Meaningful STEM Education Frameworks: Engineering Education Context

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Abstract

This research paper presented a critical analysis of contexts and frameworks for engineering in STEM education and how they relate to engineering education. Also, provided an engineering in STEM framework with research and practical recommendations. The start of the new millennium has witnessed great scientific advancements that are affecting every division of people's social and economic foundations and economies. Engineering in STEM education is considered one of the main priorities that is recently emerged as a direct reflection of such scientific growth. STEM education integrates concepts that are usually taught as separate subjects in different classes and emphasizes the application of knowledge to real-life situations. For the STEM learning environments, we are specifically referring to classrooms or schools where conscious and overt efforts are made to coordinate the learning objectives and learning activities of two or more of the STEM disciplines.

Keywords
STEM education, STEM frameworks, engineering education, and K-12 education

Introduction

Meaningful transformation of students' learning occurs when a focus on developing the learning process is based on their interests, as in the goal of science in society, projects in technology, designing in engineering, creativity in arts, and real problems in mathematics (Forawi, 2018). The transdisciplinary curriculum is the strongest and most complex integration of knowledge where the boundaries between subjects are blurred (Drake & Burns, 2004). The start of the new millennium has witnessed great scientific advancements that impact every division of people's social and economic foundations. STEM education is considered one of these priorities that is recently emerged as a direct reflection of such scientific growth (Kelley and Knowles, 2016; English and King, 2015).

The history of merging science, mathematics, and technology (SMT) in K-12 education took root in the 1980s during the Excellence Reform Movement, and was given voice start as early as 1983 through Studies such as A Nation at Risk Before It's Too Late, Rising Above the Gathering Storm and Science in the National Interest which took into custody the dynamic forces behind science and mathematics education policy at different points in recent history (Wells 2016).

Science educators stress the importance of a cumulative interdisciplinary (Science, Technology, Engineering, and Mathematics) STEM education that motivates students to study about the universal globe throughout examination, investigation, and problem solving practices (Asghar et al. 2012). Consequently, many improvement initiatives have formed teaching and learning STEM disciplines. These improvement efforts comprise a move from plain instruction lessons and carry out secluded data and skills, to allowing students to practice knowledge as scientists, engineers and mathematicians. (National Council of Teachers of Mathematics 1989; 2000)

The growing interest in STEM education has resulted in federal policy initiatives and non-government grant programs that advocate for specific educational reforms and provide funding to develop educational experiences and curricula for students (Chan, 2010). Consequently, in the past two decades, STEM education policy documents have established common concern about the United States ability to maintain the highest economic privilege in a global market in which STEM disciplines play a vital role.

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STEM education integrates concepts that are usually taught as separate subjects in different classes and emphasizes the application of knowledge to real-life situations. STEM learning environments, we are specifically referring to classrooms or schools where conscious and overt efforts are made to coordinate the learning objectives and learning activities of two or more of the STEM disciplines. A lesson or unit in a STEM class is typically based around finding a solution to a real-world problem and tends to emphasize project-based learning. A pressing need remains on how to articulate STEM education vision to the school curriculum and student learning to better the future. Instructors report that the most predominant barrier to the adoption of reformed teaching strategies include; insufficient time to learn about required reformed teaching strategies, limited training in the use of reformed teaching strategies, lack of resources available, uncertainty with the practice, and the absence of institutional support (Henderson and Dancy, 2007; Czajka and McConnell, 2016).

Engineering education assists development of engineering ''habits of mind'' including systems thinking, creativity, optimism, collaboration, effective communication, and ethical considerations [1]. Engineering design education is the fundamental part of the Next Generation Science Standards (NGSS) framework, which was developed in an effort to produce K-12 science standards rich in content and practice that are coherent across disciplines (AAA, 2013). The NGSS indicates that students are required to develop the capability to carry and transfer knowledge across science disciplines through modelling, planning, conducting investigations, analyzing and interpreting data, and constructing explanations to demonstrate understanding of core science ideas (AAA, 2013).

As there are many approaches to incorporate the implementation of STEM into the educational system, each country shares a different political, social and cultural history and views that are reflected within their educational structures, and thereby the way STEM can be incorporated. Despite the fact that there is no single view regarding the ideal method for subject integration and STEM implementation, this research presentation will discuss the theoretical frameworks and models that deal with the STEM integration process for curricular and program inclusion. Examples of those theories and models are Zeidler et al.'s (2005) Socio-Scientific Issues (SSI), Berghout's (2011) Islamization of Science Model, Clarke and Hollingsworth's (2002) Interconnected Model (IM), and Dugger's (2010) STEM Implementation Theory. A closer look into how such frameworks can be linked to the UAE context for planning and suggesting effective programmatic and pedagogical STEM education experiences to teachers and students.

Due to the continuing interest of the STEM topic, numerous in-depth studies have been conducted about different aspects of STEM education. Several papers discussed the essence of STEM education and STEM literacy (Bellard, Walker, & Kim, 2017; Stevenson, 2014). Other studies have addressed students' perceptions toward integrated STEM (Allaire, 2017; Gehrke & Kezar, 2017). In addition, Gouia-Zarrad and Gunn (2017) and Hamilton et al. (2017) studied in-service and teachers' preparation for and attitudes toward STEM education.

Therefore, the main purpose of this descriptive paper was to critically evaluate and discuss STEM contexts and frameworks with their connection to improving K-12 education practices. In particular, the key question was addressed through a critical literature review to pertinent STEM documents and studies: What are the main frameworks of STEM education that are appropriate for enhancing K-12 student learning?

STEM Frameworks

STEM education have been the center of attention in education, mainly in successful strategies to organize students for an effective, higher quality learning in STEM-related industry (Anon 2016). To come up with an effective cross-disciplinary fields require to revisit the theories of Dewey (1916), Dienes, Lesh (2003), and Capraro (2014) to observe how they their work relate to STEM education. Relying on the thoughts of these theorists and the individuals that contain prolonged on their work, this paper will illustrate the individuality of effectual STEM learning fields with a focal point STEM strategy implementation. purposely, we will dispute that for the instructional situations to be successful they must significantly put together the STEM fields, support cooperation, offer the students a genuine and real life environment in which to employ STEM content, moreover allow students a numerous access to the concepts and give them confidence them to articulate the concepts in various modes of representation. Table 1 shows Drake's and Burn's (2004) different levels of subject integration, fusion, multidisciplinary, interdisciplinary, and transdisciplinary. The model identified categories of integration and the primary assessment concern for each category. Interestingly, Drake was concerned that the primary assessment of the transdisciplinary is the authentic assessment.

Dewey, Dienes and Lesh provide the theoretical that make the most of the relations between the disciplines in incorporated STEM lessons or schools during operation and explanation of theory. Therefore, the initial footstep in construction an effective STEM instructional setting at any point of the significant incorporation of the disciplines and once incorporated the trouble within subjects will precisely be similar to practical situations. Dewey's (1916) which is substitute to divide disciplines, he was very cautious to make clear that it was not advocating career training. As he states, "the only adequate training for occupations is training through occupations". Dewey's (1916, p. 297) in this approach, instead of testing students with uncomplicated, simplified problems, students are given multifaceted, realistic problems that are "simulations of real life experiences" (Lesh & Harel, 2003, p. 158). Lesh and Dewey believed that students' tribulations in school must be based in the existent life situations, but all theses theorists agreed students must work collaboratively. Nevertheless each theorist reached it from a slight dissimilar point of view. For Dewey (1916, 1938) education is communal in nature and serves a purpose within a democratic system. Therefore, students supposed to proceed and deserve to be considered like members of the public and have the same immunity for the representative of an independent society requiring the students to work mutually as the public student. According to Lesh, authentic interdisciplinary problems exterior of school are frequently approached by group, especially when different areas of expertise need to solve the problem.

Table 1. Drake's integration categories

Approach	Definition or Description	Characteristics	Primary Assessment Concern	Features Equivalent Across All Inter-disciplinary Approaches
Fusion	Something is fused to an already existing curriculum. Infusion of a content area, thinking skills, arts techniques, etc., would mean these were taught within every class.	A focus that is embedded into all school life.	Subject specific	Mapping backwards design—using standards Exemplary teaching/ learning strategies
Multidisciplinary	*Multidisciplinary* approach is additive, not integrative. The disciplinary perspectives are not changed, only contrasted. Team-taught courses in which faculty provide serial lectures are often multidisciplinary.	A focus on the concepts and skills of each of the disciplines independent of the others.	Disciplinary concepts and skills	Set in student-relevant real-world context as much as possible Performance demonstrations as well as standardized assessment
Interdisciplinary	*Interdisciplinary* is when students and instructors come together to analyze differences in disciplinary approaches to a problem and to work toward a synthesis resulting in a new, more comprehensive view than allowed by the vision of any one field.	A focus on common concepts and skills across the disciplines	Common concepts and skills across the disciplines	
Transdisciplinary	*Transdisciplinary* approaches provide holistic schemes that subordinate disciplines, looking at the dynamics of whole systems (i.e., place-based education).	Real world context and student questions; life skills	Authentic assessment in a real life context	

For this reason, it is reasonable for students to also move toward their problems in groups. Adding to this cooperation also adds the advantage of improving communiqué and meta-cognition. Dienes was also encouraging of team work recognizing the significance of the community characteristic of learning (Sriraman & Lesh, 2007). Connecting this importance on the relations and explanations between disciplines with the format that the disciplines themselves are demonstrations of the wider concept of STEM can leads to the STEM Translation Model, which proposes a way for conceptualizing STEM thinking and STEM learning.
Capraro (2014) stated that there are several approaches to develop and implement STEM education. They are indicated in Figure 2 below.

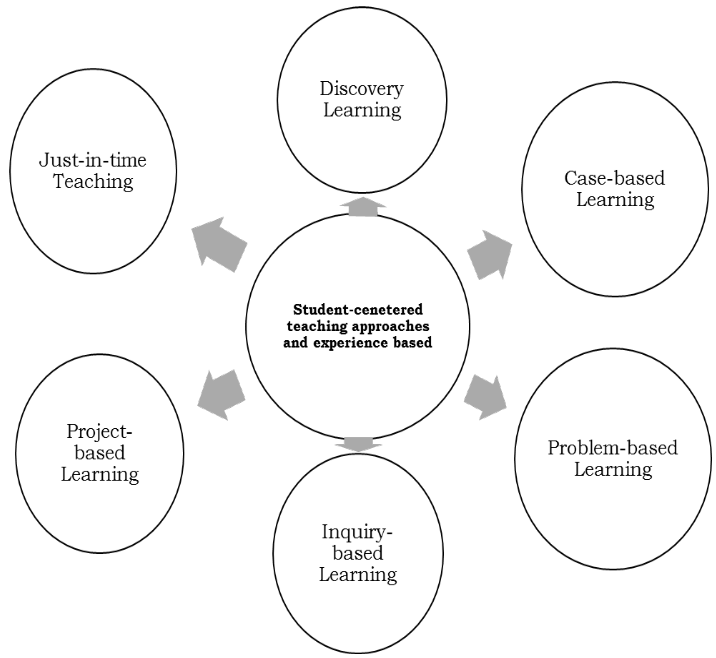

Figure 1. Capraro STEM interdisciplinary approaches

STEM Problem-based Learning Approach

Barrows' (1986) taxonomy of problem-based learning methods. Learning is driven by challenging, open-ended problems with no one "right" answer. Problems/cases are context specific. Students work as self-directed, active investigators and problem-solvers in small collaborative groups (typically of about five students). A key problem is identified and a solution is agreed upon and implemented. Teachers adopt the role as facilitators of learning, guiding the learning process and promoting an environment of inquiry

National Science and Technology Council's 5 Year STEM Strategic Plan

A report from the committee on STEM Education National Science and Technology Council developed a 5-year strategic plan (2013). Many of the CoSTEM agencies, that placed a high priority on STEM education and by developing education initiatives unique to their agency's mission, needs, and resources. To better leverage these assets and expertise, this STEM education strategic plan, demonstrated an extensive cross-agency collaboration, to articulate a strategy for making progress on this national priority. The report offered several reasons for the call, two of which is the potential professions are STEM job second US K-12 system is "middle of the pack" in international comparisons the report also added that development on STEM is significant to construct a just and comprehensive civilization (Anon 2016).

Federal strategy reports provide a mean of movement by which Congress and other vested parties advance their agendas (Spillane 2008), thus understanding the ways of constructing strategies in which curricula and reform of education can be implemented may help to achieve the set goals. This analysis is of particular importance to the potential shift in STEM education, the Framework for K–12 Science Education: Looking toward the Future of Science Education (Schweingruber, Quinn, Keller, & Pearson 2013), and the Next Generation Science Standards. (NGSS Lead States 2013). The Plan begins by providing an overview of the importance of STEM education to American scientific discovery and innovation, the need to better prepare students for today's jobs and those of the future, and the importance of a STEM-literate society (section 2) and also describes the current state of Federal STEM education efforts (section 3). The document then presents five priority STEM education investment areas where a coordinated Federal strategy can be developed, over five years, designed to lead to major improvements in key areas. This increased coordination is intended to lead to maximum impact and, as it is implemented, will lead to strategies for closer and more effective coordination among agencies with STEM investments (section 4).

The STEM Project-based Learning Approach

For this project students must be equipped with problem solving skills to be able to find solutions for upcoming problems due to technological advancements; information is available, no place for memorization, and that there is a need to develop acquire new information and project outcomes based on observation and analysis made; machines availability reduced the requirement of unskilled workers. The importance of this approach is to provide the structure needed to formulate the best solution possible and further develop the problem-solving skills. The figure below demonstrates key steps of the STEM project-based learning approach.

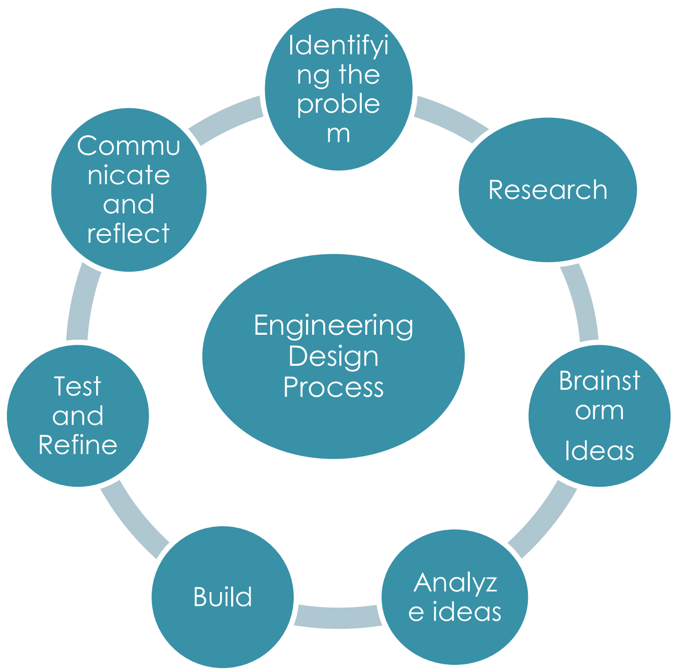

Figure 2. STEM project-based learning approach

Some of the benefits of the STEM project are 1- capturing students' interest by video clips, role player,…etc, 2- Students should consider the big picture when creating or communicating their design, 3- Teachers provide guidance were needed by providing open-ended questions, 4- Key component of PBL is effective and contentious written and oral communication, and 5- Evaluation and developing metacognitive skills to develop and improve their project design. Students engage in solving ill-structured problems where critical reflection, communication and collaboration, and the challenges and innovations of integrated knowledge in specific content, are integral aspects of learning (El Sayary, Forawi & Mansour, 2015).
Establishing STEM schools boost student achievement in science, mathematics, technology and engineering. Supporting this claim, STEM banner is presented by main national councils in USA as a strategic solution for low achieving students (NRC, 2011; NSB, 2010; AAAS, 2009; NCTM, 2006; NSTA). STEM schools in USA have solved the major issues related to low attainment in standardized tests, to the decrease in interest in STEM disciplines and to the underrepresentation of females in STEM careers. All recent studies done by Sahin et al.(2015), Bicer et al.(2015) and Bicer et al.(2014) are excellent examples of citing the difference in students' performance in T-STEM versus non T-STEM schools. Additionally, the Dubai STEM School will further provide authentic learning experiences, advance student performance in international exams, and recuperate career and technological educational (CTE) choices.

A study conducted by Hernandez et al. (2014) identified STEM education as a national priority. STEM schools are identified as the best solutions for the major dilemmas in US which is threatening the stability of its economy on the long run such as low performance of students in TIMSS and PISA, shortage of STEM graduates, and increase demand of STEM job in workplace. In this era, scientific skills are essential demand for all students regardless of their majors

(Sonyel and Perkanzeki, 2014; Hernandez, Bodin, Elliott, Ibrahim, Rambo-Hernandez, Chen, Miranda, 2014; Gasser, 2011; Sadler, 2010)

Modify the Texas STEM (T-STEM) system. The academies in the T-STEM system have been expending rapidly from 6 T-STEM academies in 2006 to 65 T-STEM in 2014 in Texas. The three types of T-STEM academies serving 35,000 students and 2800 teachers are: selective T-STEM schools, inclusive T-STEM schools and STEM-focused career and technical education (CTE). Now the T-STEM program reached a high level by almost 20% increase. Selective T-STEM: These schools serve only highly motivated and able students and focus on preparing them for ambitious postsecondary study and STEM careers. Inclusive T-STEM schools: These schools do not have admissions requirements but offer specialization in one or more of the STEM disciplines. Many have the mission of helping students from population subgroups who are not well represented in STEM fields prepare for college study and STEM careers.

STEM-focused career and technical education (CTE) may be offered in high schools that make this a theme, in such programs as career academies within comprehensive high schools, or in regional centers that serve many schools (Stone, 2011). Such programs are designed to prepare students for a broad range of STEM careers and often focus on engaging students at risk for dropping out of school.

Discussion and Conclusion

This research study provides a clear definition and purpose of STEM for K-12 students aligned with ample research literature. Pre-service, in-service, and administrative leaders can use this information to articulate the meaning, goal, and purpose of STEM within their K-12 school's curricula. Doing so will allow for better collaboration and less confusion among the in-service teachers within the schools and better mentoring of teachers. The articulation could be completed within in-service teacher preparation for the implementation of STEM, through continuopus professional development (CPD) during which the meaning, goal, and purpose of STEM could be presented by administrators and further developed with input from the teachers.

On a global level, STEM has served the strategic goal of presenting the country as modern, competitive, and innovative among the world's educational leaders. Given the size of the government bureaucracy and the lack of capacity within the national cadre to address this challenge, a new entity built on private sector ideals was established to bring about changes that traditional government institutions were unable to introduce. Non-state actors in the form of technology companies, advisors, and other educational institutions were brought on as partners to support the policy process and bring about this transformational change. Notwithstanding the role of private and other external actors, particularly in the implementation phase, and the potential influence they may have behind closed doors, national policymakers continue to preserve their central role in decision-making and to maintain strong ownership of the program. This is critical to strengthening the country's national identity among its small national population. These factors allow it to determine the model and content of the partnership to best suits its needs.

The implications of this study may influence several different groups focused on educational outcomes. Specifically, policy writers and grant funding agencies, public and private high schools' administrators and teachers, higher education faculty, and educational researchers may all find valid information within this meta-analytic research study. Policy writers and grant funding agencies could benefit from this study by knowing increased research is needed in engineering, higher education STEM student perceptions, and higher education STEM course constructs.
In conclusion, for the effective implementation of STEM in K-12 education, it is important to inform educational administrators at both state and federal levels, as well as local school administrators, to advise future decisions on policy and standards concerning integrated STEM courses. School district administration should encourage and support STEM programs at the K-12 level because it can potentially increase the number of STEM courses that can be offered at the high school level. Business and industry leaders, as well as universities, should become more invested in assisting K-12 schools with resources and teacher training. School districts should provide extensive, compensated professional development for current in-service K-12 school STEM teachers on best practices in planning and implementing integrated STEM courses in the K-12 grades, and provide continued support and training in subsequent years.

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Biography

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