MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2023, 19(8), em2303
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/13424

Triple helix components supporting STEM education to increase future STEM careers in the United Arab Emirates

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Received 08 January 2023 ▪ Accepted 11 June 2023

Abstract

Increasing communication between government schools, universities, and industry can benefit STEM education programs and STEM careers. These collaborations are pertinent in the United Arab Emirates (UAE) because the nation is aiming to meet the growing demand for a future STEM workforce by increasing the number of students pursuing STEM careers. The main purpose of the study is to investigate the stakeholder's perceptions and responses on STEM education programs, STEM careers, and triple helix components (THC) in the UAE. The researcher employed a quantitative methods approach for this study that used questionnaires. The results from this study showed that the stakeholders had positive perceptions on STEM education programs, STEM careers, and THC. Further investigation is needed to gain more information about the significant differences in perspectives between and within the stakeholder clusters.

Keywords: triple helix components, STEM education programs, STEM career development

INTRODUCTION

With the creation of a knowledge-based society, economic development can be achieved. This process can be fostered with triple helix components (THC), which represents the collaboration between the government, university, and industry (Cai & Etzkowitz, 2020). In the 1990s, Etzkowitz and Leydesdorff (1997) conceptualized triple helix model (THM) as the triadic relationship between university, industry and government. It builds on the works of Sábato and Mackenzi, along with the works of Lowe (Lawton Smith & Leydesdorff, 2014). Momeni et al. (2019) emphasized that THM focuses on mutual interactions between THC that recognize the changing nature of innovation. THM makes it possible to understand how the three components coordinate in concrete actions (Ehlers, 2020) to enable economic development and innovation in a knowledge-based society (Lawton Smith & Leydesdorff, 2014). Leydesdorff (2010) points out that THM reveals the sub-dynamics that compose a knowledge-based economy. The three sub-dynamics are identified, as follows:

(1) wealth generation in the economy,

(2) new developments produced by organized science and technology, and

(3) supervision of the interactions between the two previous sub-dynamics by the government in both the public and private domain.

Due to STEM education's potential for developing the growth and development of economies by producing well-qualified graduates (Hathcock et al., 2015), it also creates the opportunity for the UAE to achieve their goals for innovation (Ashour, 2020). As a developing nation with a growing economy, the UAE prioritizes a high-quality education for its citizens, which impacts both the students and the national economy. Al Murshidi (2019) acknowledges that thousands of Emirati STEM graduates are needed since government policies are working towards expanding an economy reliant on Emirati nationals, implying that education needs to enact strategic reforms. In this endeavor, the tripartite structure of THC can help to meet this demand (Al Murshidi, 2019). The innovative potential of THC contributes to economic development and job growth by

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Contribution to the literature

- This study contributes to developing relevant STEM curriculum that prepares students for future STEM careers by building their 21st century skills.
- The study explores how the Triple Helix can increase students' STEM self-efficacy and STEM careers motivation through internships with government schools, universities, and institutions.

supporting students to cultivate new skills and entrepreneurial talent (Ranga & Etzkowitz, 2013).

Additionally, new technologies are needed so that students can upgrade their learning through experimentation and design thinking (Kim, 2017). As a result, fostering STEM skills can be supported by THC. The UAE Government makes the connection between creating the appropriate environment and achieving goals for innovation. With the implementation of STEM education programs through the collaboration of THC, the elements that promote and enable innovation such as regulatory frameworks, comprehensive enabling services and technology infrastructures can be established.

This study aimed to investigate stakeholder perceptions on STEM education programs, STEM career development, and their connection to THC in the UAE. As a result, this study has the potential to shift policymakers' focus as it increases awareness about the positive impact of the triple helix (TH) collaborations on STEM education programs and the need to include these partnerships in STEM education policies. Currently, there is a gap in the literature on THC benefiting STEM education programs and STEM careers in the UAE. More specifically, there is little emphasis in research regarding how collaboration and communication between university-industry-government can support STEM education programs and develop STEM careers (Shaer et al., 2019). The need is emphasized by policy documents highlighting the importance of innovation for advancing a knowledge-based economy and promoting human capacity (Moonesar & Mourtada, 2015; Vought, 2018).

To better determine THC's role in improving STEM education programs and increasing STEM jobs, the perceptions of stakeholders need to be considered. Moonesar and Mourtada (2015) prioritized understanding the perception levels of cycle 2 (grade 5 to 8) and university students regarding STEM education programs to understand the obstacles preventing them from pursuing a STEM degree or career. To attain the key outcomes of the study, this research will work to find the answers to the following questions:

1. What are the perceptions of stakeholders from the government, university and industry clusters on the formal and informal STEM education programs and future STEM careers? What are the perceptions of stakeholders from the government, university, and industry clusters regarding THC?
2. What are the differences between the stakeholders' perceptions within and between clusters regarding STEM education programs, future STEM careers and THC?

THEORETICAL FRAMEWORK

Theoretical frameworks used for this quantitative study were THM, social constructivism theory (SCT), and social cognitive career theory (SCCT). THM is based on the core concept of the relationship formed between government, university, and industry (Etzkowitz & Leydesdorff, 1997). The UAE's vision 2030 centers on a knowledge-based economy, which can benefit from THM's synergic model. The integrated relationships between insider actors, such as stakeholders in the schools, and outsider actors from THC can be designed to benefit STEM education programs through real-world innovation and entrepreneurship experiences (Mandrup & Jensen, 2017). In an effort to utilize THM to benefit STEM education programs, it is necessary to understand the views of learning of the stakeholders so that future steps will be appropriate. SCT provides a means to interpret the perceptions of stakeholders regarding STEM education programs (Vygotsky, 1978). With the focus on the UAE's goal to increase STEM workforce, SCCT contributes a model to describe the predictors and mechanisms underlying the stakeholders' future STEM career development (Lent et al., 2002). SCT and SCCT acknowledge the contextual factors that shape an individual's learning and career development, as well as the individual's agency in the process. These two theories can provide implications for STEM education interventions and STEM career promotion that THC can support.

LITERATURE REVIEW

STEM Education Programs

STEM education programs are on the agenda of many countries as a STEM-oriented workforce is necessary for innovation, emphasizing its social, economic, and political impact (DeCoito, 2016; Let's Talk Science, 2017). National science board asserts that increasing STEM-capacity boosts economic activity since science and engineering careers are necessary to support the future economy. According to British Council (2018), there is a global need for educational systems to support students by preparing them for future jobs. The core purpose of STEM education programs is to increase an individuals' 21st century skills to the level that matches the changing demands of the workforce (Litchfield & Dempsey, 2015; Petersen et al., 2018). With STEM education programs, the next generation will be more prepared to confront the realities impacting society while raising the economic status of the country (Radloff & Guzey 2016; Shernoff et al. 2017). As a result, global educational standards have resulted in redirecting the UAE leaders to consider their educational approach to align the performance of Emirati students with the development of global performance standards related to STEM (Benjamin, 1999, as cited in Zahran et al., 2016) to enhance global competitiveness and economic growth (Mohammed Bin Rashid School of Government 2015). To attract and keep students in STEM, the education programs need to address issues of support in terms of curriculum, professional development, and resources.

The quality of the STEM curriculum is important because making it relevant and engaging has been linked to student motivation (Roberts et al., 2018; Wiebe et al., 2018). Improvements to the STEM curriculum can include creating STEM-based activities related to real-world problems, making it more hands-on and engaging, which can lead to an increased interest (Popovic & Lederman, 2015). Thibaut et al. (2018) also observed that developing digital competencies is embedded in STEM education programs. This is in line with other literature that underscore how STEM fosters digital competencies (Cinar et al., 2016; Global Manufacturing & Industrialization Summit [GMIS], 2019; Pasnik & Hupert, 2016; Sen et al., 2018; Yang & Baldwin, 2020), which has the overall effect of benefitting the other components of STEM education programs (Purzer & Shelley, 2018).

The surrounding environment, the role of the community, integration, and interaction of different institutions are all promoting STEM-centric career paths for students (Petersen et al., 2018). As a result, schools play a role in fostering long-term interest (Petersen et al., 2018; Worrell et al., 2019) through career fairs and field trips (Petersen et al., 2018). These experiences are important as they establish science identities (Anderhag et al., 2016). Out-of-school STEM learning experiences can also influence long-term STEM engagement, and should be designed deliberately (Habig et al., 2020). Education is moving towards an entrepreneurship model that sharpens student creativity and critical thinking skills by designing learning experiences that require students to create innovative solutions that are based on their own knowledge (Shattock, 2009). As a result, critical thinking skills are developed through STEM's problem-based approach that encourages multidisciplinary thinking (Colter, 2018; Shattock, 2009). Also, Shattock (2009) states that curriculum should focus on requiring students to use their own knowledge to create innovative solutions. STEM education programs can be supported by the collaboration between educational stakeholders and external TH actors to give students more resources to participate as creators in a knowledge-based-society, developing their confidence to live in a complex and changing world that is increasingly in need of STEM professionals (Shattock, 2009). For instance, India STEM Foundation, with worldwide partners such as John Deere, Lego, and United Technologies, has launched robotics themed challenges to promote STEM education programs through interactive learning. In 2014, 44 teams coming from 12 states in India gathered more than 300 students to participate in the FIRST India National Championship (First Lego League [FLL], 2020). Students aged nine-16 took part in FLL (2020), a robotics competition to find creative ways to solve complex tasks in teams of two-10, along with the guidance of one adult coach.

Interaction between individuals is pivotal to SCT because it is how knowledge is formed. SCT centers on the premise that learning, and development are products of social interactions (Radloff & Guzey, 2016; Resnick et al., 2015). Mediators, such as the teacher or peers, help the student to achieve a development stage that he or she cannot yet reach alone (Williams, 2017). Relatedly, STEM education programs move students to their next level of understanding through scaffolding (Admawati et al., 2018) and collaboration (Achzab et al., 2018).

Research findings emphasize that professional development for teachers contributes to the successful implementation of STEM education programs and achieving its desired outcomes (El-Deghaidy & Mansour, 2015) since the level of teacher quality impacts the quality of student learning (Kupersmidt et al., 2018). Accordingly, countries are investing in professional development for STEM teachers (Canrinus et al., 2019; Jenset, 2017; Lund & Eriksen, 2016; Müller et al., 2015). Best practices for professional development for STEM teachers include practicum extension and field placement for teachers (Jenset, 2017; Müller et al., 2015), partnerships with university schools (Lund & Eriksen 2016), teacher training schools (Canrinus et al., 2019), and professional development schools (Lowery et al., 2018; Maheady et al., 2016).

STEM Education Program Perceptions

Literature highlights positive perceptions of STEM education programs held by government, university, and industry stakeholders. Governmental schools encourage students to cultivate their experimentation and design thinking skills (Kim, 2017) through STEM education (McDonald, 2017). In the UAE, STEM education programs provide an opportunity to develop well-qualified graduates (Ashour, 2020) that can handle its needs for economic growth (Al Murshidi, 2019). This can be seen in the UAE's intention to rank in the highest performing countries in the program for international student assessment (PISA) and trends in international mathematics and science study (TIMSS). These internationally standardized tests measure student achievement in maths and science, tracing the improved performance of the UAE students in STEM fields (Schleicher, 2019).

In the industry sector, the rapid technological advances have transferred the focus of learning institutions to increasing training in science, technology, engineering and mathematics fields (Wan Husin et al., 2016). STEM provides an educational approach that enhances learning experiences for students by connecting classroom learning to real world issues (Ahmed, 2016). This trend can also be seen in the UAE as a more business-like approach to STEM education programs has become more prevalent. According to Eltanahy et al. (2020), this approach will provide students with the relevant entrepreneurial experiences that can support the UAE's target to advance a knowledge-based economy.

Universities have also increased their efforts in STEM education programs. For instance, there is growing investment in building relationships between universities and STEM experts (Andrée & Hansson, 2020). Furthermore, Fernández-Nogueira et al. (2018) highlight that universities are adapting by taking part in the entrepreneurial society and process. They cited that more higher education institutions are partnering with associations, institutions and companies. In the UAE, higher education institutions are establishing partnerships to provide their students with access to role models, extracurricular activities and career support in order to facilitate STEM identity formation and STEM aspirations (Moonesar & Mourtada, 2015; Williams, 2016).

The literature suggests that the UAE is prioritizing STEM education programs, however, the lack of a cohesive approach can impact its successful implementation. For STEM education programs, descriptive and inferential analyses were conducted to measure the following independent variables: preparing students to meet industry needs and skills development. This study proposes the following hypothesis:

H1. There are significant differences in the perceptions on STEM education between and within the governmental, university, and industry clusters.

STEM Careers

There is an increasing need for future employee's skills to match the jobs growing in demand (WEF, 2020). Cedefop (2017) notes that the top five shortages in skilled occupations are STEM professionals. As a result, there has been a significant and rapid increase in the need for educated and skilled workers in STEM occupations (British Council, 2018). Schultz and Schultz (2016) identify individual goals as a factor that influences students' career choices. It has been studied that persistence in pursuing a STEM career can be increased by a student's academic achievement and STEM preparation in high school (Green & Sanderson, 2017). However, the high school education system is not exerting much effort in supporting students to investigate a STEM pathway as a career choice. Green and Sanderson (2017) suggest that policies regarding course selection, such as encouraging or requiring STEM related courses in high school and requiring introductory STEM courses in universities, can effectively increase student interest in STEM careers.

SCCT relies on socio-cognitive constructs to explain career development (Burnette et al., 2019), and central to SCCT is the assessment of how academic and career choices emerge and translate into actions (Schultz & Schultz, 2016). Additionally, SCCT provides a model for students' career choice by measuring self-efficacy, outcome expectations, and personal backgrounds (Lent et al., 2002; Schultz & Schultz, 2016). Green and Sanderson (2017) identified motivation in school can increase persistence in pursuing a STEM career. According to SCCT, goals take into consideration both personal interests and self-motivation (Lent et al., 2002; Leong, 2008; Nugent et al., 2015).

Parent engagement also influences student STEM achievement (FLL, 2020; Milner-Bolotin & Marotto, 2018; Peterson, 2017). One program that parents found beneficial is science & math education videos for all, which included hands-on STEM experiments and explanations of concepts (Milner-Bolotin & Marotto, 2018). The family influences students' career choices because they transmit core values and beliefs that promote STEM career choices (Ceglie & Setlage, 2016; UNESCO, 2017).

The literature indicates that the pathways to STEM careers can be strengthened. For future STEM careers, descriptive and inferential analyses were conducted to measure the following independent variables: better outcomes and incentives, attracting and retaining the best minds, and future vision. This study proposes the following hypothesis:

H2. There are significant differences in the perceptions on STEM careers between and within the governmental, university, and industry clusters.

Triple Helix Model

THM is an innovation system since its dynamic interactions between government, university and industry makes innovation, entrepreneurship and economic growth possible in the knowledge-based society (Cai & Liu, 2020). The relationship between the three clusters creates an advantageous design for entrepreneurship and innovation by creating a source for new innovative designs and social interactions, as well as facilitating pathways for research to be put into use (Etzkowitz & Zhou, 2017; Ranga & Etzkowitz, 2013). Although THM is popular in the business sector, it is not commonly used in educational programs with industry partners (Karmokar & Shekar, 2018). However, the educational sector can benefit from the development spurred by TH partnerships. For instance, THC contribute to economic development and job growth by supporting students to cultivate entrepreneurial talent by promoting 21st century skills (Ranga & Etzkowitz, 2013). Additionally, technology application is a key skill in a knowledge-based society. Karmokar and Shekar (2018) mention how THC can nurture students' entrepreneurial skills by including activities that require them to apply technology in various contexts to create prototypes. It has been noted that technology needs to be employed as a supportive tool to learn with, rather than just a resource to learn from in STEM fields in order to enhance students' 21st century skills (Moon, 2016; Darling-Hammond, 2017; Pasnik & Hupert, 2016; Petersen et al., 2018). Al Murshidi (2019) also suggests that challenging technology-based learning activities will help students to advance in their future careers. Collaboration between stakeholders is needed to increase student commitment to STEM (Andrée & Hansson, 2020). As a result, THC can be integrated into STEM policy in order to increase the STEM workforce for the future.

Universities as institutions for creating and exchanging information related to technology and science play an important role for generating different problem-solving elements through innovation. Entrepreneurial universities become research bases and social and economic development can be enhanced by capitalizing on intellectual property (Etzkowitz & Zhou, 2017). This emphasizes how the collaboration, which is mechanized by a dynamic that is simultaneously autonomous and overlapping, between three THC has become an imperative element for innovation (Etzkowitz & Zhou, 2017).

Chryssou (2020) recommends that incentives for THC can facilitate communication, collaboration, and joint initiatives. Similarly, Institutional Theory also reinforces the relationship between communication and change. Improving the discourse and coherence between the institutions is necessary to make development possible (Peters, 2019; Rodrigues & Melo, 2010).

In the UAE context, there is a need to prepare future employees to meet the advanced skills of the future workforce. This is seen in both the private and public sectors, and this is noted by scholars, government officials, and business practitioners (Stephens et al., 2019). To prepare Emirati students for future workforce challenges, STEM education programs have become pivotal for educational reform. In order to promote the aims of STEM education programs, collaborations among THC can develop teacher capacity and encourage technological integration in STEM teaching (Shaer et al., 2019). Eltanahy et al. (2020) also highlight the need to improve the implementation of STEM education programs by incorporating entrepreneurial competencies. Despite the knowledge sharing that can result from TH collaborations, there are challenges along the way (Hughes, 2014).

The literature indicates that TH collaborations can positively benefit STEM education programs and STEM careers. For THC, descriptive and inferential analyses were conducted to measure the following independent variables: coordination and communication among universities, industries and STEM programs, and perceptions on STEM Strategy. This study proposes the following hypothesis:

H3. There are significant differences in the perceptions on THC between and within the governmental, university, and industry clusters.

MATERIALS AND METHODS

A quantitative method was conducted in this research. The quantitative data were collected consecutively to fulfil the research questions and included questionnaires for the stakeholders (Creswell & Clark, 2014). A quantitative questionnaire was developed using the themes from a document analysis of STEM educational policies that were ranked as high-performing according to organization for economic co-operation and development (OECD) (Husain & Forawi, 2022).

Questionnaire

The developed questionnaires focused on answering the first research question and included four sections. The first section collected demographic information, while the following three sections were designed to investigate the stakeholders' perceptions regarding formal and informal STEM education programs, STEM careers, and THC. The questionnaires were shared with two university professors to refine the statements for clarity and meaningfulness. Additionally, the questionnaires were translated into Arabic with the help of a proof-writer. A 5-point Likert scale (5=strongly agree, 4=agree, 3=neutral, 2=disagree and 1=strongly disagree) was used to measure their responses. The final version of the questionnaire was piloted with one group of 29 students belonging to the industry cluster.

The researcher used the pilot study to confirm that the instrument was able to collect the information needed to meet the goals of the research study and to make sure that the items were relevant. The pilot study also provided the researcher the ability to determine the length of time needed for the participants to answer the survey questions. Fraenkel et al. (2015) recommended that anonymity can promote candid responses and ensure the reliability and validity of the pilot, and the researcher followed this advice. Bell et al. (2018) also highlighted that the sample size for the pilot needs to be taken into consideration. As a result, the pilot study included 29 student participants, 30 teacher/leader participants and 30 parent participants to simulate the convenience sample for the study. According to Tavakol and Dennick (2011), Cronbach's alpha test is one of the most important concepts utilized in the evaluation and assessment of a questionnaire. Cronbach's alpha for the student group, teachers/leaders, and parents were 0.9, .89, and .80, respectively. Accordingly, the researcher applied Cronbach's alpha test to add validity and accuracy to the developed instrument.

Sampling

Kumar (2011) explains that sampling uses a selection of individuals to represent the whole population. This indicates that to choose an effective sample, it is essential to have familiarity with the context of the study. Since the researcher was investigating THC, which has three components, the study needed more information about relevant populations of stakeholders in each cluster. Using convenience sampling, the questionnaire was then distributed to cycle 2 (grade 5 to 8) and cycle 3 (grade 9 to 12) governmental schools, industry institutions, and universities. Students, teachers, and professors completed the questionnaire. The sample for the government cluster included six schools, 123 STEM leaders/teachers, 361 middle to high school students and 101 parents. For the industry cluster, the sample included: 101 middle school to university level students and 53 leaders/teachers. For the university cluster, the sample included 110 students and 54 leaders/teachers. The students in the government and industry clusters are cycle 2 and cycle 3 students and the students in the university cluster are tertiary students. The teachers/leaders in the government and industry clusters refer to the instructors and administrators involved in the STEM programs. The teachers/leaders in the university cluster refer to the professors and academic administrators involved in the STEM programs.

For the government cluster sample, the study used six schools taken from the list of forty-six STEM governmental schools provided by Ministry of Education (MoE, 2021). For the industry institutions supporting STEM programs, the researcher selected from institutions with partnerships with MoE (2021). The participants were taken from MoE's (2021) 49 sponsors and Abu Dhabi Department of Education and Knowledge's (ADEK, 2020) 27 sponsors. Industry institutions were defined as any informal institution that provided STEM through extra activities or provided extracurricular in STEM education programs. Eight institutions were contacted out of the 76 sponsors. These institutions were used by the researcher because ADEK (2020) and MoE (2021) are responsible for the informal STEM education programs, and they have affiliations with these agencies. Lastly, the university cluster participants were selected from the list of universities with STEM related programs in the UAE provided by MoE (2021).

RESULTS

The data collected from the government, university and industry participants were analyzed and interpreted to make meaning from their beliefs about STEM education programs, future STEM careers, and THC. For the government cluster, the perceptions of teachers/leaders, students, and parents were collected. For the university cluster and industry cluster, the perceptions of teachers/leaders and students were taken.

Research Question One

The following section will discuss the analysis and findings for research question one (What are the perceptions of stakeholders from the government, university and industry clusters on the formal and informal STEM education programs and future STEM careers? What are the perceptions of stakeholders from the government, university, and industry clusters regarding THC?).

Table 1 shows the results on STEM education programs and demonstrates that the stakeholders agreed about preparing students to meet industry needs and skills development for the future. Overall, the findings conclude that the stakeholders' perceptions on STEM education programs were positive for all clusters (government, university, and industry). For the government and industry clusters, the teachers'/leaders' perceptions were reported in the "very high" category.

For the university cluster, the teachers'/leaders' perceptions were found to be "high". For the government cluster, the parents' and students' perceptions were identified in the "high" category, and similarly for the industry cluster, the students' perceptions ranked in the "high" category. For the university cluster, the students' perceptions were demonstrated to be "very high". STEM was recognized as important for future careers because it will fulfil the future labor force demands. The participants agreed that the focus of future jobs will be on STEM skills, and they perceived that students benefit from STEM education programs with high incentives. They indicated that STEM achievements should be more recognized by the local community.

Table 2 shows the results on future STEM careers and demonstrates that the participants agreed on STEM career perceptions and career interests. All stakeholder perceptions in the three clusters were in the "high" category. The participants determined that STEM-related careers require hard work. They also agreed that

Table 1. Perceptions of governmental, university, & industry stakeholders on STEM education programs

Clusters	Independent variables		
	Preparing students to meet industry needs	Skills development	Total
Governmental leaders/teachers	M=4.21, SD=.607, & Degree=Very high		M=4.21, SD=.607, & Degree=Very high
University leaders/teachers	M=4.22, SD=.521, & Degree=Very high		M=4.22, SD=.521, & Degree=Very high
Industry leaders/teachers	M=4.37, SD=.482, & Degree=Very high		M=4.37, SD=.482, & Degree=Very high
Governmental parents	M=3.78, SD=.829, & Degree=High		M=3.78, SD=.829, & Degree=High
Governmental students	M=3.54, SD=.706, & Degree=Very high	M=3.69, SD=.750, & Degree=Very high	M=3.62, SD=.658, & Degree=High
University students	M=4.00, SD=.661, & Degree=High	M=3.99, SD=.665, & Degree=High	M=4.00, SD=.613, & Degree=High
Industry students	M=3.97, SD=.656, & Degree=High	M=3.97, SD=.608, & Degree=High	M=3.97, SD=.570, & Degree=High

Table 2. Perceptions of governmental, university, & industry stakeholders on STEM careers

Clusters	Independent variables			
	Better outcomes & incentives	Attracting & retaining best minds	Future vision	Total
Governmental leaders/teachers	M=4.12, SD=.482, & Degree=High	M=4.25, SD=.514, & Degree=Very high	M=3.53, SD=.468, & Degree=High	M=3.89, SD=.653, & Degree=High
University leaders/teachers	M=4.09, SD=.539, & Degree=High	M=3.87, SD=.604, & Degree=High	M=4.34, SD=.563, & Degree=Very high	M=4.10, SD=.449, & Degree=High
Industry leaders/teachers	M=4.10, SD=.550, & Degree=High	M=4.19, SD=.520, & Degree=High	M=4.17, SD=0.649, & Degree=High	M=4.15, SD=.370, & Degree=High
Governmental parents	M=3.87, SD=.558, & Degree=High	M=3.92, SD=.852, & Degree=High		M=3.89, SD=.653, & Degree=High
Governmental students	M=3.67, SD=.709, & Degree=High	M=3.72, SD=.770, & Degree=High	M=3.75, SD=.880, & Degree=High	M=3.71, SD=.658, & Degree=High
University students	M=3.98, SD=.626, & Degree=High	M=3.79, SD=.844, & Degree=High	M=4.15, SD=.776, & Degree=High	M=3.99, SD=.613, & Degree=High
Industry students	M=4.00, SD=.725, & Degree=High	M=3.84, SD=.788, & Degree=High	M=4.11, SD=.912, & Degree=High	M=3.97, SD=.570, & Degree=High

STEM-related careers are high in demand and can have high salaries. In order to attract and retain the best minds in STEM education programs, the participants perceived that students benefit from STEM programs that are emotionally rewarding.

The data also revealed that the general item of the study (it is important that awards are given to students with the most improved grades in my current STEM program) was given a high ranking. The data indicated the participants' recognition that the pursuit of a STEM major can help to fulfil the vision of the UAE becoming an innovation driven economy.

Table 3 shows results on THC and reveals that the participants positively agreed about coordination and communication among universities, industries, and STEM education programs. The governmental schoolteachers'/leaders', parents', and students' perceptions were reported high. For the university cluster, the degree of the university teachers'/leaders' perceptions was reported high, but it was medium for university students. For industry, the teacher's/leaders' perceptions were reported high, but it was medium for industry students. The following items were perceived to be ranked medium for the university and industry students, but were perceived to be ranked high by the other participants: my current program (related to STEM) always offers internships, my current STEM program always gives me the chance to meet STEM role models (famous people), my current STEM program gives me the chance to volunteer with companies, and institutions related to STEM and my current STEM program provides some trips to companies that are involved in STEM. In comparison, all of the participants agreed and ranked the following two items highly: my current program (related to STEM) helps me to choose my future job and after-school university workshops (related to STEM) in my current program are arranged regularly. **Table 4** summarizes the stakeholders' perceptions about STEM education programs, future STEM careers, and THC.

Table 3. Perceptions of governmental, university, & industry stakeholders on THC

Clusters	Independent variables		
	Coordination & communication among universities, industries, & STEM programs	Perceptions on STEM strategy	Total
Governmental leaders/teachers	M=3.53, SD=.468, & Degree=High	M=3.93, SD=.480, & Degree=High	M=3.73, SD=.402, & Degree=High
University leaders/teachers	M=3.67, SD=.603, & Degree=High	M=3.88, SD=.736, & Degree=High	M=3.77, SD=.628, & Degree=High
Industry leaders/teachers	M=3.54, SD=.817, & Degree=High	M=3.76, SD=.664, & Degree=High	M=3.65, SD=.647, & Degree=High
Governmental parents	M=3.62, SD=.873, & Degree=High		M=3.62, SD=.873, & Degree=High
Governmental students	M=3.19, SD=.637, & Degree=Medium		M=3.19, SD=.637, & Degree=Medium
University students	M=3.36, SD=1.13, & Degree=Medium		M=3.36, SD=1.13, & Degree=Medium
Industry students	M=3.14, SD=1.10, & Degree=Medium		M=3.14, SD=1.10, & Degree=Medium

Table 4. Summary stakeholder perceptions about STEM education programs, future STEM careers, & THC

Stakeholder clusters	STEM education programs perceptions		Mean of STEM careers perceptions		Mean of THC perceptions	
	Mean	Degree	Mean	Degree	Mean	Degree
Governmental schools: Teachers/leaders	T/L: 4.21	Very high	T/L: 3.89	High	T/L: 3.73	High
Students	S: 3.62	High	S: 3.71	High	P: 3.62	High
Parents	P: 3.78	High	P: 3.89	High	S: 3.19	High
Universities: Teachers/leaders	T/L: 4.22	High	T/L: 4.10	High	T/L: 3.77	High
Students	S: 4	Very high	S: 3.99	High	S: 3.36	Medium
Industry institutions: Teachers/leaders	T/L: 4.37	Very high	T/L: 4.15	High	T/L: 3.65	High
Students	S: 3.97	High	S: 3.97	High	S: 3.14	Medium

Table 5. ANOVA analysis of governmental school stakeholders & categories of STEM education programs perceptions, & future STEM careers & career interests perceptions

Cluster	Groups	Sum of squares	df	Mean square	F	Sig.
STEM perceptions	Between groups	31.929	2	15.964	35.600	.000
	Within groups	260.994	582	.448		
	Total	292.923	584			
Future STEM career perceptions & career interests	Between groups	18.992	2	9.496	24.101	.000
	Within groups	229.699	583	.394		
	Total	248.691	585			

Research Question Two

The following section will discuss the analysis and findings for research question two (What are the differences between the stakeholders' perceptions within and between clusters regarding STEM education programs, future STEM careers and THC?).

We analyze the perceptions towards STEM education programs, and future STEM careers between clusters (government, university, and industry).

A one-way ANOVA test was carried out to compare the responses of governmental school leaders/teachers, students, and parents (**Table 5**). As shown in **Table 5**, there were significant differences between three stakeholders' categories (leaders/teachers, students, and parents) about *STEM perceptions* at $p<.000$ for conditions $F(2, 582)=35.600$. In regard to *future STEM career perceptions and career interests*, there were significant differences between three stakeholders' categories (leaders/teachers, students, and parents) at $p<.000$ for conditions $F(2, 583)=24.101$. It is beneficial to conduct multiple comparisons post-hoc Tukey tests since statistical significance between conditions have been found.

As shown in **Table 6**, there were significant effects for perceptions of governmental school leaders/teachers and students towards *STEM education programs perceptions* at $p<.000$. Also, there were significant effects for perceptions of governmental school leaders/teachers and parents towards *STEM education programs perceptions* at $p<.000$. Also, there were no significant effects for the

Table 6. Multiple comparisons analysis of governmental school stakeholders & categories of STEM perceptions & future STEM careers & career interests perceptions

Dependent variable	(I) 1	(J) 1	MD (I-J)	SE	Sig.	95% confidence interval	
						Lower bound	Upper bound
STEM perceptions	Leaders/teachers	Students	.59014*	.06994	.000	.4222	.7581
		Parents	.43770*	.08968	.000	.2224	.6530
	Students	Leaders/teachers	-.59014*	.06994	.000	-.7581	-.4222
		Parents	-.15245	.07511	.129	-.3328	.0279
	Parents	Leaders/teachers	-.43770*	.08968	.000	-.6530	-.2224
		Students	.15245	.07511	.129	-.0279	.3328
Future STEM career perceptions & career interests	Leaders/teachers	Students	.45268*	.06553	.000	.2953	.6100
		Parents	.28991*	.08406	.002	.0881	.4917
	Students	Leaders/teachers	-.45268*	.06553	.000	-.6100	-.2953
		Parents	-.16277	.07039	.063	-.3318	.0062
	Parents	Leaders/teachers	-.28991*	.08406	.002	-.4917	-.0881
		Students	.16277	.07039	.063	-.0062	.3318

Note. *Mean difference is significant at 0.05 level; MD: Mean difference; & SE: Standard error

Table 7. Independent sample t-test of university stakeholders & their STEM perceptions & future STEM careers & career interests perceptions

Cluster	Stakeholder	n	Mean	SD	df	t	Sig. (2-tailed)
STEM perceptions	Students	110	4.32	.661	161	1.032	.303
	Leaders/teachers	54	4.22	.521			
Future STEM career perceptions & career interests	Students	110	3.96	.652	161	-1.200	.232
	Leaders/teachers	54	4.08	.452			

Table 8. Independent sample t-test of industry students' & leaders/teachers' STEM perceptions & future STEM careers & career interests perceptions

Cluster	Stakeholder	n	Mean	SD	F	t	df	Sig. (2-tailed)	Effect size
STEM perceptions	I/ L	53	4.14	.381	2.800	6.171	155	.000	1.1
	I/students	101	3.64	.514					
Future STEM career perceptions & career interests	I/L	53	4.12	.386	10.499	1.597	155	.112	-
	I/students	101	3.96	.670					

perceptions of governmental school students and parents towards *STEM education programs perceptions* at .129. In regard to their perceptions towards *future STEM career perceptions and career interests* there were significant effects for the perceptions of governmental school leaders/teachers and students towards *future STEM career perceptions and career interests* at p<.002.

Additionally, there were significant effects for the perceptions of governmental school leaders/teachers and parents towards *future STEM career perceptions and career interests* at p<.000. Also, there were no significant effects for the perceptions of governmental school students and parents towards *STEM education programs perceptions* at .063.

As shown in **Table 7**, an independent samples t-test results was conducted to compare the results of university leaders/teachers and students. No statistically significant differences were found between university students (mean [M]=4.32, standard deviation [SD]=.661) and university leaders/teachers (M=4.22, SD=.521) about *STEM programs perceptions;* t(161)=1.032, p=.303.

In addition, there were no statistically significant differences between university students (M=3.96, SD=.652) and university leaders/teachers (M=4.08, SD=.452) about *future STEM career perceptions and career interests;* t(161)=-1.20, p=.303.

As shown in **Table 8**, an independent samples t-test results was conducted to compare the results of industry leaders/teachers and students. There were statistically significant differences between industry students (M=4.14, SD=.381) and industry leaders/teachers (M=3.64, SD=.514) about *STEM education programs perceptions*; t(155)=6.171, p=.000. Effect size Cohen's d=1.1 that indicates the significant differences was high between the perception of leaders and students. In addition, there were no statistically significant differences between industry students (M=3.96, SD=.386 and industry leaders/teachers (M=4.12, SD=.670) about *future STEM career perceptions and career interests*; t (155)=-1.597, p=.112.

Table 9 and **Table 10** analyze the perceptions towards THC between clusters (government, university, and industry). An ANOVA analysis was conducted to compare the perceptions of stakeholders in the governmental school cluster regarding THC (**Table 9**

Table 9. ANOVA analysis of governmental school leaders/teachers, students, & parents about THC

Topic	Governmental groups (parents, students, & leaders/teachers)	Sum of squares	df	Mean square	F	Sig.
THC	Between governmental groups	31.535	2	15.768	37.894	.000
	Within governmental groups	242.584	583	.416		
	Total	274.119	585			

Table 10. Multiple comparisons analysis of governmental school leaders, students, & parents about THC

Dependent variable	(I) 1	(J) 1	MD (I-J)	SE	Sig.	95% confidence interval	
						Lower bound	Upper bound
THC	Governmental school leaders/teachers	Students	.51358*	.06735	.000	.3519	.6753
		Parents	.08796	.08638	.027	-.1194	.2954
	Governmental school students	Leaders/teachers	-.51358*	.06735	.000	-.6753	-.3519
		Parents	-.42563*	.07233	.000	-.5993	-.2520
	Governmental school parents	Leaders/teachers	-.08796	.08638	.027	-.2954	.1194
		Students	.42563*	.07233	.000	.2520	.5993

Note. *Mean difference is significant at 0.05 level; MD: Mean difference; & SE: Standard error

Table 11. Independent sample t-test of university students' & leaders' perceptions about THC

Cluster	Stakeholder	n	Mean	SD	F	t	df	Sig. (2-tailed)
THC	University students	110	3.37	1.13	26.359	-2.381	161	.018
	University leaders/teachers	54	3.76	.520				

Table 12. Independent sample t-test of industry students' & leaders' perceptions about THC

Cluster	Stakeholder	n	Mean	SD	F	t	df	Sig. (2-tailed)
THC	Industry leaders	53	3.32	.628	22.259	1.321	155	.188
	Industry students	101	3.10	1.102				

and **Table 10**). An independent samples t-test results was conducted to compare the university students and leaders'/teachers perceptions about THC, as well as the industry students and leaders' perceptions about THC.

As shown in **Table 9**, an ANOVA analysis was conducted to compare the perceptions of stakeholders in the governmental school cluster regarding THC. Regarding THC, there were significant differences between three stakeholders' categories (governmental school leaders, students, and parents) at p<.000 for conditions F(2, 283)=37.894. There were also significant differences between all stakeholders' perceptions (parents, students, and leaders/teachers) in THC category.

As shown in **Table 10**, there were significant differences for the perceptions of governmental school leaders/teachers and students towards THC at p<.000. However, there were significant differences for the perceptions of governmental school leaders/teachers and parents towards THC at p<.027. Also, there were significant differences for the perceptions of governmental school students and parents towards THC at p<.027.

As shown in **Table 11**, independent samples t-test results showed that there were statistically significant differences between university students' perceptions (M=3.37, SD=1.13) and university leaders/teachers (M=3.76, SD=.52) about THC; t(161)=-2.381, p<.018 in favor of university leaders/teachers.

As shown in **Table 12**, independent samples t-test results showed that there were no statistically significant differences between industry students' perceptions (M=3.32, SD=.628) and industry leaders/teachers (M=3.10, SD=1.102) about THC; t(155)=1.321, p<.188.

Table 13 summarizes the stakeholders' perceptions within and between clusters. For perceptions within clusters, all stakeholders from the three clusters ranked high or very high in the two categories, STEM education programs and future STEM careers, indicating their agreement. Although the students from all three clusters ranked medium in TH category, this also means a positive perception. As a result, all stakeholders from the three clusters perceived all three categories positively. For inferential analysis, ANOVA was used to analyze the perceptions within clusters. For example, there are significant differences between leaders/teachers and students in the government and industry clusters. There are also non-significant differences between leaders/teachers and students in the industry and university clusters, which need further investigation.

For perceptions between clusters, student perceptions showed that there were significant differences in the STEM education programs category between students from the government and university and students from the university and industry. There were non-significant differences between the leaders/teachers from all three clusters. In future STEM careers category, there were significant differences between leaders/teachers from government and

Table 13. Summary of perceptions of all stakeholders within & between clusters

Perceptions within clusters		Perceptions between clusters
STEM education programs		
Government		Leaders'/teachers' perceptions
L/T: High	Significant	Non-significant
S: High	L/T--P	Government & university
P: High	L/T--S	Government & industry
	Non-significant	University & industry leaders/teachers
	S--P	
University		Students' perceptions
L/T: Very high	Non-significant	Significant
S: Very high & high	L/T--S	Government & university
Industry		University & industry
L/T: Very high	Significant	Non-significant
S: Very high & high	L/T--S	Government & industry
Future STEM careers		
Government		Leaders'/teachers' perceptions
L/T: High	Significant	Significant
S: Very high & high	L/T--P	Government & university
P: High	L/T--S	Non-significant
	Non-significant	Government & industry
	S--P	University & industry
University		Students' perceptions
L/T: Very high & high	Non-significant	Significant
S: Very high & high	L/T--S	Government & university
Industry		Government & industry
L/T: Very high	Significant	Non-significant
S: Very high & high	L/T--S	University & industry
THC		
Government		Leaders'/teachers' perceptions
L/T: High	Significant	Significant
S: Medium	L/T--P	Government & university
P: High	L/T--S	University & industry
	S--P	Non-significant
University		Government & industry
L/T: High	Significant	Students' perceptions
S: Medium	L/T--S	Non-significant
Industry		Government & university
L/T: High	Non-significant	Government & industry
S: Medium	L/T--S	University & industry

industry clusters. There were also significant differences between students from government and university, and students from the government and industry. For THC category, there were significant differences between leaders/teachers from government and university, and leaders/teachers from university and industry. There were no significant differences between students.

Also, there were significant differences for the perceptions of university students and industry leaders towards STEM education programs perceptions. In regard to their perceptions towards future STEM careers and career interests, there were significant differences of perceptions of governmental school students and university students towards future STEM career perceptions and career interests in favor of university students. There were significant differences for perceptions of governmental school students and industry students towards future STEM career perceptions and career interests in favor of industry students. There were no significant differences for perceptions of university students and industry students towards future STEM career perceptions and interests.

DISCUSSION

The discussion section focuses on the results achieved from the quantitative analysis of the questionnaires and describes the results in relation to relevant studies.

STEM Education Program Perceptions

The stakeholders highlight the importance of formal and informal STEM education programs and STEM careers. The results of this research question are in line with the findings of Nguyen et al. (2020) who found that the teachers who are interested in applying the STEM education system view it as an important approach that provides an opportunity to enhance their role as teachers and address the challenges of developing STEM careers in their country. This link between investing in STEM education programs to develop the economy was seen in the perceptions of the governmental schools' teachers, students, and leaders. The teacher/leader participants from all three clusters, industry students and university students very highly agreed that informal and formal STEM education programs prepared the students to meet the future industrial needs. Government parents and government students highly agreed on this matter.

When designing formal and informal STEM education programs, activities that are more hands-on and engaging can lead to an increased interest in science and future STEM careers (Popovic & Lederman, 2015; Roberts et al., 2018). In a STEM classroom, the social constructivist approach utilizes scaffolding and collaboration to help students to mature through levels of understanding (Achzab et al., 2018; Admawati et al., 2018). This is in line with British Council (2018), which advises that the curriculum needs to be adjusted to remain focused on students' 21st century skills and needs. The student participants in the three clusters highly agreed on the importance of these 21st century skills.

STEM Career Perceptions

Regarding STEM career perceptions, all stakeholders highly agreed that STEM education programs will benefit a student's future, including their career. Schultz and Schultz (2016) identify individual goals as a factor that influences students' career choices. Green and Sanderson (2017) identified motivation in school can increase persistence in pursuing a STEM career. According to SCCT, goals take into consideration both personal interests and self-motivation (Lent et al., 2002; Leong, 2008). As a result, a student's motivation can be a deciding factor as to whether they pursue a STEM career. Additionally, Milner-Bolotin and Marotto (2018) emphasize that a child's achievement in STEM education programs can improve from parental engagement. The leaders/teachers and students from the governmental and university clusters very highly agreed that rewards and awards contribute to attracting and retaining the best minds. Recognition from the community is emphasized as a motivating factor. It is advised that parents are active participants in their child's school life to help them succeed in the STEM education program's student-centered approach by joining in on the hands-on activities (FLL, 2020). Lent et al. (2008) describe SCCT identifies measures of self-efficacy, outcome expectations, personal backgrounds and inputs and contextual support and/or hindrances to explain the logic behind students' career/academic choice. SCCT is used as a predictive model of interest in the STEM fields for students in cycle 2 and cycle 3 levels (Lent, 2005; Lent et al., 2008). Therefore, social and motivational factors can be cited as influencing the students' perception of STEM careers (Nugent et al., 2015).

Also, Shattock (2009) states that curriculum should focus on requiring students to use their own knowledge to create innovative solutions. The participants also highly agreed that problem-solving is an essential skill that should be developed in STEM education programs. These initiatives can improve both social and economic development, but they need support, which requires communication between external and internal partners (Scharmer & Käufer, 2000).

Triple Helix Components Perceptions

The leader/teacher participants in all clusters and governmental parents highly agreed on the benefits of the coordination and communication of universities, industries, and STEM education program. With THM, relationships between the different institutions can be improved so that developments can reach across the other clusters (Ranga & Etzkowitz, 2013; Rodrigues & Melo, 2013). For instance, Etzkowitz and Zhou (2017) express that entrepreneurial universities can foster social and economic development through research and the production of intellectual property. Etzkowitz (2008) emphasizes that improvement can be supported by the collaboration between THC. More specifically, the educational sector can benefit from the development spurred by TH partnerships. Ranga and Etzkowitz (2013) state that THC support students' entrepreneurial talent by cultivating 21st century skills, contributing to economic development. Also, Karmokar and Shekar (2018) emphasize that TH partnerships motivate students to seek future STEM jobs.

The leader/teacher participants from all clusters and governmental parents highly agreed on the need for ongoing and strong collaboration among THC. This is not always easy, and studies have pointed out that collaboration among THC face barriers (Karmokar & Shekar, 2018). Desai and Manjunath (2018) mention that disagreements and disputes can arise from clashing needs and objectives between THC. These barriers need to be overcome since it is through the collaborative synergies among THC that increase innovative development (Etzkowitz, 2008). Sustainable partnerships with strong communication channels, which are simultaneously autonomous and overlapping, can withstand the environmental conditions that can make the partnerships vulnerable (Desai & Manjunath, 2018; Etzkowitz & Zhou, 2017). Communication removes the boundaries between THC, which can benefit STEM education programs through organizational creativity (Etzkowitz & Zhou, 2017). Chryssou (2020) recommends that incentives for THC can facilitate communication, collaboration, and joint initiatives. Regarding THC, it is only the stakeholders from the industry cluster that are showing non-significant differences in perceptions, which points to a need for further investigation.

Hypotheses

This study was designed to test three hypotheses related to educational stakeholder perceptions in the government, industry, and university clusters regarding STEM education programs, STEM careers, and THC. The first hypothesis was that there would be significant differences in the perceptions on STEM education between and within the governmental, university, and industry clusters. The results show that there were significant differences within the governmental participants and industry participants among leaders/teachers and students on STEM education programs. There were also significant differences in student's perceptions between the government and university clusters, as well as university and industry clusters. The second hypothesis was that there would be significant differences in the perceptions on STEM careers between and within the governmental, university, and industry clusters. The results show that there were significant differences within the governmental participants among leaders/teachers and parents, as well as leaders/teachers and students on STEM Education programs. There were also significant differences in student's perceptions between the government and university clusters. The third hypothesis was that there would be significant differences in the perceptions on THC between and within the governmental, university, and industry clusters. The results show that there were significant differences within the governmental participants among leaders/teachers and parents, leaders/teachers and students, and parents and students. There were also significant differences within the university cluster between leaders/teachers and students. Lastly, there were significant differences between teachers/leaders in the university and industry clusters, as well as government and university.

CONCLUSIONS

This study reveals commonalities and disparities on STEM education programs, STEM careers, and THC between and within the government, university, and industry cluster's educational stakeholders. The results showed that the significant differences in all three topics reflect the need for further investigation to gain more understanding about THC's potential role in benefiting STEM Education and STEM Careers.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: Authors stated that the study was approved by the institutional ethics committee of BUID (British University in Dubai) on 23 December 2019. Informed consent was assured with participants.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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