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Critical Analysis of International STEM Education Policy Themes

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Abstract

The optimal implementation of STEM in K-12 schools is a long-range goal, yet, currently there is no clear understanding of how STEM education is defined and how schools are implementing integrated STEM curricula. The main purpose of this study was to critically analyse themes found in major international STEM education policies and practices. The main question of the study was, what are the international common themes of effective instructional policies and practices of the STEM education? The study followed a qualitative approach with use of document analysis, incorporating Braun's and Clarke's protocol for selecting the key international STEM policies, reports, and documents. The thematic analysis revealed two broad classes of implementation global themes: structural and interpersonal. The structural implementation global themes include: "subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (e.g., businesses and industry). The interpersonal implementation global themes include: leadership, collaboration, willingness, and authentic/meaningful/relevant experiences for participants. In conclusion, the appeal of integrative policy of education calls for constructivist-based approaches that are deemed highly effective within STEM curricula because of the integrative nature of its concepts that include a myriad of constructivist practices to help build 21st -century skills within students.

Key words: STEM education, STEM policies, thematic analysis, K-12 curriculum.

1. Introduction and Background

Science, Technology, Engineering, and Mathematics (STEM) education has become the topic of much debate in educational settings over the past several decades (Herschbach, 2011; Sergis et al. 2019). Another cause for changes in STEM education is the difference in the way today's students are motivated (Chittum et al. 2017). Students leave STEM fields for a number of reasons with the leading attrition factors being lack of motivation, teaching techniques, study skills, rigid course sequencing, poor grades, uninspiring introductory courses, poor advising, and deficiencies in mathematics (Matthews 2012; Hanover Research 2011; Chittum et al. 2017). A lack of student engagement in STEM activities results in lower motivation in STEM learning, lower academic achievement, and reduced efficacy in the use of metacognitive strategies (Chittum et al. 2017). This impacts the developmental processes of STEM identities, which relate to self-concept and self-efficacy, particularly for women and minorities. Ultimately, these factors influence students' interest in STEM activity and education and the decision whether or not to pursue post -secondary education STEM disciplines. Students of today are a product of the information age and the exponential times that have resulted in them rapidly adapting to new technology. Nowadays, students are able to master technology far better than most of the previous generations (Cavanaugh, Giapponi & Golden 2016).

Data related to STEM careers and jobs is another area of consideration. It can be shown that "the United States is not producing enough STEM graduates to fill the growing need for STEM related jobs.

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According to the U.S. Department of Commerce, in 2015, there were 9.0 million STEM workers in the United States, about 6.1 percent of all workers, which was up from 5.5 percent just five years earlier. (U.S. Department of Commerce 2017, p.1). In addition, "STEM occupations are projected to grow by 17% over the decade beginning in 2008, compared with about 9.8% growth for non-STEM occupations" (Langdon et al. 2011, p.61). The need for STEM jobs in world`s economy is widespread. Georgetown University's Centre on Education and the Workforce found that the cluster of STEM occupations is forecast to provide 2.8 million jobs through 2018 and is made up of "1.2 million new jobs and 1.6 million replacement openings" (Carnevale, Smith & Strohl 2010, p.5). In the Monthly Labour Review, it is stated that over the decade beginning in 2009 there would be a need to add one million more STEM professionals to the American workforce (Lacey & Wright 2009). In the report, Rising above the Gathering Storm, revisited: Rapidly approaching category 5, the National Academies Gathering Storm committee concluded that "innovation would be largely driven from advances in science and engineering and the future economy will be dependent upon new innovation to create jobs" (p.62). The report goes on to state that only 4% of the workforce is made up of scientists and engineers, but they will create 96% of future new jobs (Augustine et al. 2010). This means that STEM careers produce more jobs than other fields. These statistics show the demand for people that have STEM skills. It will fall to educational institutions of all levels to cultivate and develop students to fill these needed roles. STEM careers have one advantage however; STEM careers generally pay better than other jobs.

While the optimal implementation of STEM in K-12 schools is the long-range goal, currently there is no literature and understanding of how STEM education is defined and how schools are currently implementing integrated STEM curricula. In fact, a single definition of STEM education might be inappropriate. Rather to achieve long-range success, "broad tactical definitions of STEM and STEM education might need to be constructed" (Ostler 2012, p.19). Ostler (2012) believes that, "If STEM education programs are to be successful, educators need to develop a long-range tactical understanding of STEM content and STEM education regardless of their own localised definition" (p.10)

Another theme that surfaced in the literature related to STEM education is the need for curricular support structures if a STEM curriculum is to function successfully in schools. Since the study focused on identifying critical elements of successful integrated STEM curriculum development, curricular support structures would likely need to be explored/identified as a part of the research.

Because of the nature of STEM education and its "newness" in schools as a combined field, if it is asked from STEM practitioners it is likely that one will get a wide range of key components of an integrated STEM definition and factors that influence implementation of an integrated STEM curriculum. Therefore, the main purpose of this study was to critically analyse and explore themes found in major international STEM education policies and practices. The main question of the study was, what are the international common themes of effective instructional policies and practices of the STEM education?

2. Theoretical Framework

The theoretical framework of the study comprises of three theories, the Integrative Theory for Drake and Burns (2004), Institutional Model by Rawlings (2011), and the Socioscientific Issues (SSI) Theory of Science Education by Zeidler et al. (2002).STEM policy is an essential component in the current education systems in many countries. Indicatively, the integration theory, proposed by Drake and Burns (2004), focuses on curriculum assimilation. Provided that the researchers had an interest in the education system and, in particular the STEM policy, it is crucial to justify the incorporation of this theory. Indeed, the conceptions of multidisciplinary, trans-disciplinary, and interdisciplinary link with the scope of STEM policy, which seeks to provide relevant knowledge and skills with regard to science, technology, engineering, and mathematics. Curriculum integration is defined, collectively, as an educational approach where students study an integrated or interdisciplinary theme or topic and its related issues in the context of multiple disciplines (Bybee 2013; Drake 2012; Fogarty 2009). Additionally, Chernus and Fowler (2010) identified four key elements of curriculum integration that must also be present for a learning experience to be defined as truly interdisciplinary, standards, content, experiences, and real-world contexts.

While multidisciplinary and interdisciplinary integration involves the merging of two or more disciplines to bring an understanding of a topic, an idea, or to solve a problem, transdisciplinary integration goes beyond discipline boundaries to support and enrich learning. Learning is not compartmentalized but rather explored within the content and context of the inquiry such that, unifying issues and topics are through discipline connections (Drake & Burns 2010). Thus, it is important to understand that how subjects are integrated makes the approaches differ.

Transdisciplinary integration is presented in ways such as Understanding by Design, 21st Century Skills and Knowledge (ISTE standards, 2007), and project and problem-based learning. However, since the terms interdisciplinary and transdisciplinary mean interactive and holistic respectively, it is appropriate to denote that the approaches applied in transdisciplinary can as well be applicable to the notion of interdisciplinary (Elias, 2006).

Aligned with calls for a focus on institutional factors, recent efforts of STEM integration require transformation on the institutional level. Those transformations require transformation at three levels: student, faculty, and institution (Whittaker & Montgomery 2014). An example of the institutional model is depicted by Rawlings (2011) as a framework design to implement systemic changes in the undergraduate STEM learning and teaching to bolster change in STEM education. According to Rawlings (2011), the model demands for identification of core levels including agents, mechanisms, and structures to sustain it.

Zeidler et al. (2002), defined Socioscientific issues as a movement that incorporated all the goals of STS education "while also considering the ethical dimensions of science, the moral reasoning of the child, and the emotional development of the student" (p. 344). the socioscientific issue movement arises from a conceptual framework that unifies the development of moral and epistemological orientations of students and considers the role of emotions and character as key components of science education" (p. 113). Also, Pedretti and Nazir (2011) identify SSI as a value-centred current of STS that challenges the idea that science is value free.

Aligned with calls for a focus on institutional factors, recent efforts of STEM integration require transformation on the institutional level. Those transformations require transformation at three levels: student, faculty, and institution (Whittaker & Montgomery 2014). An example of the institutional model is depicted by Rawlings (2011) as a framework design to implement systemic changes in the undergraduate STEM learning and teaching to bolster change in STEM education. According to Rawlings (2011), the model demands for identification of core levels including agents, mechanisms, and structures to sustain it. In this context, the main structure is pedagogy, the varied practices implemented by faculty members to train students, support, and guide their learning.

Efforts alluded to in this theoretical framework are important for policy and implementation of STEM education for students and institutions. The notion of diversity in the context of STEM requires that all people are included in the policy framework; is important that all the individuals with disabilities both male and female are incorporated into the suggested education framework to ensure achievement rights as denoted in the varied agreements. Similarly, these institutional changes seek not only to improve the experiences, retention, and performance of teachers and administrators in STEM but also institutional practice and equity.

3. Literature Review

According to Treffinger and Isaksen (2005) and Lai and Viering (2012), the teaching of the integrated subjects of Science, Technology, Engineering and Maths (STEM) has gained momentum in the last decades. An interdisciplinary technique, according to Khadri (2014), incorporates rigorous application of academic conceptions that are entwined with real-world lessons, which students apply in science, engineering, technology, and mathematics in line with community, school, work, and the globalised enterprises making STEM a core tool to compete in the transnational novel economy. The conception of STEM, likewise, strives to cultivate a STEM-proficient workforce. This is fundamentally crucial to examine the changes that have been brought about to motivate nationwide reforms. As a result of these features, generating a set of channels between science academia on one hand and business, government and civil society on the other will contribute greatly in speeding up the prospective rhythm to produce excellence and transfer international knowledge networks (Bear et al. 2005; Kolodner et al. 2003; Frees & Bouckaert 2014).

STEM education includes every field under the umbrella of Science, Technology, Engineering and Math. The acronym was coined by the National Science Foundation (NSF 2003) to refer to programming dealing with science, technology, engineering, and mathematics (Lai & Viering 2012) It is a "slogan" that the education society in the United States has embraced to be interpreted to mean science or math and seldom does it refer to technology or engineering (Bybee 2013). Though these definitions are not necessarily incompatible with each other, multiple interpretations have created confusion among many educators (Hendricks et al. 2012; Roehrig et al. 2012).

3.1 Challenges of STEM Education

STEM education is often viewed as dominated by the mathematics and science discipline considerations and with technology and engineering considerations playing a lesser role (Kelley 2012). In fact, during the Mathematics/Science/Technology (MST) movement when math and science educators started to use the term MST in their vernacular, Foster (1994) claimed that MST looked less like a coordinated effort between mathematics, science, and technology and more like technology education wishing that it was a coordinated effort. Kelley (2012) states that many speculated that technology would become a stepchild to math and science. He warns that as engineering education struggles to enter the K-12 educational system, it must attempt to define itself so that engineering education will not face the unclear purpose and division within its practitioners that technology education faced in the past and currently still does. The need for an equal partnership among the STEM curricular areas is affirmed by authors de la Paz and Cluff (2009). Therefore, it is important to continuously ensure that the (T and E) are equal partners within STEM in order to provide meaningful, true integrated programmes and curricula to prepare future generations for workforce and life.

Proponents of integrated STEM education claim that "countries across the globe are not producing enough STEM graduates because there is a lack of social and economic incentives for pursuing STEM careers, and that increases in STEM courses taken in high school have not sparked interest in post-secondary STEM" (Stearns et al., 2013, p.52). The authors argue that "improvement in the quality and integration of STEM education should be the focus of national attention because increasing high school students' STEM course load in high school has been shown to be insufficient and STEM courses should focus learning on creative exploration, projects, problem solving, and innovation rather than rote memorization of current curriculum" (Stearns et al., 2012, p. 1).

3.2 STEM Way Forward

The article, "STEM Education: Proceed with Caution", points out many challenges with STEM education including: "(a) the unchallengeable curriculum (the rigidity and resilience of the school curriculum structure when proposing reform); (b) lack of clarity of the movement (there does not seem to be any clarity about what STEM education might look like in schools in terms of how the STEM subjects should relate to each other); (c) vocational vs. general education (explicit vocational approach in the STEM agenda, mainly related to science and engineering); and (d) dominance of mathematics and science over technology and engineering" (Williams 2011, p.61). Williams (2011) also argues, when examining projects developed to help teachers implement STEM activities into their classrooms, that the projects do not actually integrate science, technology, engineering and mathematics. Rather, these projects include parts of a few disciplines and primarily serve to advance the goals of mathematics and science.

Professional development and collaboration for counsellors is essential and counsellors should improve their willingness/ability to counsel students toward STEM fields for STEM to grow. Counsellors should endeavour to broaden their STEM knowledge base by reviewing theory related to age appropriate student career development, exploring specific career fields of study, and sharing relevant STEM information with students and parents (Schmidt et al. 2012).

4. Methodology

This study followed a purely qualitative approach to generally explore the common trends of STEM practices in reforms, policies and related international documents. Since the main aim of the study was to critically analyse and explore themes found in major international STEM education policies and practices, the document analysis technique was used to collect data. Document analysis is described as a process in which a document is interpreted and analysed to generate themes that share features in common. It is important to note that documents of all types offer understanding and insights relevant to the research problem (Merriam and Tisdell, 2015). Although document analysis can be used as a complement to other methods, it has also been used solely in cases where data is needed to generate new document use. In this study, a various number of documents, reports and policies were investigated. Understandably, those documents can serve a variety of purposes such as suggesting some questions and situations that need to be observed to address the changes in policy and challenges experienced within the STEM education field. This approach addresses relevant positional considerations associated with the current study. Hence, the study followed the thematic analysis method because of the flexibility and its wide use within and beyond education field.

Clarke and Burns 2013 argued that doing a good thematic analysis is a combination of following a robust process, applying an analytic eye to the data, and interpreting it in light of what we already know about the issue(s) being explored to analyse manually the relevant documents generated from the reviewed literature to identify the main themes and relationships. The document analysis protocol was adapted from an instrument created by Ortiz, Locks, and Olson (2016) which included the document type, document title, document source, document author, document objective or stated purpose, and which research questions it helps answer. The document analysis protocol also reflects the collection date and whether follow up is needed to clarify the document. Table (1) below includes the summary of the documents used in the study.

Table 1: Summary of STEM Documents of the Study

NO	Context	Document Title	Purpose
1	"Indiana, United States of America" (2012)	"Indiana's STEM initiative plan"	"A plan introducing the vision and mission of STEM in the Indiana Department of Education"
2	"United States of America" (2011)	"Successful K-12 STEM education schools"	"A project identifying effective approaches in STEM schools"
3	"California, United States of America" (2014)	"Innovate: A blueprint for STEM in California Public Schools"	"A report that was developed under the direction of professional learning support division as a recommendatory"
4	"Massachusetts, United States of America" (2013)	"A foundation for the future Massachusetts' Plan for Excellence in STEM Education science, technology, engineering and math Version 2.0: Expanding the Pipeline for All"	"An STEM plan report which is intended to catalyse a common movement across the Commonwealth that takes place at the local level in order to prepare citizens to be STEM literate and to prepare the STEM Talent Pipeline."
5	"30 European Countries: (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom)" (2015)	"Efforts to increase students' interest in pursuing science, technology, engineering and mathematics studies and careers National measures taken by 30 countries – 2015 report"	"A report about national efforts to increase students' interest in pursuing Science, Technology, Engineering, and Mathematics (STEM) studies and careers."
6	"Australia" (2015)	"National STEM school education strategy A comprehensive plan for science, technology, engineering and mathematics education in Australia"	"A report highlighted the trends that all education systems are grappling with – the performance of Australian students against international benchmarks has stalled or declined as has participation in senior secondary science and advanced maths"
7	"Australia" (2014)	"Science, Technology, Engineering and Mathematics: Australia's future"	"A report outlining the prospectus of STEM education in Australia and its future impacts on Australian education"
8	"Australia" (2014)	"Science, Mathematics, Engineering and	"A report outlining the prospectus of STEM education in Australia and its future impacts

		Technology (STEM) in Australia: Practice, policy and programs"	on Australian education"
9	"United Kingdom" (2011)	"Supporting STEM in schools and colleges in England The role of research A report for Universities UK"	"A report presenting the case studies for understanding the problem of STEM, teaching and learning – pedagogy in STEM, teaching and learning – curriculum and resources, teaching and learning – assessment, and out-of-class support in STEM."
10	"Japan" (2014)	"Consultant Report STEM Country Comparisons: Japan"	"A comprehensive report on national STEM policy in Japan"
11	"25 economies including Saudi Arabia" (2016)	"Yidan Prize Forecast Education to 2030"	"A comprehensive report on how key inputs and outcomes of five education indicators across a mix of 25 economies will change over the next 14 years"
12	"Europe, Middle East and Africa (EMEA) countries" (2016)	"Science, technology, engineering and mathematics education in EMEA advancing the agenda through multi-stakeholder partnerships"	"A comprehensive report on STEM education in Europe Middle East and Africa (EMEA), highlighting specific country and regional practices, and make further recommendations"
13	"Turkey" (2016)	"STEM Applications in Turkish Science High Schools"	"A research sponsored by Ministry of National Education, Turkey discussing on STEM projects and the vision for increasing the STEM education in Turkey and other developed countries"
14	"United Arab Emirates" (2016)	"Building an Inclusive Society: Supporting Youth Employment and Development in the Innovation Economy"	"A Policy Council paper which discussed the gatherings of government partners, educators, and industry leaders regarding an exploratory discussion around the issues involved in achieving the goal of increasing participation among Emirati youth in UAE economic development, particularly in the innovation and knowledge economy and how STEM can play role in this pursuit."

5. Document Analysis & Results

The document analysis was conducted by use the thematic analysis. The justification for utilising thematic analysis emerged from its alignment with the main research question. Thematic analysis is "the process of recovering the theme or themes that are embodied and dramatised in the evolving meanings and imagery of the work" (Van Manen 1990, p. 78). Braun and Clarke (2006) believe that thematic analysis can identify, analyse and report themes (patterns) within data. Additionally, the researchers used a specific document analysis strategy (Table 2), the directed content analysis (Cooper et al. 2016) which requires the defining of codes based on existing STEM research and theory prior to conducting new research. Table 2 below outlines Braun and Clarke's (2006) steps to perform the thematic data analysis.

Table 2: Phases of thematic analysis (Braun and Clarke, 2006)

Phase	Description of the process
. Familiarising yourself with your data:"	"Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas."
. Generating initial codes:"	"Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code."
. Searching for themes:"	"Collating codes into potential themes, gathering all data relevant to each potential theme."
. Reviewing themes:"	"Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis."
. Defining and naming themes:"	"Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme."
. Producing the report:"	"The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis."

This researcher performed thematic analysis according to Braun's and Clarke's (2006) model of analysis "which aims to identify, interpret, and report themes found within the data" (p.41). Braun and Clarke (2006) further defined thematic analysis as a "method for identifying, analysing and reporting patterns (themes) within data," and it "minimally organises and describes your data set in (rich) detail" (p. 6). Thematic analysis provided clarity about meanings of the raw data. This type of analysis "involves searching across a data set" in order "to find repeated patterns of meaning" (p. 15). This thematic analysis, as Braun and Clarke (2006) developed, allowed the researcher to commence inquiry toward the understanding of main components of STEM integration and implementation in K-12 education. Data obtained from qualitative generic thematic analysis allow a comprehensive foundation of understanding of global themes. Braun and Clarke (2006) offer following qualitative thematic analysis procedures: "1. Familiarising yourself with the data, 2. Generate initial codes, 3. Searching for themes, 4. Reviewing themes, 5. Defining and naming themes, and 6. Producing the report" (p. 87).

The steps outlined in the thematic analysis provided a distinct prescription of moving from surface level to the underlying meaning within the data. When adopting this six-step process, the researchers begin with becoming familiar with the data, move through the steps, dig deeper in each step of analysis, uncover the themes, determine the connections, define the themes, finalise the work, produce the report, reflect on scope of the study and refine themes. Further, thematic analysis was also selected because it has the ability to delve into the data presented and provide in-depth elucidations (Patton 2002), especially when multiple sources of data were collected, such as in this study. Multiple sources of data were utilised to search documents for analysis. Thematic analysis was the most appropriate tool for gaining an understanding of the raw data, which were analysed and organised in order to produce a rich, thick description of the global theme (Yin 2009). Moreover, thematic analysis fulfilled the purpose of the study, answered the research questions, and provided narrative accounts of the global theme.

Table 3: Sample of Coding Process

Open Code	Sub-Code	Pattern
STEM outcomes	STEM learning	Integration
Project tasks	Project learning	Project-based learning
STEM initiatives	STEM programs	Connection to in and out programs

Table 3 depicts the sample of coding process used to arrive at the dominant and supplemental codes. During the initial open coding process, some axial coding was used (Yin 2009). For example, if the document stated "Incorporation," the researcher wrote "Incorporation" in the margins. However, the researcher decided to rename future instances of "incorporation" to "Integration," considering that "Integration" was also found within the data with the two terms being used almost synonymously in the passages.

After generating a list of codes and keywords, the researchers began further refining axial coding with the purpose of consolidating, merging, separating, and removing codes, as well as distinguishing anomalies (Yin 2009).

The researchers initially identified 53 codes related to STEM integration and implementation. The codes were placed in two Microsoft Excel spreadsheets to establish frequency, allowing the seven most frequently encountered codes for each group to be identified. Additionally, with the seven codes identified by each population, the researchers compared the two spreadsheets to assess frequency across the documents. As a result, six codes were determined to be dominant based on frequency.

The six words, presented in descending order in terms of usage frequency included: (1) integration; (2) curriculum; (3) community; (4) connections; (5) implementation; and (6) collaboration. Axial coding was completed with the purpose of merging and condensing similar codes, such as "integration", "project-based learning", and "connection to and in program" into the code "curriculum." Nonetheless, all remaining codes were retained and were categorised as supplemental codes (Braun & Clarke 2006). Supplemental codes provided the researchers with the means to organise the findings and categorise results through identification of keywords or phrases that contributed to the formation of the dominant codes.

Then the thematic analysis proceeded to the theme search by initiating codes as a guide along with establishing some parameters. The parameters were used to assist in searching for themes that related to the research questions, global theme, and purpose of the study (Braun & Clarke 2006). The theme search was also conducted using paper and a highlighter. A pink highlighter was used to bracket phrases, lines, passages, and paragraphs that related to the codes and offered data that contributed to the study's purpose. Notes were made in the margins to document thoughts and make connections between topics. Moreover, additional journal entries were made each day the researcher engaged with the data and actively conducted the theme search. After manual theme searching, the researchers replicated the process on the Word documents using the pink highlighter option in Word.

Within the documents, particular remarks were able to contribute to the formation of 73 theme titles. The analysis of documents ultimately triggered the development of the themes, although all fifteen data sources justified the 73 themes and revealed the relationships amongst the themes related to STEM integration and implementation.

Once the themes were established, the following step of thematic analysis, reviewing themes, was initiated. In this step, the goal was to evaluate the quality of the themes and establish whether the themes were supported by the data. Further, the researcher evaluated the relationship of the themes to the overarching theoretical framework of the study and verified the connection with the study's purpose (Yin 2009).

The assessment of the themes was accomplished by analysing the data in relationship to the dominant and supplemental codes (Yin 2009). Further, the researchers reread the list of supplemental codes to re-assess the validity of the codes (Yin 2009), as well as established firm parameters for data placement based on dominant and supplemental codes. Once dominant and supplemental coding was established, the researcher revisited the pertinent literature sources and evaluated codes found in previous studies relevant to this study's global theme. This additional step was included to align terminology amongst the studies. The researchers evaluated the keywords, codes, and patterns used within the studies that revealed the gaps that contributed to the formation of this study's research questions and objectives (Braun & Clarke 2006).

After the themes were found to support the data, the connection between the themes and codes was realised. A review of the themes, codes, patterns, and excerpts was conducted by the researchers with the focus on the ability to develop a narrative account of the results (Braun & Clarke 2006). Moreover, the researchers assessed the relationships to search for anomalies, irrelevant content, and improper relationships. The connections between the themes and codes were apparent, as the codes contributed directly to the themes, as the data matched with the codes and aligned with the themes. No instances where data was forced into categories or themes were found, although some data were found applicable to two or more themes which is, according to Braun and Clarke (2006) a common aspect of thematic analysis. Further, the researchers noted the data related to the theoretical framework within the margins of the Word document to allow for immediate access to data that supported and advanced the theories. As a result, the themes were revisited in order to establish patterns that were dependent upon the dominant codes (Braun & Clarke 2006).

Then the researchers moved to step of defining the themes after organising and clustering them, communicated the captured data, identified what was interesting about the themes, and established why the themes were interesting. This process of defining themes began with identifying a journal entry to reflect the connections between the codes and themes as well as defining of the themes based on the codes-themes relationships. The entry also included a section on what each theme's data identified and how the data supported the theme. The researchers also noted interesting concepts about the data and the themes, explaining why the themes were important. Any thoughts pertaining to how the data or themes contributed to the literature, theories, methodology, research design, or other features of the study were also recorded for each theme (Yin 2009).

At this point, both researchers conducted a final review of all previous steps of thematic analysis, checking for completion, quality, and accuracy. An additional review of data was conducted and any additional supporting excerpts were added for final review. Changes were made based on the data and some patterns were renamed as well. Missing or incorrectly placed data items were promptly added and rearranged, respectively.

The final step of thematic analysis was 'producing the report' by writing the "results" section. The researcher searched for similarities and differences, accuracies in the reporting, aiming to determine if modifications were needed in presenting the narrative accounts of the participants (Braun & Clarke 2006). The selected documents were thoroughly scrutinised for STEM related key components in the content. The themes were mainly observed by those which researchers examined in their initial readings and later used in other data collection tools. Table 5 provides the complete list of the themes and their levels identified by the researchers through the reading and examination of fifteen selected STEM documents for the analysis.

Table 5: Codes, Themes, Clusters, and Global Themes from Document Analysis

Codes	Themes Identified	Organising/Clustering Themes	Global Themes
Curriculum Learning Projects Programs Connections Culture Technology Virtual Environment Professional Development Innovation and Design STEM Resources Funds	Integrated curriculum Project based learning Inquiry-based learning Connection to in and out programs Classroom Culture Integration of technology and virtual learning Authentic assessment Professional development Innovative Curriculum Design Setting up STEM Resources/Labs/Virtual Learning Environments Extra Funds for Equipment and Supplies for STEM Curriculum	Curriculum	STEM Content/"subject integration/project-based learning/design-based education"
Business Community Industry Mentorship Job Opportunities	A communicated plan across education and business STEM work-based learning experiences Mentorship and internship opportunities	Community	Outside support from organisations
Collaborations Investments Acceptance Encouragement Research Politics	Public and Private Investments and Collaborations Acceptance and Encouragement from Community, Business, Industries, and Universities Role of politicians and researchers in identifying challenges and their help in resolving them	Community focus on strategic partnerships	Outside support from organisations
Vision Mission	Vision, Mission, Values Student Achievement	Leadership domain	Leadership

Values Interdisciplinary Collaboration Creativity Teamwork Critical Thinking Problem Solving Flexible Schedule Awareness Interest Motivation	Interdisciplinary learning and teaching Collaboration Innovation and Creativity Promoting Team Work Promoting Critical Thinking and Problem Solving Involving industry and experts from the community Creating Flexible Timetables and Curriculum Delivery Enhancing Awareness and Interest of Teachers, Students, Parents, Stakeholders, and Community towards STEM field and careers		
Motivations Learning Success Persistence Parents' Support Teaching Style Self-Efficacy Experiences and Interest Family Values Clubs Organisations Financial Assistance Friends in STEM related majors	Perceptions Towards Teachers Project-Based Learning Success vs. Failure Parental Education Parental Support Parents' Sacrifices and Students' Gratitude Course Teaching Style Self-Efficacy Motivation as a Form of Gratitude Childhood experiences and interest Positive educational experiences Self-motivations Positive experiences with professors Family encouragement and values Lack of educational preparation The need for financial assistance Clubs and organisations Friends within the major	Continuity and Motivation	Authentic/relevant/meaningful experiences
Collaboration Team teaching Willingness Resources Certification Professional Development Staffing	Collaboration/team teaching/cohorts to create integrated STEM Willingness of teachers to create integrated STEM Resources needed to create integrated STEM Certification and the creation of integrated STEM Professional development and the creation of integrated STEM Staffing changes and the creation of integrated STEM Creation of integrated STEM	Integrated STEM education in School Settings	Willingness and Collaboration
Teachers' Integration STEM school curriculum School changes and structures	Teachers of integrated STEM Integrated STEM and the school curriculum Integrated STEM and changes to school structures Implementation of integrated STEM	Implementation of Integrating STEM education in a school setting	Professional development (the need for and the type of)
Assessment State Standards	Non-traditional assessment Integrated STEM and state standards	Assessment of integrated	Teacher Assessment

Testing National Standards	Integrated STEM and standardised testing Integrated STEM and national standards Integrated STEM assessment	STEM	
Knowledge of interdisciplinary lesson Samples Collaboration and Planning Shared Collaboration Lesson Plans Connecting with other disciplines Instructional strategies Resources Reflections	Knowledge of the characteristic features of an interdisciplinary lesson Opportunities to analyse sample interdisciplinary lessons Collaboration in STEM lesson planning Integration and shared collaboration Creating lesson plans that incorporate other related STEM disciplines Connecting with other disciplines Interdisciplinary lesson instructional strategies Resources for STEM integration Reflection on the practice Professional Development that supports STEM interdisciplinary integration Pedagogical content knowledge in integrated STEM education	Interdisciplinary STEM Professional Development	Professional development (the need for and the type of)
STEM definitions STEM preparation STEM challenges	Definitions and Discourse Abilities Connectivity within STEM Preparation Experiences Circumstances That Might Make STEM Difficult to Manage Confidence from Preparation Confidence from Experiences	STEM Integration Abilities	Time

6. Discussion and Conclusion

Themes were generated as the data was analysed in each of the documents. However, when the identified themes began to surface in more than one of the analyses, the themes became something more important. Some of the identified themes rise to the level of global theme that seem necessary for integrated STEM to exist. With this realisation, the global themes that were identified in the synthesis can be considered both critical components for the definition and implementation factors. There are two broad classes of implementation global themes: structural and interpersonal. The structural implementation global themes include: "subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation global themes include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support.

The structural implementation global theme that were identified all relate to physical aspects, strategies, or quantities, which according to the documents analysed must be in place for successful integrated STEM to occur. These are things that schools strongly need to consider if they are going to create and implement an integrated STEM program.

6.1 Global Theme 1: Subject integration/project-based learning/design-based education

The global theme of "subject integration/project-based learning/design-based education" surfaced in all the documents. Twelve out of the fifteen documents specifically stated that integrated STEM education must have a project-based learning approach. The concept of subject of integration of the STEM disciplines surfaced throughout all the documents. All fifteen documents also mentioned or implied the real-world nature of design-based education. The global theme of "subject integration/project-based learning/design-based education" was found documents mentioned about integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM.

This global theme was related to other global theme including assessment, professional development, willingness, and STEM content, aspects previously described in literature (Pitt, 2009; Sergis, 2019). The relationship between the "subject integration/project-based learning/design-based education" global theme and assessment can be found in the words in the documents. One document suggested that general assessments would be projects which should include interviews, discussing with students their projects, talking about what they think the value point-wise or grade-wise of what they did is and was. Another document stated indicated the task being the project and that there should beon-going assessments in the form of journaling or discussion with teachers (Rawling, 2011). Another document stated that assessments may be more of project-based when referring to integrated STEM. The document indicated this would facilitate the learning of teachers in a way that is different than a traditional high school test would look like and that project assessments are equally as important, if not more important, than standardised testing. Another document indicated that that integrated STEM assessments should be project-based, problem solving based and higher level inquiry. Similarly, the document referred that this is the best way to assess integrated STEM because a project gives a student [the chance] to really demonstrate their connections and their understanding.

The relationship between the "subject integration/project-based learning/design-based education" global theme and professional development is also found. This type of training relates closely to the design-based educational experiences in integrated environments when referring to other teachers that are interested in teaching in an integrated STEM environment. The prevalence of the "subject integration/project-based learning/design-based education" global theme, and due to the sheer number of documents that stated about it in multiple places in the content, made it a strong implementation factor related to integrated STEM education. This global theme also tied directly to the theoretical framework for the study, which again emphasised its importance (Drake & Burn, 2004; Zeidler 2002; Whittaker & Montgomery, 2014).

6.2 Global theme 2: STEM content

The global theme of the importance of STEM content was evident throughout the entire document analysis where content of documents stated integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM. This global theme was related to the other identified global theme by the documents including "subject integration/project-based learning/design-based education", professional development, and willingness. STEM content is what is being delivered by the pedagogical methods of "subject integration/project-based learning/design-based education". Based on this result, teachers must be competent with STEM content and need continued upgrade to their pedagogical content knowledge to provide the best integrated STEM environment possible for students (Chittum, et al., 2017). Finally, teachers must have the willingness to teach STEM content(Buckley, et al, 2019).STEM content is an important implementation factor for integrated STEM. While it was not mentioned specifically by all the documents, its importance seemed to be assumed by the documents when it is mentioned science, technology, engineering, and math in their contents. STEM content is also one of the legs of the theoretical framework ((Drake & Burn 2004; Whittaker & Montgomery, 2014; Zeidler 2002) of the study, which again demonstrates its importance.

6.3 Global theme 3: Professional development

The global theme of professional development was found in all the documents, which was related to the creation of integrated STEM. The need for professional development was also mentioned in various parts of each document. This global theme was related to other global themes including, subject integration/project-based learning/design-based education, authentic/relevant/real-world experiences, STEM content, collaboration, leadership, authentic/relevant/real-world experiences, outside support, and willingness. Giving the teachers the freedom or the suggestion to figure out what they really want to do themselves within integrated STEM, what they enjoy doing, what they feel comfortable doing, what do they want to learn more about, and have them figure that out before they enter the classroom and have them understand it, these are important to know. Collaboration was also mentioned as an area needing professional development. Constantly collaborating with a community is a must. Professional development needs to include situations for educators when they get a chance to come together and discuss things and share experiences (Forawi 2015). Professional development was needed to be ongoing, focused, and driven. This speaks not only to the constant, on-going nature of needed professional development, it also stresses the importance of the experiential nature of professional development that can help teachers understand and instruct in an integrated STEM environment.

Therefore, PD in STEM relates to the nature, content, and delivery of professional development which should help provide a frame of reference for those school leaders who want to implement successful STEM education. With the sheer volume of comments related to the need for and type of professional development related to integrated STEM, it should be obvious that professional development is a critical implementation factor for integrated STEM. Teachers must have diverse experiences related to the type of instruction that they are providing students. This involves teachers having authentic/relevant/real-world experiences provided by school leadership with the willingness to learn STEM content using "subject integration/project-based learning/design-based education" through a collaborative process. Professional development was also one of the support structures identified in the conceptual framework.

6.4 Global theme 4: Time

The global theme of time surfaced in all the documents. Twelve out of 15 documents specifically mentioned the need for time related to integrated STEM education. Time is needed for collaboration, for planning, for exploring, and thinking (Cavanaugh, et al., 2016). The global theme of time was found when documents discussed about integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM. The time global theme was related to other global themes including collaboration, professional development, assessment, and authentic/relevant/real world experiences. The relationship between the time global theme and collaboration is evident. The administration actually gives the team, of the different subject area matters, planning time to talk about things, to talk about the students that are in the classes(Margheri, 2016). The integrated STEM takes a commitment to the district to provide time for planning and there has to be time dedicated to allowing the teachers to find the meaningful connections among the content prior to instructing that content or providing activities and lessons that connect the content together. There has to be more instructional planning time than a traditional classroom setting(Buckley, et al, 2019).The global theme of time is prevalent throughout the documents, not just time for teaching and learning, but time for planning, collaboration and professional development to emphasise importance of time for the process of policy development and integrated STEM education.

6.5 Global theme 5: Assessment

The global theme of assessment was clearly stated in all the reviewed documents demonstrating its importance in for the STEM programmes. Several documents revealed that assessment in STEM is considered a complicated process, as it meant to develop students comprehensively, improves creativity and individual responsibility toward the group (Capraro, Capraro & Morgan 2013). STEM assessment applies to both individual and group performance using authentic assessment techniques through summative and formative assessment tasks. From the analysis of the documents, it was also apparent that schools would have to think differently about assessment for integrated STEM environments. The non-traditional nature of integrated STEM assessment is what makes it an important implementation factor. This theme also relates to the study theoretical framework (Drake & Burn, 2004; Whittaker & Montgomery, 2014; Zeidler 2002) as it directly connects to the STEM policy development, curriculum implementation, multidisciplinary organization and student attainment

6.6 Global theme 6: Outside support from organisations

The global theme of outside support from organisations for integrated STEM surfaced in most of the documents. Outside resources are an important aspect of integrated STEM and linked to almost all the other themes, yet, from different perspectives. Outside support is basically seen as a crucial tool for successful planning and implementation of STEM education experiences. It is also seen through the comprehensive training, technology, PD, ...etc. It should be noted that outside resources are also take on two facets by helping with the structural as well as the interpersonal policy development and implementation of integrated STEM. This global theme as identified in all documents to intertwines with all the other global themes, and therefore, appears to be critical for development and implementation of effective STEM education. As stated in the study's theoretical framework (Drake & Burn, 2004; Whittaker & Montgomery, 2014; Zeidler 2002), if one global theme is missing it is like removing a critical part from a complex machine. It may function, but definitely not as it was designed or as efficiently.

6.7 Global theme 7: Collaboration

The global theme of the importance of collaboration was evident throughout the document analysis. Collaboration is a universal activity for both teachers and students and natural linked to STEM education.

K-12 schools should ensure that curricula provide collaborative technical and social capacity needed for applying information and technology to decision-making, resource management, education, and workforce development. Nearly all the documents mentioned collaboration in numerous situations. The global theme of collaboration was closely intertwined with several other identified integrated STEM global theme and it can be argued that "subject integration/project-based learning/design-based education" and authentic/relevant/real-world experiences for students can only be achieved in collaborative environments, since these global theme are connected via other identified global theme. Collaboration is prevalent in the document analysis and its interconnected nature with the other identified integrated STEM global theme makes a strong case that it is indeed a key implementation factor for integrated STEM (Drake & Burn, 2004; Whittaker & Montgomery, 2014; Zeidler 2002).

6.8 Global theme 8: Willingness

The global theme willingness of teachers toparticipate in integrated STEM was evident throughout the document analysis. The global theme of willingness of teachers is also connected to the global theme of subject integration/project-based learning/design-based education, professional development,outside support from organisations, collaboration,…etc . The global theme of willingness reflected through teachers' motivation (Singh, R. (2016) and desire to participate in the planning and implementation of STEM curricula and further develop their own skills to provide effective experiences to their students. By the number and type of connections, it can be clearly argued that willingness of teachers to participate in integrated STEM is a key implementation factor for integrated STEM education (Khadri 2014).

6.9 Global theme 9: Authentic/relevant/meaningful experiences

The global theme of authentic/relevant/meaningful experiences was evident in 14 documents in several different places. It can be argued that both project-based assessments and portfolio-based assessments fit as authentic and competency based models for assessment. In fact, several of the documents mentioned the application of project-based or portfolio-based models in their description of authentic, competency-based assessments for teachers in integrated STEM. Ultimately, the assessments of integrated STEM are going to be non-traditional, where students create a product that demonstrates their skills in a real life authentic setting. The global theme of authentic/relevant/meaningful experiences is also closely connected to the global theme of professional development and outside support by people and businesses. Logically, for teachers to understand and create integrated STEM environments for students, they must be trained in these types of environments. The training must come from somewhere, so outside support by people and businesses would be important. There is also concrete evidence supporting these logical arguments, which are detailed in the professional development and outside support global theme that are included in the implications for research questions section. Authentic/relevant/meaningful experiences for both teachers and students, surfaced throughout the documents. Authentic/relevant/meaningful experiences are closely related to many other global themes and further encourages creativity and critical thinking for both teachers and students (Forawi, 2016).

6.10 Global theme 10: Leadership

The global theme of leadership related tointegrated STEM surfaced in most of the analysed documents. School leadership can be defined in many ways. For the purpose of the results, the researchers have combined comments about school leadership from anyone directly attached to the school, except teachers and students. This includes building and district level administrators, curriculum specialists, and school board members. Leadership by teachers, students, and outside the school, was also mentioned as important to integrated STEM. Possibly the best way to sum up the leadership needs for integrated STEM is through shared leadership. Each document put a unique spin on exactly who and how the leadership must be applied, nevertheless it appears leadership is an important aspect of integrated STEM. The integrated STEM takes leadership in many forms and aspects. It takes leadership from teachers, school officials, people outside the school, and students. That leadership must be present in professional development and the classroom. As with any change, leadership is crucial to its success. Leadership was found in the literature (Herschbach 2011; Jacobs 2010) as being important to integrated STEM, and leadership was one of the support structures for integrated STEM in the conceptual framework of the study. It was not a surprise that leadership was identified as a key implementation factor for integrated STEM.

Global theme 11: Dissent/concerns for schools

The final global the medeveloped in the data analysis of the documents was related to dissent among the schools. There were four major areas of dissent that must be addressed. Schools should be aware of these areas of dissent when creating and implementing an integrated STEM curriculum. They could pose potential stumbling blocks, which would need to be addressed. The primary areas of dissent present in the documents were: 1) elective vs. core class, 2) certification, 3) standardised testing, and 4) cost. The first area that was not retaliated in all the documents was whether integrated STEM is an elective or a core class. The documents; however, indicated that an integrated STEM could be a core class, or an elective, or somewhere in between. Another area of disagreement was related to certification of teachers of integrated STEM. Some documents mentioned that certification is not needed for integrated STEM teachers. The educator with a STEM certificate or a STEM degree would have a deep enough knowledge in any one of the areas to excel. Another area of dissent among the schools is whether integrated STEM would help or hinder the standardised testing culture found in education. Seven documents indicated that integrated STEM cannot be assessed through standardised testing. Eleven documents discussed the difficulty with standardised tests. Another area of contention is the cost of an integrated STEM program. The areas of dissent between the schools related to cost, certification, standardised testing, and core class vs. elective class are worth noting. These are exactly the types of discussions that must be conducted, and where compromise must be identified if integrated STEM is going to gain traction in public or private schools. Knowing the areas of agreement provides common ground for possible integrated STEM implementations, and knowing the areas of disagreement can drive discussions that make integrated STEM better if handled correctly.

7. Conclusion and implications

In conclusion, while STEM-based initiatives are not altogether new to the field of education, the recent focus by policymakers and educators has echoed many countries' call for more explicit STEM curricula within the K-12 schools to boost student attainment in STEM. The elevenidentified global themes: subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, outside support from and by businesses and industry, leadership, collaboration, willingness, authentic/meaningful/relevant experiences, and dissent/concerns for schools are critical for policy development and implementation of integrated STEM as identified in the documents. The documents further suggested that it might be necessary to hire a specialty teacher in some cases. Within the context of document analysis, it has become apparent that science is now becoming more highly prioritised within K-12 curricula and is intended to serve as a vehicle for delivering STEM-based instruction to students in UAE. Indeed, the STEM education represents a fundamentally different approach to organising the curriculum than approaches that have been used in the past. Among the greatest strengths of STEM is the promise of breaking down the barriers between the content areas and bringing together formerly isolated subject areas such as engineering or technology. STEM learning and teaching strives to boost student engagement and achievement, deepen understanding, and provide relevance to learning.

An area of implication alludes to legislators and experts in education policy should continue to encourage students to pursue a STEM career, they should also consider both the economic and psycho-sociological factors that these future STEM employees-that is, if they do make it through the first stage of the pipeline-will eventually face as they enter the STEM workforce and pursue their careers. If industry and the federal government are serious about increasing the number of scientists and engineers in the UAE, then every effort should be made to recruit as many men and women possible into the STEM professions. That means their campaign to do so starts aggressively at the educational level and should not end once the student has his or her degree. An area to consider for future research is to analyse existing STEM implementations in the context of the identified global themes, to see if the study's global themes are present. This research study can serve as a gauge for the quality of a STEM education curriculum and suggests ways to improve STEM education by incorporating the global themes.

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