Introduction of the STEM Educational Concept, and the Barriers associated with its Implementation within School Curriculum

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Abstract

Recent technological developments have served the purpose of connecting researchers and academic researchers across the globe, bringing them together in a new era of scientific globalization. Numerous researches have been conducted for the improvement of scientific education. Discussions surrounding the improvement, reformation and development of STEM-oriented curricula have become a growing necessity. This study aims to introduce and educate Arab nation about the importance of STEM education and to present different ways of integrating the methodology to middle school curricula. It may be achieved through the development of programs that aid educators in implementing and integrating STEM fields in the learning process of a student. It is important to recognize that one of the most important goals of education at every level, is to support and strengthen the disposition of learning throughout life, and this process is aided by the STEM program.

Keywords: STEM; Educator; Science; Curriculum; NSF; Technology.

1. Introduction

Historically, the concept of science-oriented education has been evidenced by National Society for the Study of Education, since the 1960s (Hurd, 1960) and has existed as a goal in American schools since 1920 (Karakas, 2010). However, the recognition of such science-oriented education as a necessity was not brought to the forefront until recent technological advancements in the field of education and globalization. Since then, numerous researches have been dedicated to explore different ways in which the art of disseminating scientific education may be reformed and improved in accordance with the need of today. Such researches have targeted the galvanization and development of new curricula incorporating science-oriented education. In 1990, National Science Foundation (NSF) initiated the use of the term “SMET” as an abbreviation for addressing individual subjects as “science, mathematics, engineering, and technology.” However due to negative feedback from the NSF program officer, this abbreviation was changed to “STEM” (Science, Technology, Engineering and Math). There has been a rise in interest in STEM-oriented instructional models across the instructional landscape. It can be seen through the dedication of energy and educational resources towards developing programs that attempt to integrate STEM individual content areas into a unified curriculum to offer a greater connection to the real world through providing students with authentic purposes for learning and solving problems (Lawrenz, Huffman & Thomas, 2006).

Earlier curriculum organization was mainly initiated and funded by NSF; recent developments have led to the support of such curriculum organization through a variety of different foundations, professional organizations, universities, publishers, school systems and producers of educational materials among different groups and individuals (Kuenzi, 2008). Numerous universities are researching ways of restructuring science and engineering curriculums, as a way of initiating STEM models. This restructuring process has additionally been noted in secondary school systems, where various modifications to existing curriculum is being made. Educational literature contains resourceful references to STEM
initiatives, and consultants and entrepreneurs are targeting the educational market place to aid the introduction and implementation of effective STEM programming.

It is to be noted that despite the increasing awareness regarding the vitality of STEM education, these fields are facing many complications in producing adequate numbers of STEM graduates to fulfill the workforce needed in these fields. This may be seen in studies that there has been an international decline in the percentage of high school students’ interest and enrollment in science majors (Dani, 2009). It is worth mentioning that a majority of these students express dwindling interest in pursuing STEM-oriented careers, especially engineering, due to lack of initial exposure to these subjects in their formative school years. However, the most prominent issue faced by science educators globally is their lack of training regarding integrating relevant STEM topics into their teaching material and curriculums (Ronal et al. 2010.)

The main purpose is to introduce and educate the Arab nation of the importance of STEM education and to present the different ways of integrating this methodology in middle school curriculums. It can be achieved by developing programs that aid educators to implement and integrate the myriad fields of STEM to eventually meet the demands of teaching the modern student. It is important to recognize that one of the most important goals of education at every level, is to support and strengthen the disposition of learning throughout life, and that process is aided by the STEM program.

2. STEM Education

It was noted by studies that the vision of STEM education, or meta-discipline, relies on the integration of a mix of disciplinary knowledge to form a unified curriculum (Asunda, 2011). The unification of the curriculum is a way of promoting education in areas pertaining to science technology, mathematics and engineering in order to equip students with the knowledge they need to pursue STEM-oriented fields in the future. The history of STEM education was established by the process of integration and combination of respective subjects by academic organizations such as the National Council of Teachers of Mathematics (NCTM), the American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the International Technology Education Association (ITEA) in an attempt to develop national standards that enhance student learning and STEM preparation. It is to be noted that STEM is not merely an amalgamation of aforementioned disciplines; rather, it is a broad field that provides a greater understanding of the real world through authoritative purposes for learning and problem solving. As an example, NSF defines STEM as an incorporation of social/behavioral sciences as psychology, economics, sociology, and political science in addition to the common categories of STEM as natural sciences, engineering, mathematics and computer and information science (Green 2007). Implementing STEM education help removes the traditional barriers between the four educational subjects, aiding a teaching and learning experience that helps students to making sense of their education by linking it to real-world applications (Lantz, Jr., 2009).

3. Importance of STEM Education

Recent advancements in the level of scientific and technological innovations mean that knowledge pertaining to these arenas has become increasingly essential today. Moreover, these developments mean that it is a necessity for students to acquaint themselves with scientific knowledge in a way that was not as required in the past. This was addressed in a study that stated “If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950s, it would have to be inquiry” (DeBoer, 1991). The nature of the relationship between teaching scientific methods and scientific inquiry in a classroom has been an ongoing debate among educators in different fields.

In fact, a variety of studies have expressed concern regarding the dwindling scholastic interest in STEM-oriented fields and laid emphasis on the necessity of student engagement in the classroom. It was discussed by Coffey et al. (2013) in a study pertaining to the complications in educating and learning science-oriented courses that a primary factor for the growing disinterest in this field was the utilization of traditional discrete teaching methodology. This study discussed that such methods had an adverse effect on the students and drove them further from the acquisition of productive inquiry and class involvement. This was further corroborated in an additional study that recommended the use of student-centric education over traditionally structured lectures in order to re-vitalize the learning process and help students learn science-oriented subjects in a more productive manner (Levitt, 2002). The distinction between traditional teaching approaches and inquiry-based instruction was demonstrated in a comparison study at a junior high school in Taiwan, which aimed to compare the effects of the two teaching methodologies. The results illustrated that the inquiry-based student test group scored higher than their counterpart group and demonstrated keener understanding and attitudes towards the subject matter (Mao & Chang, 1999).

In 2009, the Obama administration launched the Educate to Innovate campaign that sought to equip public-private partnerships for the improvement of STEM education within United States. Three major concerns were identified. Firstly, it was deemed essential to increase STEM literacy to enhance scholastic critical thinking. Secondly, it was necessary to improve the quality of teaching, when subjects such as mathematics and science were being taught. Lastly, it was considered essential to expand the sphere of STEM-oriented education and conduct developments in the field so that women and other minority groups could be provided with opportunities to participate in this sector (Prabhu, 2009; Asunda, 2011).
As discussed earlier, it was deemed necessary for the implementation of STEM-oriented education in schools that a more active learning approach towards these courses should be adopted. It meant that it was highly relevant to make use of various interactive approaches in order to develop an educational setting where students are encouraged to inquire about scientific concepts and theories. This approach would aid in inducing the development of skills such as inquiry, curiosity, critical thinking and creativity in students that are exposed to such a learning approach. These skills are not only integral to the future success of these individuals within their educational settings and work environments, but they shall help them to attain a keen overall understanding of the world around them (Asunda, 2011). This may be indicated through a meta-analysis pertaining to integrated curriculum research that students that were educated using an integrated curriculum were able to achieve far better targets than their counterparts who were only taught singular subjects (Hartzler, 2000).

It is to be noted that a student’s middle school years serve as the foundation for intellectual development. Thus, it is essential to acquaint students with STEM-oriented subjects during their formative middle school years. This was corroborated by studies that discussed the importance of implementing STEM-oriented courses well before high school years (George et al., 1992). Introducing knowledge pertaining to STEM at an early age enables students to develop an interest in these core subjects and instills the skills required for a successful career, since most occupations require proficiency in science, math, and logical thinking prior to engaging in problem solving (Hartzler, 2000). A further investigational study by Knezek et al. (2013) explored six different middle schools across different states of the US in order to study the effect of middle school hands-on genuine project activities on students’ STEM content knowledge and perceptions. It was seen that in addition to increased conceptual knowledge, students witnessed an improvement in their creative tendencies and perceptions regarding STEM (Knezek et al. 2013). This therefore means that promulgating scientific knowledge at an earlier age helps expose students to conceptual knowledge earlier and enables them to develop the essential skills needed to combat real-world problems.

4. STEM as a Curriculum Concept

Commonly adopted teaching approaches revolved around the implementation of ‘separate concept curriculum pattern’, in which different subjects are taught separately through the utilization of a knowledge transmission procedure. The educator teaches each subject by assigning tasks to be followed rather than following an inquiry-based approach to teaching. This is disadvantageous because the creativity of the student is not challenged if such a teaching approach is implemented. Furthermore, using the separate concept curriculum pattern means that the interrelationships between the courses are not explored even though they may be linked in several ways. These disadvantages may be overcome through the utilization of an integrated curriculum design when teaching STEM-oriented subjects. Such an approach explores the interrelationships between different subjects and helps students gain clarity on the way such knowledge may be implemented in real-world applications (Herschbach, 2011). Modifications in curriculum are the need of the moment; such modifications incorporate reformations in educating and learning methodologies. STEM-oriented programs and courses are commonly incorporated in educational curricula. However, as discussed earlier, proper implementation of such programs is needed through the utilization of a specialized curriculum model that may be followed. This model may extend to be used for any educational approach that may be relevant to science, technology, engineering and mathematics and is thereby called STEM innovation (Herschbach, 2011).

5. Implementation of STEM

Despite the international concern in STEM education, little discussions have been made regarding STEM’s exact meaning in terms of a curriculum concept and the way it should be implemented in schools as part of the assigned curriculum (Herschbach, 2011). When it comes to the design, development or reformation of the curriculum, there are three considerations that must be taken into account; the society, its students and the subject of matter (Tyler, 1950). When considering the support for a STEM approach into a curriculum design, people must bear in mind that school curriculum structures are very resistant to change. A very progressive curriculum approach would be required in order to be able to shift the usual educational arrangement that incorporates science, technology and mathematics courses, to an integrated form in order to provide students with STEM-essential knowledge (Avery & Reeve, 2013). Dugger (2010) argued that there are multiple ways to implement STEM in schools that depend on the capability and resources of each school, country or region. The first approach is to maintain following the traditional way of teaching the four disciplines of STEM (Science, Technology, Engineering and Math), that is, as each distinct subject. The second approach, which is considered as the most common method used in the United States, is to teach each of the four disciplines individually with prominence to one or two of the four subjects. The third way is to integrate one of the STEM disciplines into the other three, such as integrating engineering aspects into science, technology and mathematics. Finally, a more radical approach is to combine all four aspects into a single integrated subject matter (Dugger, 2010).

Herschbach (2011) described two ways to integrate STEM in school curricula. The first is the correlated curriculum pattern approach, where each subject area retains its separate identity with coordination among the different stand-alone subjects. The challenge of this approach is the high level of the on-going coordination required from the educator’s side, in order to make sure the students are on the same page in all subjects. Additionally, organizational modification of the subject might be required to meet the requirements of coordination with other associated subjects. The second method is the broad fields
pattern approach, where different related subjects are integrated into a single area of study through a single course or with a sequence of related courses. The primary challenge associated with the broad fields curriculum design is to create an effective organizing framework for instruction, which is difficult to retain and convey through an integrated curriculum design (Herschbach, 2011).

The decline of United States position in global economy is partially linked to the lack of fundamental knowledge of its people in STEM fields. In 2012 the National Research Council released A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas to guide the development of the Next Generation Science Standards (NGSS). The goal was to propose new scientific approaches in order to enhance students’ interest in STEM fields and ensure that by the end of grade 12, students would possess sufficient knowledge in science and engineering to engage within their daily lives. First, the framework escalates on the idea of learning as a developing process. This is done by encouraging students to build upon their previous knowledge and abilities when learning so that they may be guided towards a logical view of learning and understanding STEM subjects. Secondly, the framework focuses on reducing the amount of core ideas in each of the STEM subjects. This gives students and educators the opportunity to go through each topic in depth and helps them to connect the knowledge gained in one course with different disciplines. This increases the depth of students’ scientific engagement, investigational and argumentative abilities and therefore contributes to a deeper comprehension of the core ideas presented. Thirdly, the framework intends to address the significance of the collaboration between knowledge and practice when designing scientific learning experiences (NRC Framework for K-12 Science Education, 2012).

It was discussed in studies that the key answer to educational progression did not lie in simple isolated efforts to radically implement STEM subjects in school curricula. Rather, teachers play an essential role in the preparation of a scientifically literate population, one that is qualified to overcome the twenty-first century demands (Dani, 2009). Educators are constantly faced with new challenges, new methods of communication, technology, and teaching practices especially with the rise of the global competition of STEM curriculum integration. In this educational era, teachers require a certain set of new skills and knowledge necessary to begin integrating technology and engineering concepts into their classroom practices (Rockland et al. 2010). As the need for students to become stronger in STEM grows, so does the need for well-qualified STEM teachers that understand what is needed to develop relevant and high-quality STEM programs. Provision of professional development (PD) programs for teachers is therefore vital to the adequate implementation of STEM-oriented programs. Efforts to provide opportunities for those involved in the teaching of STEM is required, so that science educators may learn how to effectively integrate various instructional approaches and teaching techniques, such as engineering design in their teaching and learning environments. This will help promote a deep understanding of the subjects of matter along with the best pedagogical practices to facilitate student-learning journey (Avery & Reeve, 2013).

6. Barriers of STEM education

Integrated curricular design is not a twenty first century feature; it has emerged since the 1920s as a part of school programing era (Kilebard, 1987). At that time educators in charge thought that subject integration would take away the intellectual characteristics of integrated subjects and therefore focused on the development of individual subject teaching and learning schemes, that were built on instructional modes. This educational environment is built on developing separate subject orientation methodologies, and results in students being constrained by course content restrictions and school/teacher boundaries. Academic achievement is mainly determined through testing the scored results in each independent subject rather than focusing on making such education relevant to the students. This means that students are gradually losing interest in STEM-oriented subjects (Herschbach, 2011). The recent call for subject integration programming implied by STEM creates a number of practical programming issues that are yet to be resolved, making it unrealistic to expect success in a short-term period, especially in secondary schools. Hence, the STEM initiation must be approached with caution and a careful gradual long-term plan. Some of the barriers to the implementation of STEM integration program are as outlined below.

6.1 The Concept of STEM

The indefinite definition of STEM and the many possible ways of implementing it, and the fact that there is no solid prescription or curriculum practices to implement have resulted in disorganization, incoherence and reluctance, posing a problematic challenge to all educators, schools, countries and societies (Williams, 2011). Moreover, the lack of a unified implementation structure makes it difficult to assess the quality and success of the newly implied program. Anderson-Roland et al. (2002) described that the ongoing educational system associated with the pressure of assuring the standards of academic content implementation are associated with high-stakes state-wide assessments, were barriers to the level of curriculum change or modification within science instructions.

6.2 Lack of Meticulous Math and Science Standards

There is no standardized curriculum for teaching mathematics and sciences across the countries. Currently adopted teaching approaches focus on the fulfillment of the assigned requirements rather than paying attention to students’ abilities and roles
in using their conceptual knowledge to solve real-world problems. This widens the barrier to a unified and upgraded STEM program.

6.3 Teachers Content knowledge

The quality and quantity of curricular materials in STEM subject areas are scarce. Educators have not yet been trained or experienced to combine individual STEM subjects into their curriculum and instructions. This is especially relevant to individual secondary teachers, who lack the skills and knowledge that are necessary to teach STEM-oriented subjects. This shortfall in the numbers of qualified teachers is a chronic problem. However, it is unfair to expect individual teachers to promulgate an integrated approach without providing them with the essential training required to cover a wide range of academic concepts and principles while making meaningful connections between various academic subject areas (Williams, 2011). Teacher preparation programs are not keeping pace between the ongoing curriculum developments strategies and students’ needs.

6.4 Insufficient Student Preparation for Post-Secondary STEM study

It has been noted that there is a great dissonance in the quality of mathematics and science-oriented education in the formative schooling years of a student. Therefore, a majority of students that have not been exposed to such challenging courses from an early age are unfamiliar with advanced student-centered teaching techniques. Such students lack the confidence and practice required in relying on their inquiry skills to come up with creative problem-solving ideas. These students are not capable of pursuing STEM-oriented post-secondary education and need special preparation programs to be able to understand and practice STEM skills.

6.5 Failure to Motivate Students’ Interest in Math and Sciences

In most school systems, math and science subjects are disconnected from other subject matters; students often fail to resemble the relevance of these subjects within their daily lives. Most students and parents believe that STEM subjects are too demanding, tedious or exclusionary and therefore there is a lack of interest in pursuing in STEM fields (Hall et al., 2011). There is a significant role to be played by the teachers and parents of such students in order to help their intellectual and creative development in such fields of education.

7. Recommendations

In order to improve math and science education and inspire students to study and pursue their careers in STEM fields, it is necessary to have the government’s commitment and support. There needs to be a radical change in curriculum implementation. The first step in achieving STEM education is to firstly introduce conceptual knowledge regarding STEM to students, the society and educators themselves. Change toward subject integration should take place within stages and through gradual steps. Improving STEM education within Arab society is associated with providing opportunities for excellence to the next generation and the future of society as a whole.

Governments need to increase their investments in encouraging educational agencies to help students gain a solid foundation in STEM subjects and related disciplines. This may be done by developing and implementing a public awareness campaign to raise the prominence of STEM and the promising future it holds to individuals and society as a whole. Additionally, it is essential that local educational agencies be given the flexibility to adopt current and updated educational policies, guidelines, and judicial initiatives regarding curriculum and instructional advancements and enrichment. Furthermore, encouragement of public-private partnerships needs to be provided. This will enable the coordination of public and private educational sector stakeholders regarding the enhancement and implementation of STEM education within school curricula throughout the primary, secondary and post-secondary levels. It is also necessary to focus on strengthening the areas of curriculum design and instruction, by providing curriculum-developing programs to ensure appropriate STEM curriculum integration. STEM institutions need to introduce the concept of STEM innovation to students by providing after-school STEM-oriented programs and activities. This will aid in the introduction of an integrated approach to STEM learning and help the students consider the real-world applications of the knowledge acquired.

Aside from these, it is also essential to develop and support effective STEM Professional Development programs for teachers through: redesigning current preparation programs to provide more instruction and concentration in science and mathematics; developing science preparatory measures and support for research-based STEM preparation especially for general education teachers at elementary and middle school levels, who have the most contact with potential STEM innovators during their formative years; developing strong standards and evaluation systems for professional development programs in STEM areas, with motivational rewards to those teachers who are dedicated in improving their instructional practice; providing incentives to students and teachers in the STEM disciplines through scholarships, fellowships or residencies for high school students to pursue their careers in STEM; and encouraging coordination between different schools in order to form new school models, relations and networks.
8. Conclusion

Despite the international consistent efforts of governments, organizations and educators in STEM progression, there is still a lack of highly educated teachers, students and professionals in STEM fields. Researchers need to profoundly understand and measure the required change in current educational plans in order to develop effective firm strategies that can practically be implemented. It is to be noted that although educational innovations are complex and the process of proposing affirmative ideas is always exciting, translating such innovations and ideas into firm reality is fraught with challenges. In order to overcome the obstacles faced by STEM education implementation, there is a need to expose students from elementary to graduate levels to STEM-oriented education. It is the responsibility of the society at large to ensure that students are provided with qualitative STEM-based education. Exposure to a solid foundation in science, technology, engineering, and mathematics (STEM) at early educational stages at this point is crucial. Primary teachers are already geared with basic knowledge required to teach all subjects, so an integrative approach in early school years is not such a radical move at this level. Students need to make demands of their educational institutions to teach STEM classes. Additionally, counselors, should promote students to pursue STEM fields. Educators are obligated to teach students the relevance of STEM in real-world applications. Furthermore, parents are required to instill a deep appreciation of the sciences in their children. Responsible organizations and educators need to consider new ways to think about schooling, its purpose, and the organization and presentation of instructions. The unrealized potential of the STEM initiative is that a new curricular reformulation will not only expose students to the way that formal knowledge is learned. Unfortunately, Arab countries lag behind with regard to such educational evolutions. Thus, it is necessary that a call for more regional research be made to improve scientific educational systems and keep up with the rapid development pace. As stated in a study, “improving education: emphasizing the acquisition, increase, and dissemination of knowledge, and empowering innovative thinkers are keys to economic growth” (El-baz, 2004).

Acknowledgement

The author is very thankful to all the associated personnel in any reference that contributed in/for the purpose of this research.

References


