STEAM Education Implementation Roadmap

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ABSTRACT

The purpose of this chapter is to present a brief overview of the implementation of STEAM education in schools in developed countries such as China, Australia, United Kingdom and United States of America and to provide a roadmap of its implementation in the context of the United Arab Emirates. The research study in this chapter adopts a qualitative approach whereby purpose sampling of secondary data is collected, compiled and analyzed. Themes are generated after coding the content: implementation of STEAM, challenges related to STEAM application and implementation and requirements for success implementation. For the purpose of ensuring proper integration of STEAM in UAE educational system, a roadmap is proposed with policy drafting recommendations, such as curriculum reform, technology integration, teacher professional development and financial funds.

Keywords: STEAM Education, Roadmap for STEAM Policy Development.

1. INTRODUCTION

Globally, national education programs are emphasizing the understanding of knowledge and practices related to mathematics and science, as well as that of engineering and technology [1]. The Next Generation Science Standards (NGSS) implemented in the United States includes engineering practices and design as one of the core and primary element of science education [2]. Keeping with the practices of the world, the United Kingdom (UK) has also developed an educational policy agenda for the promotion of integrating Science, Technology, Engineering, and Mathematics (STEM) practices, both inside and outside of schools [2]. Henriksen [3] cited the findings of the Institute for the Future who has estimated that the jobs which 85% of today's K-12 learners will be doing by 2030 have not been identified yet. Moreover, he highlights that this finding has wide implications, especially towards the demand of a workforce which is both adequately prepared to effectively respond to real-life problems. Dell'Erba [4] added that these findings also led academic scholars and practitioners to argue the inclusion of 'arts' in the STEM policy.

Inclusion of 'arts' in the current STEM policy can have wide implications for student achievement and teaching practices; it can encourage students to creatively solve real-life problems while building upon the existing STEM approaches [4].Considering the constantly changing demands of the workforce, policymakers in the developed countries of world are increasingly emphasizing on including the aspect of arts in the STEM policy to develop and implement Science, Technology, Engineering, Arts and Mathematics/Applied Mathematics (STEAM) programs [3], [4]. For the purposes of this research, STEAM education is characterized as an approach to teaching in which the students will have the potential of demonstrating critical thinking, innovation, and problem-solving skills. The integration of arts is used as an instructional approach in STEAM education, and for promoting inquiry-based and experiential learning [4]. Finally, Shaer, Shibl, and Zakzak [5] highlighted that the Government of the United Arab Emirates (UAE) must develop policies which will efficiently allocate both human and financial resources for the implementation of STEAM education at both the local and national level. Evidence based reforms on STEAM can enable improvements in the education system of the country. A report published by the Education Commission of States argued that investments in the implementation of STEM Education are more likely to fail if they are not supported by adequate and reliable funding on an annual basis [6]. Thus, changes in education policy from STEM to STEAM will bring reforms in current procedure, which might positively affect the UAE development as well.

The sustainable development of UAE is currently hindered by three issues: the pressure of economic transformation, lack of high-level talents in the workforce, and difficulties in reforming education at a national level [5]. Considering these issues, there exist a high-level need of innovative and practical talents in the workforce with enhanced skills and knowledge; however, the current educational policies and standards are not aligned with this goal [6]. These problems can be solved through developing and implementing a new model of "talent cultivation" which can synchronize with the development needs of UAE. Thus, based on this focus on promotion [6], a further step is urgently required for the innovation of education and advancing current teaching practices. Guo, Xu, and Wang [7] highlighted that STEAM education can be of significant assistance for the highlighted focus as this policy provided new tools and strategies. Moreover, they have shown that over the years STEAM education has been widely adopted due to its advanced teaching methods, a teaching system of multidisciplinary integration, and a unique curriculum concept. Due to STEAM education's feature of multidisciplinary fusion, it cultivates the engineering literacy and innovative capabilities of students [7]. Further, the implementation of STEAM education standards and policies at the national level is also the vision of Mohammed Bin Rashid Al Maktoum's Global Initiatives [5]. Therefore, this chapter is based on comprehensive review of related journal studies, texts, reforms of STEAM materials whereby it explores a roadmap for STEAM education implementation in the education sector in the UAE, specifically addressing this roadmap to be adopted in elementary private and public schools throughout all Emirates. Although this context is associated with all education sectors (schools and university), the implementation of STEAM will lead to powering students with necessary skills and creativity that will ultimately lead to educational and economic growth.

Purpose of the Study

The aim of this research is to review the implementation of STEAM education in schools in developed countries and provide a change in roadmap of its implementation in the UAE elementary schools, both public and private for which STEAM education standards and policies proposal draft might be based on. In order to address the main purpose of this chapter, the following research question will be addressed:

- What are the major features of STEAM education implementation roadmap for which a STEAM draft policy might be based on in UAE?

To achieve this aim, the research will complete the following objectives:

- To understand STEAM education initiatives implemented in developed countries including the UK, USA, China and Australia.
- To explore major features of a STEAM education implementation roadmap for which a STEAM draft policy might be based on in UAE.
- To explore the in-progress implementation of STEAM education in UAE and compare with the framework on which implementation initiatives was carried out in developed countries.

2. LITERATURE REVIEW

This section of the research shall focus on establishing the link between variables of the research objective. Factors affecting STEAM implementation shall be evaluated to determine the link of each on education system. The theoretical framework, thus, consists of implementation models which translates policies into action. The theoretical framework of this research is grounded on the Behavior Change Wheel (BCW). Michie, Van Stralen, and West [8] define behavior change interventions as coordinated set of activities with the purpose and intention of changing specified behavioral patterns in any individual or group of individuals. The determination of the broad approach to be adopted is primarily the first step in the process of designing change interventions and then work is conducted on the specifics of the intervention(s). Once this step is completed, the specific components of the intervention are identified [8], [9]. This literature review will, therefore, discuss the policies and their interventional components that are to be translated into action while remaining in the framework of the Behavior Change Wheel.

2.1 Behavior Change Wheel

The "behavior change wheel" that arises from the transtheoretical model of the change admits the existence of four, five or six stages, in the form of a (circular) wheel. Thus, people go through the different stages of the wheel, as if they were sliding through them [9]. The circular shape of the wheel reflects a reality that a change is not linear: in any process of change, the person revolves around the process several times before reaching a stable change. First, these stages of change are usually represented by a wheel to symbolize the fact that the person "spins" several times around the process before achieving a stable change. On the other hand, the model considers relapses as a normal event in the process of change, and subjects are often even told that each relapse "takes another step toward improvement." This is not intended to encourage relapse, but to motivate the subject to continue with his process of change [9].

However, before focusing on behavioral change, the psychologist must face an even more complex challenge: motivational change [9]. This step must always precede the intervention itself because it is easier for those who are willing to change. It is important to know in what motivational state the patient is to know if it is feasible to ask for a change in behavior or if he is still in a premature phase.

The behavior change wheel model can be evidenced from Figure 1 [10]. Exploring the implication of this model on the selected research problem, it can be demonstrated that individuals can show a change in their behavior as per three important elements, which can include opportunity, capability and motivation.

2.2 The Transdisciplinary Essence of Bibliological-Informative Theory

The complexity of the world in which we live forces us to value interconnected phenomena. Current physical, biological, social and psychological situations do not act but interact with each other. The description of the world and current phenomena demands a new way of valuing it from a broader perspective, with a new way of thinking that demands finding a new paradigm capable of interpreting current reality. This brings us to the transdisciplinary conception [11], [12].

When making a brief characterization of the set of elements, it can be demonstrated that conditioned the appearance of the informative bibliological phenomenon, and we would have to start it from the history of human communication itself, that is, language and writing. Although universal culture does not escape these precepts and the transition from oral to written culture produced revolutions that influenced the behavior of man as a social being, today's transformations of technology show a nascent digital culture that leads to new approaches in the treatment of communications and information [11]. All this generates that at present there is talk of "informative phenomenon" as a set of manifestations that have arisen and that characterize in a very peculiar way the incomparable world of current information [12]. This is giving rise in the quantification of information, its storage and communication with others so that effective use of knowledge can be done. This theory has created a rise in technological transformations, which is applicable in a variety of fields, and this can also be applied in the education sector of the UAE.

2.3 Integrative Theory

Integrative or integrated theories are those that are constructed "from the combination of parts or ideas taken from a variety of existing explanations" [13]. These new theories are consistent with the new criminological approach that understands the criminal act as a multicausal event. This criminology theory shows that changes are arising in criminal offences of individuals with the changes evidenced in culture and social aspects of life.

The influence of social learning has the potential to affect the acts of individuals. Throughout its evolution, this theory integrates different aspects such as that of the delinquent subculture, inequality of opportunity, social learning, differential association, tension, control, labeling and rational choice [14]. This demonstrates the fact that social learning of individuals can affect their decision-making processes, their ideas as well as acts. Hence, social learning in educational systems of the UAE should be focused as the theory shows positive social learning can impacts positively. Integrative theory can be incorporated in theoretical framework of the study as it directs social learning attributes, which can cover up STEAM education policy.

Finally, the theoretical framework referenced the policy context for STEAM Education and the important policy areas on which the UAE Government should work to ensure the effective implementation of STEAM, at both public and private levels. There exists a lack of research on policy areas for the implementation of UAE and those which are available are rarely supported by empirical research.

Literature Review

3. POLICY CONTEXT OF STEAM EDUCATION

STEAM education is grounded on the concept of innovation where education is the key component for developing critical thinkers to lead the innovation economy [15]. Clarke (2019)[16] asserts that the perceived need for linking arts with science as one of the key workforce and education policy concerns is one of the primary reason policymakers are emphasizing STEAM more than STEM. STEM to STEAM is the term associated with this shift of focus with the primary purpose of workforce education to instill skills, creativity and flexibility in the nee workforce. This is achieved through arts integration and aligning it with the academic core already developed within the education system [16]. The author explored STEAM education within the context of research and highlighted that it is viewed as a key tool for the promotion of innovation between and within different disciplines including arts, sciences and humanities. Graduates' not possessing innovative and creative spirits are a commonly held view among policymakers and are believed to have an impact on economic development [17]. They added that this view has further exaggerated the shift to STEAM approach in many developed countries, especially including Japan, China and the USA. Adherents of STEAM education contend that this approach has the potential of fostering critical thinking, personal growth, creativity and team-working skills which can positively influence workforce opportunities to contribute effectively to societal needs while gaining employment [15], [16].

3.1 Policies for STEAM Education

Shaer, Shibl, and Zakzak [5] identify the current state of STEAM Education in UAE private schools. The authors reported that though some private schools have implemented STEAM Education for early year education, its implementation is not guided by policies or standards. Subsequently, certain policy-focus areas have been recommended by these authors; however, they have not been viewed through a critical lens. Within the theoretical framework of this research, the key policies suggested in their report will be critically analyzed in the light of peer-reviewed literature for identifying the most high-priority areas on which the UAE Government should work. They have also discussed several policy-related challenges for the implementation of STEAM education in the UAE. These included the integration of curricula, capacity of teachers, allocation of resources – especially financial, incorporation of technology, and balancing the requirements of the curricular with that of STEAM objectives. Shaer, Shibl, and Zakzak [5] ended up their research by discussing several policy-related interventions for these identified challenges; however, this research explores the three most crucial areas: curricular integration, professional development of teachers (capacity of teachers), and allocation of resources.

3.2 Curricular Integration

Shaer, Shibl, and Zakzak [5] recommended the implementation of an interdisciplinary STEAM guide and framework for providing the schools and educators tools for effectively integrate STEAM education with curricula, and to measure the success of integration. Dell'Erba [4] provided certain policy considerations for STEAM Education including access, finance, and statewide coordination. The education department of South Carolina implemented an implementation guide and continuum for STEAM Education in liaison with relevant governmental educational authorities [18]. The purpose of this framework was to achieve statewide consistency and to provide guidance for STEAM Education at all educational levels. Dell'Erba [4] also cited the case study of the education department of Georgia Department which developed similar frameworks that also included reflection and self-assessment tools for the educators. These tools ensure that educators can measure the quality and progress of STEAM implementation or use these tools for the planning of quality implementation [4]. The author further highlighted the importance of understanding the STEAM educational practices to achieve curricular integration in relation to STEAM education. These include: leveraging of concepts from one or more STEM frameworks for the creation of purposeful artwork, embedding 'intention' during the design process, focusing on outcomes that have an aesthetic and personal meaning, conducting open-exploration in the context of both art and science;, achieving communication about the process as well as the outcome, and iteration through several prototypes, drafts and/or models [4]. Finally, Chu, Martin, and Park [19] added that governments have to ensure that these core teaching practices of STEAM education are effectively followed to enable its effective implementation.

3.3 Professional Development of STEAM Teachers

Despite an increase in interest in STEAM education, teachers still find it challenging to integrate and adopt this approach into their subject matter [3]. Herro and Quigley [20] added that this might be due to the fact STEAM implementation has often been viewed through the narrower lens - understanding it as a simple integration of arts into the sciences. The authors further added that the acronym of STEAM might also cause confusion to some as they might consider it as just plugging an 'a' into STEM. Bahrum, Ibrahim, and Wahid [21] added that some consider STEAM Education as the sole amalgamation of 'arts' with 'science' which can have consequences. Some teachers are uncertain about the inclusion of an 'a' into STEM and others might lack the artistic capabilities required to effectively achieve arts integration [3]. Teachers who have artistic capabilities might be uncertain about how to incorporate the arts into STEM. This calls for the need of STEAM with an inclusive approach that encompasses various disciplines and provides entry points to teachers across various contexts [22]. Henriksen [3] added that this view of STEAM has multiple aspects; it focused on the integration of arts but also on creativity, interdisciplinary, project-centered thinking, and real-world learning.

Hong, Jho, and Song [23] advocated that the capabilities of STEAM educators should be strengthened through constructing learning and research communities beyond individual-level training programs. Hong [22] detailed the implementation of policies related to STEAM Education in Korea and highlighted that a "STEAM Bridge Center" model was developed, which promotes collaborative research between teachers and academic scholars. This results in the improvement of teacher's capabilities regarding arts-integration and the integration of STEAM in their educational practices. Clarke [16], however, highlighted that governments have a major role to play in the development of such programs and 'future strategies' and 'roadmaps should focus on this aspect.

4. FINDINGS

This chapter referred to previous studies (secondary data) in order to address the research problem. As findings of the critical analysis of the research topic, all chosen studies were put side by side in Table 2 and compared against each other as this set-up allows to draw on the conclusion about STEAM

implementation, challenges and success criteria through which implementation becomes possible.

In order to address the first objective related to understand the STEAM education initiatives in different developed countries, it has been assessed that implementation of STEAM initiatives started from elementary level schools. This has positively affected lesson planning of schools in other countries. Whereas, the in-progress implementation of STEAM education in the UAE shows that it is only limited to early years and STEAM policies should be developed by the government.

Referring to Table 1, the implementation of the STEAM-related educational modules is beneficial; however, there were numerous problems. All four of the selected in the above table, range from the years 2013 to 2017 and in all of them similar authors exist, thus, linking the researches together and making them significant for the analysis. It is significant because the challenges identified during the research done in the year 2013, challenges relating to the STEAM application were identified to be teacher's experience, availability of finance, lack of organized structure to implement STEAM modules.

The gap was filled in 2014 by taking responses from the experienced teachers; however, the problem persisted. Although the teachers agreed with the benefits, they claimed that experience could not aid them in getting around unsynchronized course material developed in the country or financial funds required to implement these modules. The authors concluded that in addition to financial support, the teachers required a clear policy on the kind of material available for the students. The research conducted in 2017 supported the fact, that in order to manage the benefits from STEAM modules in true essence, financial support is required for reorganizing the curriculum. The difference in the material available through textbooks and modules generated results confused students.

Final research selected for the comparison is also performed in 2017; nevertheless; it is different from the prior researches because it researched the application of STEAM modules in schools. After policy related to course material had been put into effect, the answers to a survey from experienced teachers aid us to conclude that if the UAE is also to apply the STEAM technique, the course material of the textbook as well as modules implementation, would have to be facilitated by drafting policy. In order to ensure a proper implementation and policy drafting recommendations of STEAM education in UAE a roadmap showcased in Figure 2 is proposed based on the research literature review and document analysis sections.

The roadmap scheme is nonlinear, reflecting the reality of the map as one can always go back and reflect in order to improve the areas mentioned. However, for an effective implementation all four components need to be well addressed. Starting by a clear definition of STEAM for all stakeholders and subject involved in order to ensure consistency. Moreover, a reform in the curriculum is needed in order to integrate the STEAM objectives within the curriculum, explore all its discipline by recognizing arts as one of its subjects in order to gain knowledge and cognitive skills and upgrade course materials by developing collaborative plans. These materials should be in line with the STEAM modules so that the students do not get befuddled with the contrasting test results and course material of the textbook. It will be more efficient if this integration was adopted as the national curricula as it will ensure consistency in delivery across all schools. Ensuring appropriate professional development for teachers that allows them to explore STEAM as an interdisciplinary learning and delivers STEAM through its best recommended practices set by experts and understands the importance of creativity within this framework. It is suggested as well to integrate a section on STEAM in the teacher licensing exam set by the country. To add, according to Atkins, Michie, and West , the roadmap and policies are going to be implemented through teachers; thus, their behavior is another essential ingredient for ensuring that STEAM modules are applied. Therefore, psychological training will be given to teachers in order to motivate them, change their mindset and be able to accept the following STEAM frame as lots of teachers are afraid to try anything that is out of their comfort zone and that is why the BCW is very important. In addition, the technology subject in STEAM is highly important in order to cope with the fourth industrial revolution. This can only happen through preparing teachers to use and handle advanced technology such as simulations, virtual reality and much more in a way that stimulate STEAM education. It will be best if all teachers can be International Computer Driving License (ICDL) certified in order to ensure that the basic usage of a computer and other devices are met. Finally, nothing can be planned and executed without proper funding. Allocating these resources ensure the equity and allocation of STEAM resources to all students. These could be funded by the Ministry itself, the schools without increasing its tuition fees in an abnormal way, increment needs to be monitored/set by the ministry or even organizing a charity within the country that ensure the funds for this purpose.

4. FIGURES AND TABLES

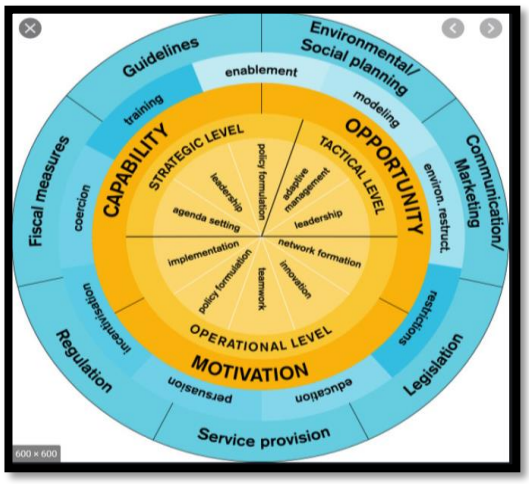

Figure 1. Behavior Change Wheel Model [10]

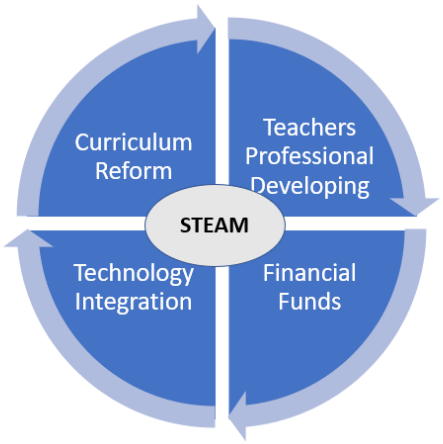

Figure 2. STEAM roadmap in UAE

Table 1

Comparison between old and subsequent research

Older research	**Subsequent research**	**Comparison**
Hye Jeong, Jiwon, and Jung Bog [24] noted that South Korean teachers implemented the STEAM education system in their schools. Because they thought that the system's implementation should generate interest for arts, math's, science and engineering. Nevertheless, the system is difficult and time-consuming moreover; its successful application also requires significant experience as well as a change to the curriculum. Changing the curriculum is not only difficult but is not possible without financial back-up.	Byun, Park, and Sim [25] observed that the majority of experienced Korean teachers thought positively about the STEAM framework. Authors found out that the system can permeate learning into students; however; significant change to current educational curriculum structure is required. Moreover, the system can also generate interest in the students; however, there are problems that are causing this program to fail in generating benefits. These problems include a lack of developed educational curriculum structure in line with the framework required for STEAM. In addition, financial support is also required because a significant investment might be needed.	The research conducted in 2013 revealed that teacher's experience, as well as finance, is required to conduct the successful implementation of STEAM education system. These points were covered when research performed in 2016 by authors including several as well as the ones, who were part of the research in 2013. They covered the gap related to the experienced teachers nevertheless; it was found that unless significant financial support is available. As well as a major change to the curriculum is not made, the STEAM cannot be implemented for generating effective results.
Soo-min, Tae-sang, and [27] conducted research about STEAM education modules implementation in middle schools. The authors found that though teachers had implemented the modules in the school and the interest related to it is very high. However, problems came out when the students were unable to connect the textbook to the results of STEAM education. The reason is that the curriculum had not been re-organized to facilitate the benefits of STEAM education system. In addition to the development of curriculum, paving down of methods related to dissemination of STEAM is also important.	Bolger and Kim [26] concluded that drafting of policy related to STEAM education in South Korea began in the year 2009. It had been found that with careful instructions related to the embedment of STEAM modules into the curricula of the Science, Arts, Math, Engineering and Technology aided the benefits management among the students. The authors engaged 119 elementary level teachers, who were experienced to conduct lessons based on STEAM. In the post-policy application, the teachers' commitment had improved significantly, and their lesson planning had become a lot easier after clarification of the curriculum.	Author Kim was part of the research conducted on the application of STEAM in 2014 as well as in 2017. In both instances, elementary school teachers had been asked to participate and respond to the survey related to a STEAM application. The research conducted in 2014 found that teachers believed in the benefits of teaching STEAM subjects through modules. However, these benefits cannot be felt unless significant changes are made to the curriculum of the subjects. The problem is corroborated because the research performed in 2017 focused on gathering data from elementary school teachers. Who were part of schools where upgraded course material had been applied, teachers found it a lot easier to apply STEAM-related modules, thereby earning students' interests with simple clarification of the policy related to the subject matter.

5. CONCLUSIONS

In conclusion, this chapter has reviewed the implementation of STEAM education in schools in developed countries whereby it has showed that most of the schools do not have a proper roadmap and policies that guides and assure the effectiveness of STEAM implementation. Throughout the literature review and analysis, it can be concluded that for the implementation of the STEAM modules in the UAE, the government must pen policies. Because education is not an individual's work, it rather shapes the future of the society, and therefore, the education course material should have to be made as per the requirements of the UAE industry. Moreover, stakeholders should be involved in drafting STEAM related policies beside the ministry of education as they are the primary line of contact with students. Since children then later in their life become part of the industry, they must be using their skills and therefore it is suggested that industry practitioner's perspective need to be heard when drafting the policy. These skills require evaluation of the data and gaining an insight into their decisions. These skills shall be developed through educational knowledge which is taught from the course books available in the schools. According to Shaer, Shibl, and Zakzak [5] , UAE private schools had implemented the STEAM techniques for giving education to early year students. However, in the absence of the proper policies identifying the correct application of the structure or the kind of change in students to be expected, it is impossible to measure the change being wrought in students due to these policies. Therefore, in order to integrate the STEAM modules into the UAE education system, clear policies must be drawn, and roadmaps need to be followed so the appliers can measure the change this can only happen through commitment, change in the people (parents, students, teacher and society) mindset and behavior in terms of opportunity, capability and opportunity that are offered through STEAM implementation and that are highlighted through the BCW. Finally, defining STEAM for all stakeholders, curriculum reform and integration, teachers training, advanced technology training and support and financial findings are the road that leads to effective STEAM implementation as well as they constitute core standards required to draft a STEAM policy. Implementation and monitoring process of the following proposed roadmap will be studied in further research.

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