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Using NGSS-based science and engineering practices in delivering STEM curriculum: Pedagogical approaches designed to innovate STEM education

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Abstract: This study aims to examinedifferent classroom instructional approaches designed based on the Next Generation Science Standards (NGSS) science and engineering practices to deliver science, technology, engineering, and mathematics (STEM) curriculum. At present, educational reform of science curricula delves into integrated STEM curriculum design and instructional design. Through using a qualitative document analysis methodology approach, this study analyzes the structure of the NGSS curriculum, the effects of integrating science-engineering approaches to student learning, and different instructional strategies to deliver content. STEM education is a means to encourage students to choose science-related careers, according to the findings in this study. Moreover, increased student engagement, learning, and interest were evidenced in many studies as a result of science-engineering integration.

Keywords: Educational reform, STEM education, Engineering Design, Instructional Strategies

Introduction

The call for innovative curriculum designs connecting different disciplines and refining teaching and learning stems from the need to address the challenges in promoting 21^{st}-century skills in schools. Selecting a suitable curriculum content is a crucial factor that affects the improvement of the educational system (Uchechu, 2013). The ever-evolving educational sector aims at equipping the next generation of learners with the knowledge, skills, and competencies required to face real-world challenges. The role of education is more critical now than ever due to the rapid changes in the economic, political, and social world. (Tan and Leong, 2014). Across the United States, for instance, there are urgent calls to implement science, technology, engineering, and mathematics (STEM) education (Hess, Kelly & Meeks, 2011; Atkinson, 2012). Judith A. Ramaley, former assistant director of the National Science Foundation, coined the term “STEM”(Doheny, 2011). One of the pressing concerns in the USA at present is establishing mechanisms to improve student achievement in mathematics and science. (Gnigue, et al 2013). Multiple studies reported sharp declines in the number of candidates interested in STEM education and of employed people in STEM-related careers. According to research, fewer students are opting for science-engineering careers. Increasing the competency of K-12 STEM education is a national priority. (Hernandez et al., 2014). STEM curriculum integration in the educational system can be a key solution to resolving the above-mentioned issues. (Gallant, 2011; Laboy-Rush, 2011).

Outlining the structure of STEM education, the Next Generation Science Standards (NGSS) emphasizes a set of science and engineering practices. As outlined in the NGSS, a STEM curriculum is extended to focus on designing instructions that encompass all STEM disciplines, as well as instructional strategies, and learning opportunities. The alignment between content and instruction is a need for this particular aspect. Quality education can be achieved only when content and curriculum are in line with instructional approaches (Snehi, 2011). To promote high expectations for student learning within STEM disciplines, adopting the best instructional practices in STEM education is a must. High student involvement and engagement in learning are demanded by the NGSS structure as students are required to articulate scientific ideas, apply real-world skills, and develop their science learning experiences rather than solely reciting facts. In education, developing students’ abilities and skills to model and create is closely paid attention to opposite to promoting memorization of facts (Sadler, 2010). Hence, there is a strong need for instructional strategies that promote student discourse and offer students a variety of opportunities to share and revise their ideas. Hernandez et al. (2014) state that enhancing students’ cognitive synthesis of the co-dependent nature of mathematics and science is the essence of true STEM education to generate improvements in engineering and technology.NGSS is designed to promote richness in content and practice, which serves as the foundation for designing STEM curriculum guidelines. (Kolar, et al., 2015)

Purpose and Research Questions

The purpose of this study is to scrutinize the structure of the NGSS curriculum and examine the effects of science-engineering integration on student learning, and the instructional strategies that should be used to deliver the content of a STEM curriculum. Exploring science-engineering integration in student learning remains as a main focus in addition to the instructional strategies used to deliver NGSS engineering-design content. Therefore, the study seeks to answer the following questions:

1. How is the NGSS curriculum structured to act as a foundation for STEM curriculum guidelines?
2. What instructional strategies incorporate science-engineering practices into classroom instruction?
3. What effects does STEM education have on student interest in science careers?

Theoretical Framework and Literature Review

This research study delves deeper into the structure of the NGSS curriculum, with a particular focus on STEM education. Researchers have been propelled to investigate the link between science-engineering education and choosing science careers with the recent calls for educational reforms. According to numerous studies, one of the crucial needs to successful education reform is utilizing instructional strategies focused on the pedagogy of integration. (Lachappelle& Cunningham, 2007; Fortus, Krajcik, Dershimer, Marx &Mamlok-Naaman, 2005; Kolodner et al., 2003).

The theoretical framework will discuss the theories of learning that support inquiry-based learning, whereas the literature review outlines the history of reform within STEM education, the NGSS structure, and research relating to STEM integration within education.

Conceptual framework

The conceptual framework presents an overview of the theories, frameworks, and research findings that underpin STEM education, curriculum structure, and pedagogical practices to the aim of this study.

The National Science Foundation (NSF) formed the acronym "STEM" which refers to science, technology, engineering, and mathematics. The goals of STEM are to cultivate future STEM experts, ensure a STEM-capable citizenry, build a STEM-proficient workforce, and close the gap between achievement and participation. STEM as an interdisciplinary approach aims at cultivating a deeper understanding of each discipline focused on the interrelated nature of science, technology, engineering, and mathematics. However, it is important to note that STEM is not restricted only to science, mathematics, engineering, and technology; it encompassesother fields of study, such as arts, social studies, and English language arts (Sanders, 2009; Bybee, 2010).

There are three reasons why STEM education is of high importance. First, it prepares all students for the challenges of the workplace and the demands of the 21st-century economy. Second, it improved the abilities and dispositions of K-12 students to solve real-life issues. Third, it cultivates a generation of STEM-literate citizens characterized by increased productivity, value, and innovation.

In delivering STEM education, establishing a well-structured curriculum in line with instructional strategies that promote student-centered learning is a requirement, including training highly-qualified teachers, and utilizing pedagogical approaches and technology-based learning tools. Efforts to establish well-designed STEM education components to inspire students in becoming more interested in STEM education are expected within schools. Students' lack of inspiration is a major obstacle that hinders STEM education to be successfully implemented (Ejiwale, 2013). If the learning environment is supportive of quality science learning, real-life scientific application, and integration of all disciplines, many students will be encouraged to pursue STEM-related careers. Student engagement in integrated disciplines allows for better opportunities to make sense of the world (Basham, Israel, and Maynard, 2010).

Curriculum and pedagogy are closely interrelated. A curriculum is a set of educational goals and content enacted by the teachers' pedagogical approaches and strategies. A curriculum is defined as a series of translations, transpositions, and transformations (Alexander, 2009). There is a strong link between curricula, instructions, and assessments. Alexander (2009) states that curricula, pedagogies, and assessments influence one another. There are four models of curricula: content-driven curricula, process-driven curricula, objectives-driven curricula, and competence- or outcomes-based curricula. STEM curriculum is identified as competence-based. Curriculum is defined as a dynamic interplay of doing., knowing, being, and becoming (Barnett and Coate, 2005). Yates (2009, p. 127) defines a curriculum as follows:

> Curriculum asks us to think about what is being set up to be taught and learned, what is actually being taught, what is actually being learned, why agendas are taken up or not taken up, who benefits and loses, whose voice is heard and whose is silenced, what future is being formed for individuals and what future is being set in train for Australia as a whole. Curriculum is concerned with effectiveness but also with expansiveness and voices, and who gets a say.

Activities that cause a change in the learner are components of pedagogy.Pedagogy is defined as "an activity designed by a person to enhance learning for another person" (Watkins and Mortimore, 1999). Bernstein (2000) defines pedagogy as a process of acquiring new forms of conduct, knowledge, practice and criteria from a provider. Pedagogy has two models, according to Bernstein: the performance model and the competence model. Alexander (2001) states that pedagogy is an act and discourse, whereas teaching is an act. A new dimension to the definition of pedagogy, is known as "effective pedagogy"(UNESCO, 2005). The creative, emotional, and social development in student learning is promoted through effective pedagogy, which results in quality learning. Many researchers (Alexander, 2008; Barrett, Sajid, Clegg, Hinostroza, Lowe, Nikel, Novelli, Oduro, Pillay, Tikly, Yu, 2007; Moreno, 2005; Barrow, Boyle, Ginsburg, Leu, Pier, Price-Rom, Rocha, 2007) define quality learning as the quality of human interactions in the classroom obtained through appropriate pedagogy. Indicators of quality learning arise after this understanding. Equity of learning (Leu and Price-Rom, 2006; Price-Rom and Sainazarov, 2010) and resources (Alexander, 2007; Barrett, Sajid, Clegg, Hinostroza, Lowe, Nikel, Novelli, Oduro, Pillay, Tikly, Yu, 2007) are identified as key indicators of quality learning.

Theoretical Framework

John Dewey (1910) developed the idea of using experiments in the early 1900s, which is based on transferring knowledge as a method to learn and explore scientific ideas. Dewey's idea was adapted by Robert Karplusin the 1950s, who started using an inquiry-based learning approach as a model for teaching science. Joseph Schwab suggested the learning cycle method in 1960, in which science instruction, inquiry, and science laboratory-based activities are used before introducing scientific concepts. Eventually, Marshal Herron formalized and developed the Heron scale in 1971.Bybee, adapted and developed the five steps for Inquiry-based learning (IBL) in 1997.

To deliver a STEM curriculum, there are three main approaches: problem-based learning (PBL), integrated units of instruction, and inquiry-based learning.

Inquiry-based learning (IBL)

Inquiry-based learning (IBL) is a pedagogical approach that enables students to experience the processes of knowledge creation.

Learning stimulated by inquiry, a student-centered approach, a move to self-directed learning, and an active approach to learning are the key attributes of IBL. Students learning through an IBL environment develop research skills and become life-long learners (Crismond, Gellert, Cain and Wright, 2013; Dalimonte, 2013; Lazaros and Borman, 2013). Through the IBL approach, students direct their learning through real-world science simulations to acquire advanced critical thinking skills. Students experience joy and self-satisfaction when they confront and solve real-life problems for which others have not yet found solutions (Gasser, 2011).Using science-process skills to discover information, students determine their chosen areas of inquiry and experience hands-on learning. A platform for providing IBL is a K-12 engineering curriculum (Ortiz, 2015). As a result, students' critical thinking is enhanced and they become responsible for their own learning, whilst simultaneously building a learning culture that values student ideas.

The study entitled "*Practicing What We Teach: A Self-Study in Implementing an Inquiry-Based Curriculum in a Middle Grades Classroom*", concluded that the IBL approach allows students to explore and discover scientific facts in multiple ways (Dias, Eick and Dias, 2011). Designing creative and relevant learning opportunities that connect students' daily life experiences is one of the important roles that teachers play, which contributes to using open forms of inquiry-based instructions.

According to Alan Colburn (2000), there are four approaches to inquiry: structured inquiry, guided inquiry, open inquiry, and learning cycles. In the structure inquiry approach, the teacher defines parameters and procedures for student inquiry. Students are provided with a hands-on problem, materials, and a procedure for investigation. Using the data collected, students can discover relationships between variables and are able to reach conclusions and make generalizations that result in the discovery of the expected outcomes.The second approach is guided inquiry, whereby, the teacher presents a problem for student investigation in addition to the necessary materials. In this approach, the students are responsible for devising their own procedure to solve the given problem. The third approach is open inquiry wherein students formulate their own problem and procedure. Science fair projects are one application of open inquiry. The last approach is learning cycles. In this approach, students are engaged in cooperative learning activities to unfold a new concept, after which the teacher explains the core idea. Students acquire new knowledge by applying it in a different context.

Problem-based learning (PBL)

Hmelo-Siver (2004) defined problem-based learning (PBL) as experiential learning focused on investigation, explanation and resolution of meaningful problems. PBL is a collaborative teaching approach that promotes inquiry and discovery among students within authentic contexts, allowing for multiple perspectives. Students are at the center of the learning process in this pedagogical approach, wherein the teacher acts as a facilitator and students collaborate to learn. (Etherington, 2011; Berland, 2013; Cutright, Evans and Brantner, 2014). Students retain information, develop lifelong learning skills, and explore real-life experiences through solving problems via the PBL approach.Klegeris and Hurren (2011) emphasize the impact of PBL strategies in increasing student-teacher interaction and improving student skills and competencies.

Klegeris and Hurren (2011) conducted a study that aims to investigate the impact of PBL in a large classroom size. The lecture strategy used to deliver the content was complemented byPBL activities to deliver the content. The findings showed that students who attended classes using the PBL approach were more motivated to attend, participate and attain compared with students learning in classes that adopted the lecture strategy. Diaz and King (2007) adopted an engineering curriculum and applied it to teaching mathematics in the elementary grades to study the impact on student achievement. To deliver the content, the PBL approach was adopted. Using innovative tools and manipulatives, students complete the tasks. The results of the study reported that participants who studied engineering did better in mathematics than those who had not. Based on these studies, STEM curriculum integration through PBL has a positive effect on students' interest level, motivation, and achievement.

Integrated units of instruction

An integrated unit of instruction outlines a set of learning objectives from more than one discipline. To connect different disciplines together, themes are derived from subject-based concepts. For an integrated unit, connections should be established in instructional planning for specific lessons and learning opportunities (Carr and Strobel, 2011; Cunningham, Lachapelle and Hetel, 2012; Cantrell, Pekan and Hani, 2006).

A study of integrated units of instruction was conducted by Burghardt and Knowles (2006). Engineering design strategies integrated with mathematics were used in teaching elementary-level students. The study revealed that significant positive change in students' attitudes toward learning mathematics.

According to researchers, the integration of science and engineering to deliver STEM concepts creates positive gains for students (Guzey, Tank, Wang, Roehrig& Moore, 2014; Hernandez, Bodin, Elliott, Ibrahim, Rambo-Hernandez, Chen and Miranda, 2014; Keeley, 2013; Lazaros and Borman, 2013; Lehman, Kim and Harris, 2014)

Theories and models

The social cognitive theory, communication theory, and the theory of discovery learning are three main theories with a direct impact on peoples' involvement and behavior.Bandura (1986), with his social cognitive theory, describes self-confidence as a key to taking action. Based on the strong points of students, confidence is cultivated. Self-efficacy is the ability to do and achieve. Students' confidence in their abilities, competencies, and behavior affects their self-efficacy. The educational designs can be linked to stages of readiness upon determining learners' self-efficacy level. Through recognizing students' progress, giving rewards, and reinforcing concepts when any task or subtask is completed, each learner's confidence is built. Confidence is reinforced when achievements are followed up and evaluated. When complex scientific tasks are divided into subtasks with specific milestones to identify their progress, girls gain more confidence in their scientific abilities.

Communication theory states that communication processes are central to encouraging or discouraging a certain behavior(Bettman, 1979; McGuire, 1984; Roger, 1983). The answers to such questions as "Who says what to whom and with what results?" guide effective communication. Interaction between people aims to influence their opinions, attitudes, knowledge, competencies, and behaviors. Enabling effective communication to achieve STEM objectives is influenced by the learning environment, the targeted audience, and the approach of the teacher. The effectiveness of the outcomes is affected by the method of delivering content. It is essential to communicate knowledge to engage students. Transferring knowledge to students using appropriate instructional strategies is a trait of outstanding teachers. With the appropriate instructional strategy framed for the STEM content, middle school girls are guided on what to think about and how to think about it. What attracts girls are the pedagogical approaches adapted to deliver STEM education, allowing them to better participate in their own learning and to share their impressions with confidence.

The theory of 'discovery learning' is proposed by Jerome Bruner. Discovery learning is an inquiry-based, constructivist learning theory that places students at the center of their own learning process. The learning environment is an actively engaging place that promotes independence, motivation, creativity, and responsibility. Learners interact to perform experiments, solve problem situations and discover knowledge on their own. Discovery learning theory calls for student-teacher interaction characterized by independent learning.

Teachers act as facilitators who direct the efforts of students without dictating to them what they have to do, whereas students construct their own knowledge by themselves.

Theoretical consolidation

The need to raise awareness of STEM careers, opportunities to engage with STEM industries, and the decline in student attitudes about STEM propelled researchers (Wiebe et al., 2009; Mahoney, 2010) in conducting their studies. By studying these factors, unifying the STEM framework with the participation of all stakeholders involved in the learning process of middle school girls can be possible. Raising interest and engagement among middle school girls is a direct impact of unifying the STEM framework.Many researchers (Breiner, Harkness, Johnson, Koehler 2012; Bybee, 2010) have identified an urgent need for a common definition of STEM education. There is a need to ensure the pedagogical alignment between STEM content and the learning environment considering age-appropriate dimensions. PBL and challenging questioning strategies are the most suitable instructions for delivering STEM content (Bruce-Davis et al. 2014.

In contrast with the PBL approach, integrated units of instruction are based on content connections within disciplines that are formed around a theme, not a problem that needs to be solved.

History of reform within STEM education

The analyses of standardized test results such as TIMSS and PISA in 2008 showed a considerable gap between US students and international students(Beecher and Sweeny, 2008; Tan and Leong, 2014). The need for change is concluded based on these results. Educators in the 21st century are highly challenged to prepare students to compete in an ever-expanding global marketplace to increase student attainment (Gasser, 2011). According to numerous studies, the rates of student enrollment as science majors are significantly decreasing (Samuel and Seymour, 2015; Shores and Smith, 2011). The main national councils of Mathematics and Science in the USA proposed a STEM banner as a strategic solution (NCTM, 2006; AAAS, 2013; NSTA, n.d.). STEM disciplines provide opportunities for meaningful applications of scientific and mathematical skills, which increase student performance and motivate students to choose STEM careers (Carr and Strobel, 2011; Gallant, 2011; Sanders, 2009). With the STEM curriculum guidelines derived from NGSS engineering design, students develop integrated knowledge and skill sets that can prepare them for future careers and social responsibilities.STEM students are characterized as problem-solvers, innovators, inventors, and critical thinkers (Morrison, 2006).

For teachers to achieve STEM curriculum standards, a suitable learning environment setup is required. In a STEM classroom, a variety of learning styles are utilized to serve students in a student-centered environment.Students in a student-centered classroom learning environment are engaged in problem-solving activities facilitated by the teacher (Estes et al., 2014). The learning venue promotes collaboration, interaction, and invention.Unless a STEM curriculum is equipped with purposeful pedagogies to deliver it, it will neither be effective nor impeccable (Beecher and Sweeny, 2008; Rissanen, 2014; Cutright, Evans and Brantner, 2014; Shorres and Smith, 2011; Tan and Leong, 2014; Berland, 2013). STEM serves as a driving force to ensure effective integration across content areas. Engineering education, for instance, supports the effective integration of mathematics, science and language arts subjects (Martinez, 2015).

The NGSS structure

During the development of the NGSS, scientific and educational research communities were involved in the formulation of core ideas that were articulated across grades. The Framework for K-12 Science Education was first constructed by the National Research Council (NRC) to ensure validity and accuracy. A team of eighteen experts in science, engineering, cognitive science, teaching and learning, curriculum, assessment and education policy collaborated to author the framework. Theinterrelationships among practices, cross-disciplinary concepts and disciplinary core ideas were the key components of the framework. In the summer of 20210, a draft was released to obtain comments from the public by the NRC, and in 2011, the final report was released. An independent, nonpartisan, nonprofit education reform organization and one of the partners in NGSS named Achieve, facilitated the next step. State policy leaders, higher education, K-12 teachers, the science and business communities, and others joined the state-led process of developing science standards within the framework. Moreover, multiple opportunities for public feedback, review and discussion were given to all stakeholders.

In 2011, the NRC released the framework for the NGSS (NRC, 2011).Based on the premise that learning is continuous and progressive, the NGSS curriculum was established. Young learners are supported through this design in building and revising their innate and acquired knowledge and abilities, starting with their curiosity and initial conception about how the world works. According to Bybee (2011), practitioners began to inquire about the reasons that justify the shift from scientific inquiry to science practices.Scientific inquiry as outlined in the NGSS structure is one form of scientific practice, according to Osborne (2011), supporting Bybee's claim.

A limited number of core ideas in science and engineering within and across disciplines are outlined in the NGSS.The focus is on learning science and engineering with the integration of content knowledge and practices needed to engage in scientific inquiry and engineering design. Through the strengthenedengineering aspects of NGSS students understand the relevance of science, technology, engineering and mathematics to everyday life. The curriculum design that promotes enjoyment, challenge, and hands-on learning for students allows them to apply their math and science knowledge in engineering learning (Cooger& Miley, 2013). The three dimensions of the foundation box indicate the interconnection of the four STEM fields which are based on the framework published by NR: Scientific and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts (NRC, 2012).

The main practices that guide the scientific inquiry process are outlined in the NGSS, giving teachers a clear picture of what scientific literacy is. A study focused on the principles of STEM curriculum design and the importance of raising a scientifically-literate generation was conducted (Tan and Leong 2014). The researchers described a scientifically literate learner as one who has good literacy skills, sound decision-making skills, knowledge about how the world works and mental and physical strength.NGSS design connects performance expectations to engineering, scientific engineering practices and the nature of science.

A STEM Education Program

This study is grounded on the achievement gaps in science (Bowers, 2007; Gopalsingh, 2010; Murphy, 2009; National Center for Education Statistics, 2012; Wagner, 2008), inquiry-based learning and instruction (Marshall & Horton, 2011; National Research Council, 1996; Piaget, 1928/2009), program assessments (Ali, Yang, Button, & McCoy, 2011; Burton & Frazier, 2012; Lee & Ready, 2009), and science skills (Asunda, 2011; Baine, n.d.; Feller, 2011; National Center for Education Statistics, 2012; Schiavelli, 2011).

The principles of the theory of discovery learning outlined by Jerome Bruner serve as the driving force of a STEM education program. There is strong incorporation of inquiry learning, discovery learning and inductive reasoning into STEM curriculum guidelines, supported by the complete integration of ICT resources.Tracing its roots, inquiry-based instruction stemmed from constructivism as discussed by researchers such as Dewey (1916) and Piaget (2009). For each component of inquiry that a student should learn, teachers will have to use various delivery methods (Minner et al., 2010).

In accordance with relevance to context and social parameters, middle school students conceptualize their ideas. They analyze challenging problems, investigate new ideas, articulate knowledge, and synthesize information. When there is a strong connection to other subject areas, their understanding of scientific facts is solidified.Students master concepts when they find target information independently using materials rather than having them provided with the target information (Alfieri et al., 2011). Students achieve higher attainment in standardized tests when they are able to analyze, synthesize and apply the abstract knowledge that they learned in solving word problems. It is not sufficient to have scientific knowledge alone. Although manyfactors influence student learning and achievements in standardized tests, curriculum structure and instructions have the greatest impact according to Uchechi (2013). Hence, another crucial aspect that has a huge impact on student motivation and achievement is curriculum guidelines.Many researchers, such as Allen (2007), Burton & Frazier (2013), Schmoker (2006) and Sheninger&Devereaux (2012), reported that curriculum planning increases student achievements.

Methodology

This section presents a qualitative descriptive study that examines a variety of documents as sources of data. The analysis of documents that are either printed or electronic is performed systematically to answer research questions. According to Bowen (2009), document analysis examines and interprets data to explore meaning, gain understanding, and develop knowledge.Since the focus of this study was to analyze the K-12 NGSS curriculum framework, the NGSS document acted as a primary source of data. Additional forms of data included books, journal articles, maps, charts, and organizational and institutional reports. To track changes in and the development of concepts and theories over the years, collective documents are used. The accessibility of multiple sources of data allows the researcher to compare, identify and obtain a clear picture of how the ideas evolved over time (Bowen, 2009).

Underpinned in this study is the collective analysis of previous studies. Using the description and interpretation of data based on the analysis of information found in previous studies conducted on the same topic in recent years, this research paper was created. Questions arose from the information collected from documents about STEM curriculum guidelines, alignment of curriculum and instructions, and the suitability of instructional strategies used to deliver the content. The analysis of documents served the purpose of this study as it provides rich information about the context of STEM. According to Anger and Machtmes (2205), document analysis enables the researcher to explore the beliefs and practices related to their studies about integrated technology and curriculum enrichment.

Other sources of data offered additional perspectives for further investigation, although many studies have similar conclusions about the importance of STEM education and its effectiveness and about the suitability of instructional strategies.

The selection of documents to be analyzed proved to be a critical factor that has a direct impact on qualitative document analysis. As stated by Bowen (2009), document analysis requires proper data selection, not proper data collection. The groundwork for this study includes a selection of journal articles based on the most-cited articles index, recent studies conducted in the field, the most-downloaded articles and Journal Metrics Index.Merriam (2009) states that document selection depends on the individual's imagination and seriousness.

Results and Discussion

The purpose of this study was to examine how the outlined STEM curriculum guidelines in the NGSS are delivered using appropriate learning activities in a conducive learning environment.

To address the first research question, student participation in eight science and engineering practices is emphasized in the NGSS.The shift of focus from the NRC standards to the NGSS, highlighting what students should be able to do rather than what they need to know, is emphasized. Building a new generation equipped with the skills and competencies to face real-world challenges is the main target of the NGSS science and engineering practices. The new educational reforms that promote knowledge, skills, and responsibilities are required to address the changing needs of industry, economy, and society (Sonyel and Perkanzeki, 2014).

One of the demands of the NGSS is for students to take ownership of their own learning experiences. In delivering the content of a STEM curriculum, classroom instruction plays an important role. According to Berland (2013), a STEM curriculum requires an engaging, learning-goals-driven approach. Students are provided with opportunities to discover, innovate, and invent through the alignment of NGSS goals for science and engineering practices with instructions. The National Science Teachers Association and the California Department of Education, are the notable organizations developing curriculum frameworks to support the implementation of the NGSS. To support the successful implementation of the NGSS, a school structure setup that specifies time, resources, and teaching strategies is required.Implementation of a new curriculum is a complex and difficult task owing to the constraints of knowing the appropriate pace, resources, and teaching approach (McNeil et al., 2006; Beyer, Delgado, Davis &Krajik, 2009)

In response to the second research question, and as indicated in the different studies reviewed in the literature section, there are various instructional models which can be adapted to deliver science-engineering practices. Soleimani (2013) focuses on scientific visualization and MBR (model-based reasoning) activities, which improve perceived value for learning in a STEM domain. Berland (2013) promotes standardized engineering design process (EDP), learning opportunities, and engaging students in purposeful practices. Berland (2013, p. 26) states that

> "Problem-based challenges typically emphasize science and math learning goals, while design-based challenges foreground engineering goals and STEM-design challenges are targeting both."

The importance of using lesson-opener learning experiences that engage students to design their own experimental procedures is emphasized in other research studies. Opening-up strategies increase the productivity of students to explore and investigate (Ford, 2018). Teachers should pose suitable questions as an opening strategy according to McNeil and Knight (2013). In support of the claims of Ford (2008) and McNeil and Knight (2013), Skinner (2010) argues that probing questioning in a classroom encourages students to articulate their perceptions and ideas in addition to teasing out their understanding.

Another major implication is the importance of learning theories reflected in classroom practices. A dominant approach recommended for science classes is using the constructivism theory perspective. Problem-solving, critical thinking, and open-ended inquiry are three essential features of a science class according to Forawi(2014). The opener of the lesson, the questioning strategy or the hands-on activity must engage students in their own learning to make that learning relevant and attractive to the students, no matter what practices are designed for a STEM class.

Finally, the effect of STEM education on students was examined.To improve education, there are current reforms focused on adapting STEM discipline. There was a significant decline in the number of students opting to major in science streams according to researchers (Samuel & Seymour, 2015; Cutright, Evans and Brantner, 2014). Students are equipped with the skills and abilities to solve global issues and become engaged in future STEM careers as a result of science-engineering practices embedded in STEM curriculum guidelines. STEM integration within education improves the generation's abilities to fill future STEM careers according to researchers (Gallant, 2011; Laboy-Rush, 2011; Sanders, 2009). Increased student motivation, attitudes, and interests in STEM disciplines are attributed to implementing STEM integration education (Burghardt& Knowles, 2006; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Jocz&Lachapelle, 2012; Knight & Cunningham, 2004; Satchwell&Loepp, 2002). These findings enrich the educational literature available within STEM education and its effect on students.

Conclusions

To guide the efforts of teachers to achieve the required aims in an educational system, the curriculum design structure plays a major role in this aspect. A curriculum map is a reference for teachers to create unit plans and design their daily lesson plans (Tan & Leong, 2014). The alignment between the three pillars of education such as curriculum standards, instructional strategies, and the assessment process should be reflected in the curriculum map. The vital need for establishing proper alignment between curriculum guidelines and instructional strategies is emphasized in many studies (Snehi, 2011; Blumberg &Pontiggia, 2011; Wilson, Sztajn and Edgington, 2013). If STEM education is delivered correctly in a dynamic learning environment, the goals of attracting students to science careers and enabling them to achieve better results in international mathematics and science standardized assessments will be achieved. The core of an innovative curriculum is alignment with applied learning and design of each unit is based on applied learning and inquiry-based pedagogies (Tan & Leong, 2014).

Inquiry-based approach is the only common element among the models presented in various studies to deliver STEM curriculum guidelines. Through inquiry, students are guided without having to dictate their learning pathway and are allowed to discover ideas, connect different learning disciplines, innovate to draw conclusions, and think critically. Through this inviting approach to learning, students are motivated to try, regardless of their abilities and interests. Inquiry-based learning is described as a student-centered approach that enables students to develop research and critical thinking skills to become life-long learners (Crismond, Gellert, Cain and Wright, 2013; Dalimonte, 2013; Lazaros and Borman, 2013). In this approach, every single student is allowed to progress and develop. Only when students take ownership of their learning will we witness an improvement in their skills and abilities. The essence of an inquiry-based approach is to engage students in high-order thinking experiences through the use of manipulatives, technology and cooperative learning activities (Gningue, Peach and Shroder, 2013).

Recommendations

If the nation envisions a generation of students pursuing STEM-related careers through improved STEM education, then it is crucial to empower teachers through high-quality professional development. In order to yield good results, training teachers in designing and refining appropriate instructional activities to meet NGSS expectations is recommended. CPD trains teachers to implement engineering design lessons in the classrooms (Guzey et al., 2014). The effectiveness of classroom instruction originates from the teacher (Hartsell et al., 2009). Supporting Hartsell et al. (2009), Dodeen et al. (2012) insist that teachers play a significant and direct role in improving student achievement.

This study provided an outline of how to align instructions with the goals of the NGSS, however, additional research is needed to further understand the criteria that guide teachers in instructional planning. Although the objectives for student outcomes in science are explicitly specified in the NGSSspecific instructional strategies to attain these goals were not clearly outlined.

It is highly suggested to conduct a field study to investigate the idea of STEM integration within the UAE context. Further investigative studies related to STEM curriculum alignment with scientific IBL strategies can suggest the structure of an engineering design cycle.

This study was aimed at investigating issues related to STEM through qualitative document analysis. Its objective was to connect the content standards outlined in a STEM curriculum to instructional strategies. The findings of this study should be interpreted cautiously based on teachers' knowledge, efforts and capabilities.

We will welcome a new era of science education once teachers are fully equipped with the abilities to incorporate NGSS science and engineering practices into their classroom teaching.

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