Theoretical and Conceptual Framework for A STEAM-Based Integrated Curriculum

Masooma Ali Al-Mutawah,
Bahrain Teachers College, University of Bahrain

Ruby Thomas,
Bahrain Teachers College, University of Bahrain

Nisha Preji,
Bahrain Teachers College, University of Bahrain

Yazan M. Alghazo,
Bahrain Teachers College, University of Bahrain

Enaz Yousef Mahmoud,
Bahrain Teachers College, University of Bahrain

Correspondence: **Masooma Ali Al-Mutawah**, Bahrain Teachers College, University of Bahrain, Kingdom of Bahrain. P.O. Box 32038, Tel: +973 1743 7152. E-Mail: malmutawah@uob.edu.bh

Abstract

In the context of this changing world, children need to develop scientific knowledge through the integration of the 21st century skills that equip them to be better problem solvers. This article introduces such a STEAM activity that help students to integrate science, technology, engineering, art and mathematics in accomplishing a specific target. The theoretical and conceptual framework details the STEAM content, context, instructional approaches and learning domains at each stage, developed as a recommendation to the curriculum developers on how the current paradigm and practices of education can be further improved. According to their age and the depth of the curriculum content covered, the activity helps students to look for additional information and incorporate specific technological skills and artistic sense. The study investigates the dimensions of designing an integrated STEAM curriculum that fosters students' cognitive and conceptual understanding through the five disciplines simultaneously. Moreover, the paper focuses on and emphasizes the pedagogical aspects of designing STEM curricula.

Key Words: STEAM Education, Integrated Curriculum, Learning Domains, Instructional Approaches.

Introduction

In the 21st century, economies are in growing need for individuals who are capable of innovation within their fields and, in addition to their expertise within their fields, possess knowledge and skills across different fields such as Math, Science, Engineering, and Technology (Yildirim, 2016). According to the current increment of knowledge, it became crucial for scholars, educators, and policy makers to classify knowledge under new headings (Kiray, 2011). There is an increasing demand of integrating science, technology, engineering, arts, and mathematics (STEAM) curricula in current education to improve learning accomplishment and students' learning interest (Madani & Forawi, 2019). Based on the nature of these five curricula, they can be taught in parallel during classes to improve students' cognitive and reasoning capabilities to improve their analytical and problem-solving skills. Hence, the integrated curriculum approach emerged to the field of education and has been adopted by many educational institutions (Yasar, 2013).

Despite the growing need for these skills, educational systems around the world are failing to produce graduates that are highly qualified in STEM fields (Yildirim & Selvi, 2015). Therefore, countries around the world are implementing new educational reform efforts in order to improve the quality of their educational systems to meet the growing need for graduates with expertise, knowledge, and skills within STEM areas (Corlu, et al., 2014; Yildirim, 2016). To achieve the ambitions of the 21st Century, states, educators and the business community should work in harmony. That stakeholder's equilibrated participation is crucial. Unless the governments want to empower all individuals in today's competitive world as lifelong learners, they will start from the beginning. STEM education is thought to be the perfect solution for rising in a world powered by global awareness (Bakırcı & Karışan, 2017).

Integrating these five knowledge disciplines is a necessity in order to bridge the gap between education system and job requirements in the 21st century (Becker & Park, 2011). It is very important to have integrated curriculum in the early years of students' education rather than advanced age stages to establish a solid base of knowledge and skills to allow students to build on that in later educational stages (Cabarse, Cabusa, & Baran, 2018). Students are still suffering from insufficient knowledge level and low performance in STEAM parts (Rochman, Nasudin1, & Rokayah (2019). Hence, having a sloid connection between work environment and taught knowledge is essential for avoiding mistakes and increasing profits in workplaces (Christian, Ojha, Herbert, 2018).

The Purpose of this paper is to investigate the capacities of designing an integrated STEM curriculum that promotes students' cognitive and conceptual understanding through the five STEAM disciplines simultaneously. Moreover, the paper focuses on and emphasizes the pedagogical aspects of designing STEM curricula. This study provides a STEAM-Based curriculum activity where the students can experience how the five STEAM subjects can support each other to build a real-life experience that can connect what they learn in this discipline with the real life and market needs.

Early Beginnings of STEM Education

The concept of STEM education was first used by American biologist Judith A. Ramaley, director of the National Science Foundation, in 2001 (Fioriello, 2014).

STEM as a concept was initiated and implemented in workplace and, particularly, the industrial sector decades ago. Initially, STEM concept was used in engineering field to invent and produce machines and technology tools. Most of the old inventors had no education or some little training. They used STEM approach to invent many important instruments. Later on, STEM was adopted as an approach of education that combines four types of knowledge (White, 2014).

Until 2000 in the United States the word 'SME&T' was used as a common term for science, mathematics, engineering and technology. Some acronyms include 'SET' or 'MST' for scientific and technical disciplines. Following an interagency conference on science education held at the US National Science Foundation, the word 'STEM' came into common usage after 1996, although the new concept was simply a rebranding of previous words used since at least the 1990s. Upon comprehensive review of the state of undergraduate education in science, mathematics, engineering and technology in America, it was proposed that the current and less palatable acronym 'SMET' be updated to STEM. (Siekmann & Korbel, 2016).

However, STEM as a terminology was created by the National Science Foundation (NSF) to enable the students having important skills, including: critical thinking and problem solving, to be more successful in workplaces. Lately, STEM became an advantage of students to accept their applications in workplace or colleges (Slavit et al., 2016).

Defining STEM Education

While some scholars define integrated STEM education as the collective teaching and learning activities across all four subjects, and across the different grade levels (Corlu, Capraro, and Capraro, 2014; Gonzalez and Kuenzi ,2012). According to Siekmann and Korbel (2016) “STEM is an acronym of the disciplines of science, technology, engineering and mathematics. It has grown to be an umbrella term for a variety of concepts, classifications and initiatives pertaining to not only learning and working in science and technology-related disciplines but to a nation’s social contract and productivity. Principally, STEM learning is a multi- or interdisciplinary approach to learning, in which academic concepts are coupled with real-world lessons to make connections between school, community, work and business.” (p.17)

Stohlmann, Moore, and Roehrig (2012) define integrated STEM education as “an effort to combine science, technology, engineering, and mathematics into one class” that emphasizes the corrections between these subject areas, however, they also argue that not all skills and all four subject areas must be covered in one class and by the same teacher.

STEAM Integrated Curriculum

Teaching by using integrated curriculum is heavily influenced by teachers and students’ individual characteristics when using new instructional strategy or tool. Teachers and students’ perception about the new teaching designs can play a major role in accomplishing learning outcomes (Becker & Park, 2011). School facilities and infrastructure impact the deliverability of new integrated curriculum that need to be taken into consideration. National standards, educational policies, and curricula can direct the way of designing and implementing new integrated curriculum. For optimal results, it is significantly important to have an ongoing collaboration between teachers and educational administrative specialists (Gamette, 2020).

STEAM is one of the most preferred interdisciplinary integrated curriculum to be taught in the last two decades (Fitria et al., 2018). The five STEAM areas have common and similar relationships, concepts, and patters. They can be taught based on interdependent ways of learning. They share very similar scientific and cognitive processes, critical thinking, problem solving, inquiry, and reasoning (Balague et al., 2016). Real life situations can be very beneficial to apply these areas and to discover new phenomenon (Pang & Good, 2000).

Each one of STEAM parts is important to achieve better understanding and knowledge acquisition of other parts (Riordaina, Johnstonb, & Walshec, 2015). The exitance of STEAM integrated curriculum in modern education facilitate students to compresence the big picture and apply knowledge to learn new knowledge. STEAM parts as integrated curriculum have to be taught in parallel to build meaningful learning and to learn how to learn (Moseley & Utley, 2006). However, applying such integrated curriculum requires to determine the way that integration transpires in the class and continuous revision of the outcomes (Carbonell et al., 2016).

Benefits of Integrated STEM curriculum

STEM is an educational approach that prepares students to the next generation and enhances the workforce and deals with the major challenges and foster skills of the 21st century. STEM education can be described as a constructivist and self-regulated learning. STEM is constructivist because students construct their knowledge instead on acquiring it from the instructor. And it relays on identified learning outcomes, pre-designed activities, & assessment tools. STEM is self-regulated learning because students go through three sequential phases, including: planning, performance, and self-reflection (Reynders et al., 2020). STEM focuses on designing activities and inventing new products using different types of knowledge to solve problems in creative ways (Yata et al., 2020). STEM education is about educating the society in more scientific, literate, and practical way to be able to achieve the workplace goals (English & King, 2015).

Research has shown that students generally demonstrate more knowledge growth within an integrated STEM curriculum than within a traditional departmentalized curriculum. Han, Capraro, Capraro (2015) specifically focused on the effect of a Project Based Learning (PBL) approach within a stem integrated curriculum on student achievement and concluded that lower performing students and students with lower socioeconomic status benefitted to a greater extent than their peer with higher socioeconomic status, which greatly reduces achievement gaps.

A Global Shift Towards STEM Education

Because of the general recognition of the importance of STEM education, several institutions have shown interest in STEM and support it by providing technical assistance, consultation, activities, logistics, professional experts, programming, trainings, or financial supports. NYS STEM Education Collaborative, is one of the leader organization that sponsors STEM activities in the world. It provides STEM learning facilities and innovative classrooms. It organizes meetings between STEM stakeholders to bring solutions and improve strategies. It advocates funding, training, technical support for STEM institutions. STEM Teachers NYC is another organization that supports STEM by providing workshops, training programs, STEM labs, and online STEM community support. It provides technical assistance, STEM materials, and designs teaching strategies.

Indeed, it is clear now that there is a global turn to STEM and a huge amount of effort is exerted by governments and the private sector around the world. This shifting increased the number of research and studies that put STEM at the top of their priorities (Freeman, Marginson, & Tytler, 2019).

According to Pawilen & Yuzonb (2019) the important Core Content Standards to Learn in a STEM Curriculum are Science Concepts (life sciences, physical sciences, chemical sciences), Technology Concepts(technology as tools, technology as ideas, technology as product of science)Engineering Design Concepts(models, designs, problem-solving, communicating ideas, planning, implementing), Mathematical Concepts (numbers, problem solving, geometry, measurement, representation of math ideas using objects, symbols, and words). Individuals with great spatial thinking have increased success and achievement in science, technology, engineering, and mathematics (STEM) disciplines. (Burte, Gardony, Hutton, & Taylor, 2019).

To achieve a well-developed integrated educational system with STEM methods, teachers must have adequate training to implement these numerous training programs. Of this reason, teachers or lecturers should have clear knowledge of the STEM material and a good understanding of applications to construct STEM curricula for these students in all stages from primary to secondary school years. (Kubat & Guray, 2018). Therefore, Enhancing teachers' training in improving their teaching skills is one of the benefits of STEM. It can be beneficial in stimulating innovative strategies in aligning demands and supply. It provides the opportunity for teachers to master their skills instructional design and developing problems as well as conducting research (Ismail, 2018).

Science in Integrated Curriculum

Science can be fit perfectly in integrated curriculum due to its nature as an applied knowledge. When integrating science, that allows students design and examine new science knowledge (Johnson, 2017). By doing so, students are more able to transfer knowledge and solve problems in real life scenarios (Kurniati,, & Annizar, 2017). Integrating science is seen as a beneficial strategy and has a positive impact on helping students to demonstrate higher level of thinking skills and maximize their gaining of science knowledge (The California Center for College and Career, 2010). Reasoning and planning skills are improved while students are involved in integrated science curriculum and help them to avoid misconception (Carbonell et al., 2016). The observation and analysis skills are developed rapidly when using science integrated curriculum because students use them in other subjects to describe different content (Clements & Sarama, 2017). Creativity, communication skills, vocabulary skills, and prediction skills are significantly increased when using science experiment in integrated approach with other disciplines (Kim & Kim, 2019).

Technology in Integrated Curriculum

Technology is promising areas where students can reflect of their learning. It requires students to apply their understanding while study them (Yasar, 2013). Applying technology integrated curriculum improves the students' capability in solve technical challenges. Integrated technology support students to develop better understanding of other disciplines by using new knowledge in relevant applications (Rochman, Nasudin1, & Rokayah, 2019). Students use technology in integrated curriculum to facilitate collaboration among each other and contextualizing learning problem solving (Pang & Good, 2000). It is very helpful in reducing the instructional time and save effort while teaching other disciplines. It allows students to apply their knowledge in a practical way (Vargas & Alvarado, 2020).

Engineering in Integrated Curriculum

Engineering as an integrated curriculum play an important role as a means of teaching and integrating other disciplines (Rochman, Nasudin1, & Rokayah, 2019). It helps students to learn in teamwork environment to develop their problem solving in parallel with design skills using knowledge from other disciplines. Students can interpret the use of knowledge in real life and to explain why they learn this knowledge and a practical way (Ivan et al., 2017). It is interesting to know that low achiever students improve better than medium or high achiever students when they encounter engineering integrated curriculum (Becker & Park, 2011). Integrating engineering in curriculum can bridge the achievement gap between students' levels when learning other disciplines (Clements & Sarama, 2017). Integrated engineering is seen as motivation booster for students and it increases their positive attitude towards other disciplines because it enables them to accomplish better understanding by doing (Gonzalez & Escala, 2016).

Arts in Integrated Curriculum

Arts allow students to experience the work in different disciplines in order to apply creative solutions to solve learning problems. Hence, students can construct and demonstrate new knowledge using an art frame. By integrating arts, this gives students a deeper and comprehensive understanding of how and why they learn. It enables students to naturally combine learned skills that need to be practiced and demonstrated (Yakman, 2008). Students have to apply and fully understand techniques of materials, instruments, and strategies of arts practices. Considering arts standards enables students to avoid harm situation and avoid risky arts practices. Students need arts in their learning merge knowledge and practice successfully. Arts integration is not only for increasing the enjoyment and entertainment part, but it is a vehicle to achieve better learning outcomes (Hunter-Doniger, 2019).

Mathematics in Integrated Curriculum

Mathematics can be integrated in other disciplines' curriculum to maximize students' achievement. Students have higher level of performance on statistics when having integrated mathematics (Kermani & Aldemir, 2015). Critical thinking skills, problem solving skills, and positive attitudes are improved when students study integrated mathematics (Riordaina, Johnstonb, Walshec, 2015). It can be used as a context where students create meaningful connections between different disciplines and mathematics (Fitria et al., 2018). In order to develop an adequate level of applied mathematics, integrated mathematics with other disciplines provides a golden opportunity for students to practice it because it improves their analytical, reasoning, and problem-solving skills (Tatar, Colak, Lederman, 2016). Synthesizing knowledge and skills among several disciplines enables students to successfully handle the instructional challenge (Carbonell et al., 2016).

STEAM Learning Domains

Different learning domains provide different insights of how learning occurs and, consequently, affects the design of curriculum based on the domain which guides the design process (Thibaut et al., 2018). Kelley and Knowles (2016) emphasize on learning domains in ensuring students achievement of specific learning outcomes. They assume that understanding learning domains are essential in the delivery of targeted curriculum. They help teachers and students to see the connections between different subject areas they are dealing with simultaneously and choose the post suitable teaching approach to teach each content in light of relevant influential variables. They also proposed a conceptual framework for STEM education in which the emphasis is on pedagogy and learning theories that ensure students achievement of specific learning outcomes. Their model assumes that content pedagogical knowledge is essential in the delivery of STEM curriculum, where teachers have enough pedagogical content knowledge to help students see the connections between the different subject areas they are being taught simultaneously, instead of hoping that students will realise those connections on their own.

Many researchers have proposed that an integrated STEM curriculum is deeply imbedded within the social cognitive learning theories as a general category. In general, learning theories are categorized into three main categories; behaviourist, cognitivist, and social-cognitivist. In their study of 23 different studies about STEM integrated curriculum, Thibaut et al. (2018) concluded that the majority of researchers in the field of STEM education agree that STEM education practices and curriculum lend themselves to study within the social-cognitive theory category. According to social-constructivists, the student is considered an active participant in the learning process and knowledge cannot be transmitted, but is constructed through students' experiences and prior knowledge. Moreover, learning is viewed as a "shared experience rather than an individual experience" (p.4).

Cognitive domain places much of its emphasis on the functions within the mind and assumes that learning is an active process of inquiry, analysis, sorting, and memorization that happens within the brain (Thibaut et al., 2018). Nonetheless, both the behaviourist and the cognitive domains share the underlying assumption that learning is an individual process. Also, both domains assume that "knowledge exists outside the person" (p. 3).

Psychomotor domain can interpret a large spectrum of performance learning. As a psychomotor task, the student needs to receive a large amount of data, including: visual, auditory, and haptic. Other stimuli can be gathered upon the type of learning task. Attention plays an important role in data filtering to short-term memory. Creating internal images and representations leads to perception and conceptualization of new knowledge. It explains the process of concept formation that allows knowledge storage into long-term memory. Students can recall and execute the psychomotor task when needed (Shaker, 2018).

Affective domain plays an important role in explaining the invisible inner side of students' learning. It sheds the light on the beliefs, desires, and emotions that sand beyond learning. It provides the teacher with the best practices of increasing students motivation towards learning in general or towards learning a specific content. This domain helps teachers while designing their instruction to eliminate the psychological factors that passively influence students' learning. It helps teachers to improve the positive emotional impact of their teaching and design their instruction based on the psychological characteristics of their students (Ruitenberg, Santens, & Notebaert, 2020).

Social constructivism domain as well as the constructivist theory assume that knowledge is constructed through one's own experiences within a learning environment and call for a curriculum that provides the needed learning environments in which students can make their own connections and build their own knowledge within these carefully planned and designed learning environments (Ertmer & Newby, 2013). It introduces the opportunity to students to discover the connections among ideas in a social atmosphere. It enables students sharing their knowledge and exchanging experience with others to ascertain a better learning (Mohr & Welker, 2017).

Behaviourism focuses on how one behaviour affects another behaviour and assumes no importance for the cognitive functions of the mind (Dilshad, 2017; Thibaut et al., 2018). This indicates that through reinforcement and punishment, learning can occur without the need to provide students with meaningful experiences that help them see connections and achieve deeper conceptual understanding.

Zollman (2012) indicated that developing STEM literacy requires working on three strata: first; literacies of each one of the STEM four or more subjects. Second; looking over personal, societal, and economic needs. Third; STEAM associated learning domains. He gave an example of this by saying “with respect to the personal needs of a student, the student must operate technology efficiently (e.g., muscle memory for typing); personally, obtain competence and value the sciences; and be able to apply factual, procedural, and conceptual knowledge to solve problems and attain personal goals” (p. 15).

STEAM Instructional Approaches

As it is well known, teaching and learning are significantly influenced by the used instructional approaches. Hence, students’ performance and knowledge achievement in STEAM are relayed on the suitable instructional approaches that teacher uses to help students achieve the learning outcomes (Hiong & Osman, 2013).

Scientific inquiry is considered to be a capstone instructional approach through using STEAM in teaching. It enables students to use the proper steps and procedures while discovering new knowledge. Avoiding possible mistakes and wasting time can be eliminated when following the scientific inquiry. It is necessary to practice the knowledge and skills mastery. Students can synthesize different types of knowledge pieces in an organised way to be able to use them later when needed. When scientific inquiry is applied in teaching, learning can last for a long time. Long-term learning becomes a meaningful learning through transferring knowledge and performance to find solutions and take decisions (Sayuti & Rahiem, 2020).

Posing questions is seen as an effective instructional approach that STEAM emphasizes on. It enables students to generate questions relevant to the new targeted knowledge and skills. Questions can be generated from among teachers and students in all directions on a predefined topic or performance topic (Kermani & Aldemir, 2015). While thinking about questions, students can explore new content and construct connections among background and new knowledge (Kiray, 2012).

Investigations is one of the fundamental instructional approaches of teaching via STEAM. It requires students to build conceptual junctures to discover the different characteristics of each taught concept according to pre-defined guidance. It trains students to act and think like scientists using a systematic approach of thinking and information processing (Cavadas at al., 2019).

Problem based learning is an instructional approach that consider a higher level of thinking. It requires students to have an advance stage of data processing to be able to apply it in different situations. It is enables students to convert their knowledge to different forms to find solutions. While students learn by this approach, they become inventive problem solvers. It promotes students to develop their creativity in dealing with authentic problems to find creative solutions (Cooke, Fannon, & Campean, 2020).

Design based learning is considered a fruitful instructional approach that STEAM focuses on. Students are exposed to a body of complex knowledge. This technique requires multiple sequential procedures to follow in order to achieve the targeted learning outcomes (Frykholm & Glasson, 2005). The design has several pre-determined steps where missing any of these steps can cause a misconception, information lost, and consumes more time to learn. It promotes students to be more organized, disciplined, and specific. Teacher provides students with needed guidance, instructions, and directions to follow in order to acquire new concepts or perform new skills (Fitria et al., 2018).

Student centred learning is an interesting instructional approach while teaching via STEAM. Students are the core of the learning process that requires them to have multiple learning roles under their teacher's supervision. It helps students to develop their self-direction skills and their abilities of setting plans to achieve learning goals. Students will develop their effort and time management, risk management, and their learning independence. It sparks students' creativity by using their higher level of thinking skills and discover strategies. It enables students to assess the quality of their learning with teacher's facilitation (Hiong & Osman, 2013).

Cooperative learning is a helpful instructional approach in teaching STEAM. It enables students to share their knowledge and experience in a social learning environment. This purposeful sharing sparks their motivation towards learning new content because they learn from each other. Students can refine their learning and fix possible misconceptions while they learn new concepts and skills. Learn how to learn is important in this strategy because it leads the students to find their own way of learning using the suitable available experience provided by their classmates (Prince, 2004).

Thibaut et al. (2018) summarized the instructional categories used and emphasized in the majority of STEM education practices into nine categories: 1) Integration of STEM disciplines, 2) Focus on Problems, 3) Inquiry, 4) Design, 5) Cooperative Learning, 6) Student-centered 7) Hands-on, 8) Assessment, and 9) 21st century skills. These instructional approches are used as the guiding conceptual framework in the design of the STEM activity presented in this paper as shown in diagram 1.

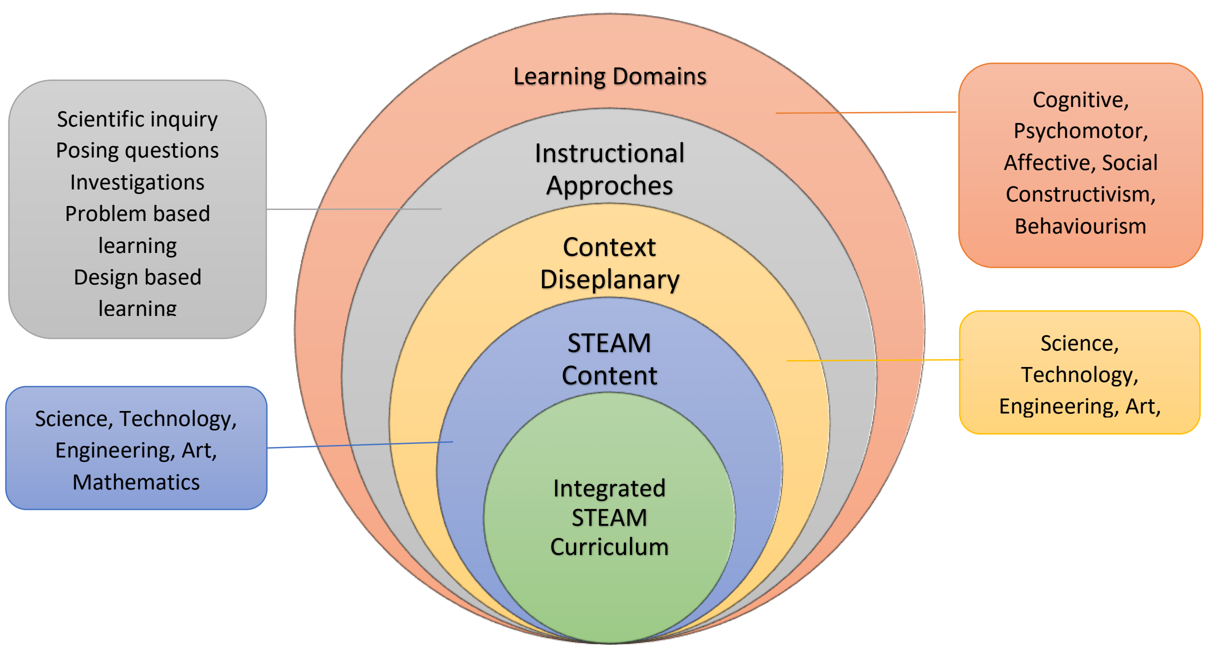

Diagram 1: Suggested framework of the design

STEM Content and Context Disciplinary

Many researches explained the relationship between STEM disciplines and how these subjects can play primary or supportive roles within a specific context in the curriculum. The integration of STEM subjects in authentic contexts is a complex process according to the huge global challenge of preparing new STEM qualified experts. Accordingly, they find it extremely difficult to connect between contents of STEM disciplines. Therefore, students become demotivated to learn contents of STEM disciplines when they learn them in a separate context without having them in a connected and joined manner. Also, this disjoining causes a huge gab and crosscutting of connection between contents of STEM disciplines and application in the real-world life (Kelley & Knowles, 2016).

English (2017) mentioned that STEM integration is not only about teaching few subjects with the support of the other subjects in STEM education, but also more about being specific and plan to consider both the content and the context intentionally in the learning process. Part of this by deciding if the integration will have learning objectives from multiple STEM subjects, or by having main objective from a specific STEM subject and use the others as supporting, or finally by using the context of one subject to help achieving the objective of another.

Blackley (2015) mentioned that engineering design context can play the role of a motivator of teaching the science and math content, while engineering skills as a primary content can help the students to develop their math and science content within the context was used to teach the engineering skills. Since the engineering is not part of the school curriculum, that is why it is important to use the contextual integration of engineering to have an authentic learning experience while teaching math and science in schools.

Kelley and Knowles (2016) emphasized on the importance of infusing science content into curriculum to teach engineering and mathematical reasoning contents. Teaching engineering content in a scientific context can be enhanced because it encourages students to apply science knowledge to facilitate learning the joined disciplines, which are in their findings: engineering and mathematical reasoning. This process enables students to transfer science knowledge to authentic situations of learning other disciplines, which is the key component of mastery learning.

Yildirim and Topalcengiz (2019) indicated to the need of teaching science content in a technological context. This integration offers effective teaching strategies and techniques to support students' learning in classrooms. The multimedia and technology tools can escalate students' achievement in science due to dealing with different learning styles. Designing a technology context to teach science content requires a solid content knowledge and high quality of technological skills. Technology context enables students to solve scientific problems in a shorter consumed time and motivating environment for better achievement.

Designing STEM-Based Learning Experience

We will build a frame of knowledge, skills and practice. So not only context of learning but also the social aspect of learning will be considered. move from a novice understanding of knowledge, skills, and practices toward mastery as they participate "in a social practice of a community. In a community of practice, novices and experienced practitioners can learn from observing, asking questions, and actually participating alongside others with more or different experience. Learning is facilitated when novices and experienced practitioners organize their work in ways that allow all participants the opportunity to see, discuss, and engage in shared practices. efforts to integrate mathematics and science should be founded, in part, on the idea that knowledge is organized around big ideas, concepts, or themes, and that knowledge is advanced through social discourse.

An integrated STEM approach should leverage the idea that STEM content should be taught alongside STEM practices. Both content and practices are equally important to providing the ideal context for learning and the rationale for doing so.

This is an activity designed to provide students, relevant and meaningful learning contexts through a real-life scenario that engages them with science, technology, engineering, art and mathematics content. This activity is aligned with the science concepts which are Force & Gravity, Properties of materials, weather & Climate and Energy as well as Mathematics concepts which are Measurement, Ratio & Proportion, Scale drawing and Estimation & Costing. Students working in mixed ability groups on the completion of this activity and present their unique design in front of their classmates, in which they demonstrate their content knowledge in applying them in the realistic circumstances. They can be as creative as possible to incorporate artistic ideas and design a cost-effective home satisfying the needs of the residents while promoting reasoning and problem solving skills.

Students working cooperatively on a given scenario in which they are brainstorming for ideas to meet the needs of the land and the occupants. The focus of this activity is to apply scientific and mathematics concepts within a real life scenario incorporating technology, engineering and art. Students design the house while using many mathematical and design processes with the final outcome being a complete house design with all specifications and cost.

Scenario & Specifications

The task is to design an ideal space for a family of six people, two grandparents, two middle aged couples with a son and daughter studying in middle and primary classes at the beach side. They have dogs and birds as pets and the lady of the house is fond of gardening. Most of the members of the family are music lovers and they prefer to have a home theatre as well. They have two cars and children have bicycles. The diagram 2 gives a summary of the final requirements to be met by the students.

Activity Name: Building a beach house

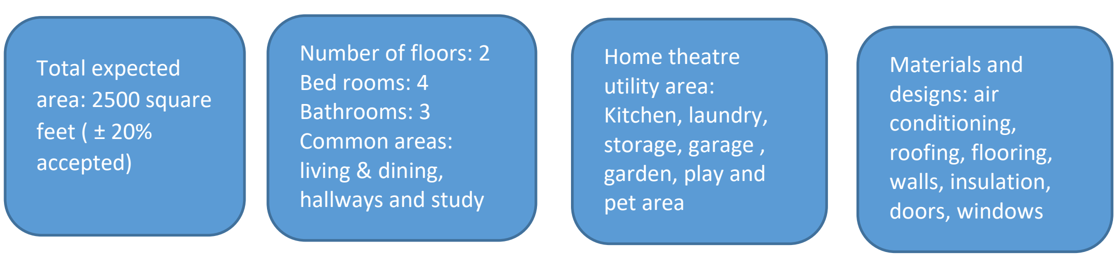

Diagram 2: Expectations of the final product

The activity starts with the presentation of the final task and definite criteria to the students by the teacher followed by a whole class discussion and brainstorming of the necessary topics that support the prescribed design. Afterwards, divide the class into groups and followed through the subsequent stages. Stage 1 is described in Table 1 with clear objectives and guiding questions to help the students to focus during the discussion. The STEAM content and context as per the framework is also included.

	Integrated STEAM Curriculum			STEAM Content	Context Diseplanary
	Objectives	KPIs	Questions to reflect		
Stage 1	Identify suitable design specifications of the house at the beach side.	• Identify the risk factors and the government norms for construction based on the chosen location. • Compare various designs and discuss about the impact of certain climates and natural disasters. • Identify the effect of gravity that works against the building and make the structure stay upright.	○ What are the government norms to be followed for constructing a house at the beach? • Types of soil supporting a building foundation (A compacted mix of sand and gravel does not expand because it does not retain water, but the materials can wash away over time and leave gaps beneath the foundation). • How environmental loads (natural forces) include seismic movements, the weight of snow, the pressure of wind, as well as expansion and contraction caused by temperature changes impact the structure by comparing various existing designs? • How gravity works against buildings (how to make buildings stay upright)	Science Focus Areas: • Gravit y • Force • Proper ties of Soil • Weath er & Climate	Science-Background knowledge of the basic requirements for constructing a beach house such as: • govern ment norms: distance from the costal boarder, permissible height and so on. • risk factors: direction of the wind, soil and climatic conditions, and so on.
Instructional Approaches		Inquiry-based Model, Cooperative learning			
Learning Domains		Cognitive Domain of learning			

Table 1: Stage 1 of the activity

Researches showed that students improved both academically and socially when they are given the opportunities to interact with each other to achieve shared goals. As students brainstorm and gather information about the basic scientific information using the inquiry-based model of instruction, it helps focus on open questions or problems to use evidence-based reasoning, creative thinking and problem solving to form a conclusion they can defend. Furthermore, Johnson and Johnson (1999) mentioned that when students worked cooperatively, they put more effort into achieving positive outcomes because of the supportive relationships with their peers in constructive ways, promoting cognitive and analytical thinking developments. Inquiry-based learning can improve students' analytical thinking by engaging students in science classrooms and laboratories (Colburn, 2007b). Science teachers need to promote the use of inquiry-based learning in order to show students the learning process and to develop each student's sense of curiosity. It helps students construct knowledge through real world problem-solving based on information gained during experimentation (Krajcik *et al*., 2000; Zion and Sadeh, 2007). Also, inquiry involves the creation of a constructivist learning environment. Students are assessing the feasibility, risk factors, benefits and generate ideas for development to transfer their knowledge and skills to the new situation. Table 2 and Table 3 helps students to select appropriate materials depending on the conditions of the soil and climate with the help of the guiding questions provided incorporating the STEAM content and context.

	Integrated STEAM Curriculum			STEAM Content	Context Diseplanary
	Objectives	KPIs	Questions to reflect		
Stage 2	Select appropriate materials for the construction	• Identify various building materials that can protect the house from various weather conditions and climate. • Identify the measures to be taken to ensure flow of air efficiently in all the climatic conditions and maintain proper acoustics. • Identify the type of soil to support the construction of the foundation. • Identify the measures to be taken	○ How can we make the structure strong at the beachside? ○ How do certain materials protect us from the weather and to provide comfort by ensuring maximum airflow inside the house at all times? ○ How do we rustproof the house to avoid corrosion? ○ What are the three components of acoustics to ensure sound proofing?	Science Focus Area: Properties of Materials, Rust & Corrosion, Airflow & Ventilation, Light & Sound Engineering Focus Area: Positioning of doors, windows and ventilations. Acoustics design Solar/wind energy panels	Science background knowledge about Properties of materials: Materials that can be served as insulators to control the temperature inside the house at various climates. Rust & Corrosion: materials and precautions to minimize rust and corrosion Light & Sound: Ensure maximum natural lighting and sound proof.

		to build an environmentally sustainable house, making provisions to utilize the renewable energy sources.	○ How can the design ensure maximum availability of renewable energy such as wind & sunlight to produce electricity?		Engineering Focus Areas: Positioning the windows, doors and ventilations to ensure maximum airflow & light. Acoustics: Components of acoustics to sound proof the house Environmental Sustainability: make use of renewable energy sources to produce electricity
Instructional Approaches	Inquiry-based Model, Cooperative learning				
Learning Domains	Cognitive Domain of learning				

Table 2: Stage 2 of the activity

Tranquiglobal (2019) provides guidelines for better construction: To protect beachfront homes from the threat of hurricanes and storms, it's well worth it to invest in impact-rated glass for your windows and doors. A house on the beachfront may also be at higher risk than one a little more inland, protected by other houses and trees. According to the National Oceanic and Atmospheric Administration (NOAA), buildings at the coast areas are at greater risk of damage due to flooding, wind and severe coastal storms and rust, erosion and mold caused by an endless onslaught of sun, sea, and sand. Raised beach houses are a good design for areas likely to be hit by some floods, as it stops interior from being damaged by water. Knobs, C.(2018). Floods can also damage foundation and electric systems, which is easily avoidable by raising or lifting the house's foundation. Where soil conditions are poor it is advised to use piled foundation that reach the bedrock. The basic factors that affect the acoustics of a building are shape, size and the material used inside the building. Tranquiglobal (2019). Hard surfaces reflect sound waves while soft surface absorb sound. Concave shape tend to bring sound to one focal point while convex shape diffuse sound in multiple direction. To make use of natural sun light, install solar panels and temperature regulating walls. Can make provisions to use the renewable energy sources, wind and sunlight to produce electricity.

In both stages 1 & 2, students develop their scientific knowledge of the government norms and basic directions to follow during the beachside construction. They analyse the relationship between the qualities of materials to be selected to meet specific requirements to make the structure strong and to give comfort to the residents by meeting all their aspirations.

	Integrated STEAM Curriculum			STEAM Content	Context Diseplanary
	Objectives	KPIs	Questions to reflect		
Stage 3	Design the house that can withstand that climatic conditions.	• Decide the dimensions of the house/rooms/door/windows…. that constitute the built-up area. • Calculate the surface area and volume of the house/rooms and prepare the ratio.	• What are the dimensions of the rooms? What % should be each area? • How tall do the doors/windows and the building should be? What are the design specifications? • What is the volume of each room? • What is the surface area of the walls, ceiling and the floor? • What is the ratio of surface area to volume of the house using the surface area of the home exterior and the volume of the entire house? •	Engineering Focus Area: Design and structure of the building Science Focus Area: Energy Mathematics Focus Area: length, measurement, surface area, volume, ratio & Proportion	Engineering: Position and dimension of the doors, windows, ventilation, roofing, slope, flooring Science: Heat gain & loss related to surface area, Mathematics: measure the dimensions, calculate the surface area, volume, calculate the ratio
	Prepare a floor plan of the design	• Use appropriate scaling to prepare the floor plan, label the rooms with its distance and measurements. • Incorporate artistic elements in the design. • Prepare a 3D design with the help of technology.	• How would you scale the house in a model and prepare a floor plan? • What are the artistic elements that can be added to the interior and exterior design? • How can you develop a 3D model of the structure?	Mathematics Focus Area: Ratio & Proportion, Scale drawing Art: Artistic Design	Mathematics: Prepare ratios of the measurements to sketch the scale drawing Art: Prepare artistic design for the constructions (lines, shapes,

			•	Technology: Prepare 3D models	space, value, form, texture and colour) Technology: Prepare 3D model of the house layout using available software
Instructional Approaches	Inquiry-based Model, Problem solving, Social Constructivism				
Learning Domains	Cognitive , Affective and Psychomotor Domains of learning				

Table 3: Stage 3 of the activity

During stage 3, as described in Table 3, students develop their mathematical skills in problem solving, geometric construction based on the required built-up area, calculation of area, perimeter, volume, ratio and scale drawing. Their creativity and imagination will also be enhanced by incorporating artistic element to the design. Engineering capabilities are also be boosted while designing the structure. They have to prepare the 3D design of the house with actual measurements using available technology that lead to cognitive and psychomotor development. students learn cooperation as group members share responsibility for each other's learning by using critical thinking and social skills to complete an assignment. Subsequently, this strategy helps to improve listening, communication, and problem-solving skills.

	Integrated STEAM Curriculum			STEAM Content	Context Diseplanary
	Objectives	KPIs	Questions to reflect		
Stage 4	Estimate the cost of construction.	• Select good quality, cost effective and suitable materials. • Calculate various costs involved in the design.	• How do you compare the quality and cost of required materials available in the market? • How do you estimate the cost of construction,	Mathematics: Economic Purchase, Costing Science: Types & Properties of materials	Mathematics: Compare the price of different building materials to do economic purchase without compromising quality. Estimate the cost of construction, considering various

			materials & labour?		stages of construction. Science: Compare materials according to their properties such as corrosion resistance, density, ductility, malleability, elasticity and hardness. Compare materials according to their types such as glass, fabrics, wood, metal and plastic.
	Presentation of the final product	• Demonstrate a good understanding of the features and precautions to be incorporated in the construction of a good beach house.	Presentation should include: What are the design Specifications and the cost of construction? What are the rationale for selecting appropriate materials? How well the scale model is prepared? How good is the 3D model? How good the artistic elements are incorporated in the design? •		

Instructional Approaches	Problem solving, Social Constructivism
Learning Domains	Cognitive , Affective and Psychomotor Domains of learning

Table 4: Stage 4 of the activity

In this stage, students demonstrate the knowledge to prepare a budget for the proposed design by accurately measuring the area, perimeter, volume and comparing the quality of materials and economic purchase. The guiding question given in Table 4 will help students to reach the objective. They have to present the model and explain the proposal explains the appropriate reasons for the specifications. They are demonstrating their design and mathematical skills as well as problem solving and estimation and communication skills.

Conclusion and Suggestions

In the face of a rapidly changing world, it is important to educate new generation with 21st century skills and engineering and design skills in order to play an active role in scientific and economic development. This study explored the capacities of designing an integrated STEAM curriculum that promotes students' cognitive and conceptual understanding through the five disciplines. This research utilized a STEAM activity using an inquiry approach to help learners acquire scientific concepts behind the construction of houses at a coastal area. This fosters communication through exchanges of information in both virtual and face-to-face settings, demonstrate how to apply scientific and mathematics concepts within a real-life scenario with the incorporation of technology, engineering and art. Students develop a design of the proposed house while using many mathematical and design processes with the final outcome being a complete sketch of the house and a virtual design with all specifications and estimated cost without compromising quality of construction. It will provide them the tools and methods to explore new and creative problem solving with innovation and linking multiple fields. More over, this will equip students with the transferable skills that include creativity, curiosity, resilience, collaboration and confidence which are the 21st century skills. STEAM education helps students of all backgrounds and interest to develop innovative mindsets with the ability to generate and think creatively.

This study suggests how to implement integrative activities where science, technology, engineering, art and mathematics are made interrelated. Also, it points out practical suggestions to use these approaches in various contexts. To further develop this line of research, quantitative investigations would be useful to analyse teacher and student characteristics, context, learning domains, instructional approaches, student engagement and so on. As per literatures, the JIGSAW model of cooperative learning in the classroom gives many effects such as improvements of academic performance, higher self-esteem and more positive views about school altogether (Winslow, 2020). Hence incorporating jigsaw model with the brainstorming and inquiry model is suggested for enhanced output and learning enjoyable. It is also beneficial if the activity includes a reflection for each group to evaluate their own design with the other groups' work based on a set criterion.

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