensive.

8. Poor resources to support practical (laboratory) activities.

Opportunities

1. The political commitment of establishing more STEM schools.
2. There is a possibility for a variety of STEM research.
3. Change the view of STEM education in Egypt.
4. Good authority support for STEM education.

Threats

1. Lack of unified strategic future directions.
2. There is no STEM national curricula.
3. Lack of industry sector dedication and arrangement with higher education institutions.
4. Lack of community and media recognition and awareness of the importance of STEM skills and careers.
5. Lack of government funding and limited resources.
6. There is no a national governance structure for STEM education.
7. Lack of STEM background in basic education.
8. Secondary schools do not teach and learn about Engineering.
9. Secondary school graduates are not efficiently prepared for postsecondary pathways.
10. Science and Math curricula in secondary schools lack consistency and depth.
11. Poor training and professional development of secondary teachers.
12. Lack of awareness of the job opportunities (STEM and non-STEM jobs) existing for STEM graduates.
13. There is varying connectedness to information and communication technologies.

8. Vision for STEM education in higher education in Egypt

Egypt will be one of the most innovative countries in preparing a national pipeline by guaranteeing that all students in higher education have the STEM education and experiences needed to able to contribute to the innovation economy.

9. Strategic future directions

Strategic future directions for STEM education can be summarized as follows:-

1. Developing and adopting national STEM content standards.

This strategic direction can be achieved by:-

- Developing national definition of sufficient STEM education standards for Egyptian students that are benchmarked against international standards.
- Providing all the necessary information to inform curriculum development within the framework of national content standards.

2. Increasing public appreciation for and understanding the importance of STEM education in leading the innovative economy.

This strategic direction can be achieved by:-

- Preparing messaging campaigns for drawing students, parents, the public, policy makers, employers and all Egyptians attention to STEM education as an essential tool for promoting Egyptian economy .

3. Making STEM education in the early grades a national priority.

This strategic direction can be achieved by:-

- Facilitating a national agenda to develop kindergarten to college STEM education.
- Developing a strategy to describe national STEM content guidelines that would define the vital knowledge and skills needed at each grade level.
- Multiplying the time dedicated to Science and Mathematics in the early grades.

4. Achieving the vertical arrangement of STEM education from Pre-K through graduate education

This strategic direction can be achieved by:-

- Establishing a national council for STEM education.
- The national council for STEM education will revise the STEM education system from Pre-K through graduate education for vertically aligning the STEM education system.
- The national council will develop a vision and set quantifiable goals and time frames for application of STEM education development and coordination.
- Aligning pre-K-12 STEM standards with higher education requirements.

5. Increasing the number of STEM secondary schools to provide all K-12 students with opportunities in STEM education to prepare them for STEM-related post-secondary educational pathways.

This strategic direction can be achieved by:-

- Developing partnerships with private sector to support building more STEM secondary schools.
- Persuading the largest number of STEM education supporters to build more STEM secondary schools.

6. Establishing particular educational programs that guarantee students graduate from secondary school STEM literate, well-prepared for STEM-related post-secondary educational pathways.

This strategic direction can be achieved by:-

- Developing a set of standards and an assessment system for technology and engineering as well as math and science.
- Aligning national STEM standards and an assessment system to international benchmarks through participation in the Program for International Student Assessment (PISA) and/or The Trends in International Math and Science Study (TIMSS).
- Ensuring that all K-12 students have access to many of extended day and summer activities that are STEM-related.
- Carrying out more STEM interdisciplinary projects.

7. Developing teacher education programs at institutions of higher education in order to prepare their students to teach curricula according to the national STEM content guidelines.

This strategic direction can be achieved by:-

- Preparation of STEM teachers should be based on actual collaboration between the colleges of education and the colleges of arts and sciences and engineering to make sure that STEM content knowledge is gained at appropriate depth to be functional in their future roles as teachers.
- STEM educators should be supported with sufficient mentoring during the first few years in their classrooms.
- Developing techniques for continuous, standards-based, data-driven, and relevant STEM teacher professional development.

8. Develop an alliance to back-up establishing STEM education in higher education institutions

This strategic direction can be achieved by:-

- Establishing a national STEM advisory board to put the roadmap for establishing STEM education in higher education institutions.
- Linking current stakeholders at the national level to communicate and implement STEM directions and activities.
- Initiating a public-private partnership of STEM advocates to strengthen the implementation of the strategic STEM directions and activities.
- Granting permanent, reliable funding resources to sustain establishing STEM education in higher education institutions

9. Preparing and qualifying STEM academic faculty.

This strategic direction can be achieved by:-

- Developing national STEM academic faculty certification standards.
- Developing policies and procedures supporting institutions of higher education to prepare and qualify STEM academic faculty based on national STEM content standards.
- Establishing centers of excellence to research and develop STEM curricula, effective teaching strategies, and professional development models.
- Developing programs that scientifically indicate the role of technology and cyber-enabled teaching in facilitating STEM learning and teaching.
- Supporting STEM professionals to practice research on teaching and learning in their particular STEM fields.
- Providing a forum to communicate and disseminate information on smart practices in STEM teaching and learning.
- Setting regulations and procedures facilitating STEM academic faculty movement between higher education institutions by creating national STEM academic faculty certification standards.

10. Creating STEM programs that meet economic development requirements.

This strategic direction can be achieved by:-

- Identify quality in STEM education in terms of higher education institutions, and economic development requirements.
- Creating systems for using labor market information to customize program and curricula that is based on constant feedback from stakeholder that reflecting evolving employer-driven requirements and practices in the related STEM fields.
- Aligning career advising between higher education institutions and secondary schools.
- Developing employer incentives for internships and apprenticeships that make jobs and job experience possible for students.
- Mapping STEM programs with Egypt economic development strategy.
- Creating suitable STEM learning environments.

11. Opening multiple pathways to STEM through improving Math preparation and developmental education to improve student's success to STEM.

This strategic direction can be achieved by:-

- Redesigning Math preparation for STEM pathways.
- Aligning the curriculum between secondary school and college-level Math.
- Defining the essential aspects needed for the entry, selection, education of talents, with great attention to transition points during the educational career of those talents.

12. Focusing on student completion through creating new routes, processes, and procedures that result in degree attainment.

This strategic direction can be achieved by:-

- Establishing structured and accelerated models through higher education institution as pathways to completion.
- Establishing STEM centers for strengthening improved teaching and learning.
- Supporting STEM education outside the classroom through vast learning opportunities that advance and keep student interest.
- Providing the resources that attract and retain excellent STEM students and faculty.

Conclusion

Many countries have developed legislation, policies and strategic directions to create a coherent framework for providing STEM education. Such strategic directions aimed at advancing the STEM labor market to develop the innovation economy. Strategic directions varies in terms of their central point, purpose, education level and some other associated matters such as curriculum, pedagogy and teacher education.

Strategic directions could aim to increase participation and performance in school-level science and mathematics, and higher education-level STEM disciplines or STEM-based professions. Strategic directions frequently express a variety of STEM programs, and guarantee the availability of budget allocations. There are divergent strategic directions approaches between Western European countries, and East Asian countries regarding developing STEM education.

There are noteworthy similarities between strategic directions for developing STEM education in many countries, which have become important to all. At the same time, when STEM education programs work their way through the national context, they come across diverse traditions, customs and expectations about professional roles and responsibilities. Analyzing the initiatives of some of the most successful countries in STEM education generated general lessons that can be communicate to the Egyptian higher education in order to widening and deepening the contributions of STEM to the Egyptian national innovation economy.

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Appendix:1: Table 1. Detailed STEM occupations and Standard Occupational Classification (SOC) codes. (Langdon, David et al. ,2011) .

Occupation	SOC code	Occupation	SOC code
Computer and Math occupations			
Computer scientists and systems analysts	15-10XX	Network systems and data communications analysts	15-1081
Computer programmers	15-1021	Mathematicians	15-2021
Computer software engineers	15-1030	Operations research analysts	15-2031
Computer support specialists	15-1041	Statisticians	15-2041
Database administrators	15-1061	Miscellaneous mathematical science occupa-tions	15-2090
Network and computer systems administra-tors	15-1071		
Engineering and surveying occupations			
Surveyors, cartographers, and photogrammetrists	17-1020	Materials engineers	17-2131
Aerospace engineers	17-2011	Mechanical engineers	17-2141
Agricultural engineers	17-2021	Mining and geological engineers, including mining safety engineers	17-2151
Biomedical engineers	17-2031	Nuclear engineers	17-2161
Chemical engineers	17-2041	Petroleum engineers	17-2171
Civil engineers	17-2051	Engineers, all other	17-2199
Computer hardware engineers	17-2061	Drafters	17-3010
Electrical and electronic engineers	17-2070	Engineering technicians, except drafters	17-3020
Environmental engineers	17-2081	Surveying and mapping technicians	17-3031
Industrial engineers, including health and safety	17-2110	Sales engineers	41-9031
Marine engineers and naval architects	17-2121		
Physical and life sciences occupations			
Agricultural and food scientists	19-1010	Physical scientists, all other	19-2099
Biological scientists	19-1020	Agricultural and food science technicians	19-4011
Conservation scientists and foresters	19-1030	Biological technicians	19-4021
Medical scientists	19-1040	Chemical technicians	19-4031
Astronomers and physicists	19-2010	Geological and petroleum technicians	19-4041
Atmospheric and space scientists	19-2021	Nuclear technicians	19-4051
Chemists and materials scientists	19-2030	Other life, physical, and social science technicians	19-40XX
Environmental scientists and geoscientists	19-2040		
STEM managerial occupations			
Computer and information systems managers	11-3021	Natural sciences managers	11-9121
Engineering managers	11-9041		

Appendix:1: Table 2. Detailed STEM undergraduate majors. (Langdon, David et al. ,2011)

Computer majors		
Computer and information systems	Computer science	Computer administration management and security
Computer programming and data processing	Information sciences	Computer networking and telecommunications
Math majors		
Mathematics	Statistics and decision science	Mathematics and computer science
Applied mathematics		
Engineering majors		
General engineering	Environmental engineering	Petroleum engineering
Aerospace engineering	Geological and geophysical engineering	Miscellaneous engineering
Biological engineering	Industrial and manufacturing engineering	Engineering technologies
Architectural engineering	Materials engineering and materials science	Engineering and industrial management
Biomedical engineering	Mechanical engineering	Electrical engineering technology
Chemical engineering	Metallurgical engineering	Industrial production technologies
Civil engineering	Mining and mineral engineering	Mechanical engineering related technologies
Computer engineering	Naval architecture and marine engineering	Miscellaneous engineering technologies
Electrical engineering	Nuclear engineering	Military technologies
Engineering mechanics physics and science		
Physical and life sciences majors		
Animal sciences	Genetics	Physical sciences
Food science	Microbiology	Astronomy and astrophysics
Plant science and agronomy	Pharmacology	Atmospheric sciences and meteorology
Soil science	Physiology	Chemistry
Environmental science	Zoology	Geology and earth science
Biology	Miscellaneous biology	Geosciences
Biochemical sciences	Nutrition sciences	Oceanography
Botany	Neuroscience	Physics
Molecular biology	Cognitive science and biopsychology	Nuclear, industrial radiology, and biological technologies
Ecology		