An investigation into links between UAE STI Policy and the Federal Universities STEM Majors' Enrolments, Graduates and Research Development: an evidence-based exploration of the impact of UAE STI policy

Rima Abou Khreibi[1]

1. Faculty of Education, The British University in Dubai, P. O. Box 345015, Dubai, UAE

*Corresponding author's email: 20170113@student.buid.ac.ae

Abstract

The current study investigates the impact of the United Arab Emirates (UAE) STI policy initiatives on STEM majors' enrolments, graduates and research and development within Higher Education Institutions within the UAE. A sequential exploratory mixed method approach was used, which involves initial qualitative stage of data collection and analysis exploring to what extent the STEM programs enrolments, graduates, R&D has changed, while the second stage interprets and explores the findings using quantitative data analysis. In summary, the research findings show that STI policy has influenced STEM majors HEI enrolments in two federal universities: Zayed University (ZU) and Higher Colleges of Technology (HCT), where there was an accelerated enrolment like other countries, such as ASEAN and BRIC countries. The major STEM enrolments were seen in the engineering, and computer sciences. Zayed University-Dubai had greater STEM majors' enrolments compared to Zayed University-Abu Dhabi. HCT STEM majors' graduates showed no significant differences from AY 2010 to the AY 2017; the latter shows that although STEM enrolments have increased in HCT, graduates of STEM are consistent and unchanged, meaning that somewhere during their tertiary education, students are not continuing their studies in STEM majors. In terms of United Arab Emirates University (UAEU), there has been a decrease in STEM programs enrolment, while STEM graduates in UAEU has stayed steady at 1/3 STEM majors compared to 2/3 non-STEM programs. The results confirm previous studies findings and expectations where it showed that more male students than female students enroll in STEM programs in both HCT and UAEU. In terms of R&D, UAEU has shown improvement on the global ranking, ZU has shown a slowdown in R&D. Therefore, in terms of R&D, the impact of STI policy could not be ascertained and further investigations looking at detailed HEI data are recommended.

Keywords STI, Policy, UAE Higher Education, Research & Development

1. Introduction

Countries have envisioned the Knowledge-based Economy (KE) as a sustainable model of economic development. Economies with higher human-capital stocks involved in research experience an accelerated economic-growth rate, international competitiveness, individual earnings, social cohesion, and justice (Rezny, White & Maresova 2019; Al Qasmi Foundation 2012). Wiseman (2014) asserts that the KE linkage to educational systems is important in developing nations, linking education to economic-growth and global competitiveness. Consequently, economies must invest in innovation, education, and knowledge creation. Industrialization has relied on science and technological innovation demanding increased educational level, triggering a 21st century global shift and promoting Science and Technology (S&T) knowledge (Wiseman 2014; ElSayary 2018; Alfaki 2013).

Universities contribute to the knowledge and skill development, enhancing innovation and scientific knowledge leading to economic well-being (UNESCO 2015). Scientific knowledge plays a critical role in sustaining socio-economic global wellbeing and integration. Therefore, nations strive to become S&T knowledge creators rather than users (ElSayary 2018; UNESCO 2015). Countries focusing on intellectual abilities while driving innovation, and S&T develop KE through competitive policies development, supporting improved work skills through innovation and S&T (Schwalje 2012; ElSayary 2018).

Arab economies suffer from weak S&T knowledge, and knowledge development (Ahmed & Al-Roubaie 2012). United Arab Emirates (UAE) KE readiness assessment

35

ranked 27th in the 2011-2012 World Economic Forum (WEF) report and the third in the GCC, fairing low in the training and higher education pillars (Al Qasmi Foundation 2012).

Accordingly, a UAE strategy to enhance KE was planned where a budget of three hundred billion dirhams was invested in education, technology, finance and legislation. UAE's education budget exceeded 20% of the total government allocated budget and was higher than the average government's benchmark of 13% (ElSayary 2018; Byat & Sultan 2014). Al Qasmi Foundation (2012) and UAE Vision 2021 (2020) stress the importance of increasing Science, Technology, Engineering and Mathematics (STEM) enrolments, graduates, as well as Research and Development (R&D) for increasing the UAE knowledge competitiveness.

The World Bank considers human-capital development as a crucial element of KE, stating that a society should possess a minimum human-capital level prior to efficient innovation system and research development (Molla & Cuthbert 2018). In the UAE, there has been a shortage of STEM labour force and STEM majors' enrolments, and graduates in Higher Education Institutions (HEI) among Emiratis (Moonesar et al. 2015). Federal universities enrolments in STEM majors in 2014 was 21%, from this percentage 61% are majoring in natural science, and only 31% are studying engineering majors, most of the 21% are males and 16% are females (ElSayary 2018; Moonesar et al. 2015). Countries that are resource-based and oil-based economies such as the UAE tend to score lower on international exams compared to countries that are KE (Ahmed & Al-Roubaie 2012; Wiseman 2014; Alfaki 2013; UAE 2015; Al Qasmi Foundation 2012). The latter has led to a UAE Science, Technology, and Innovation (STI) policy development as a

demand-led manner, to deal with market slow down, and to address asymmetries among information and externalities (Padilla-Pérez & Gaudin 2014; Alfaki 2013; Ahmed & Al-Roubaie 2012).

Policies that promote STI learning, act as levers for competitiveness leading to structural jobs and growth creation reform (Ahmed & Al-Roubaie 2012; UNESCO 2011). R&D and human-capital investment leads to technological progress and economic-growth (Jung & Mah 2014). Accordlingly, successful KE is closely linked to increased academic higher education STEM education and increase in R&D (Alfaki 2013).

UAE Vision 2021 aspires to produce a country where Emiratis partake in the building of an innovative, technology based KE. Therefore, this study will analyze STI policy and investigate the impact of UAE STI policy on federal HEI STEM majors enrolments, graduation rate, and R&D. The results will be used to inform further policy implementation, and will provide recommendations based on the present status for future purposes that can be used to establish a group of young Emirati innovators. The study focuses on the impact of UAE STI policy on the federal HEI STEM enrolments, and graduates related to the Knowledge-based pillars of STI policy during the years 2010 – 2018. The main aim of the research is to explore the extent to which the STI policy influenced Emirati students' enrolments and graduation from STEM programs within the UAE federal universities and how the research improved from the years 2011 to 2019 within these universities. The following research questions will be used to realize the purpose of the study:

1) To what extent has the STI policy impacted the enrolments, and graduation of Emirati students in STEM programs in UAE federal universities from the years 2011 - 2019?

2) How has the research (R&D) improved from the year 2011 to 2018 in UAE federal universities?

UAE Vision 2021 resulting from The Government Strategy (2011-2013) aims to develop a competitive KE through research, innovation, and science education by increasing STEM HEI enrolments, graduates, and R&D (UNESCO 2015). In November 2015, the UAE's president adopted STI policy focusing on S&T innovation, leading transformation from oil-dependence towards KE wealth (UAE Government 2015; Alfaki 2013). STI policy outlines a strategy encompassing HEI's talent investment, and increasing intellectual property, entrepreneurship, and partnerships. Talent's investment increases Emirati STEM labour force, equipping them with S&T, and R&D skills, where policy accelerates UAE STEM education (Moonesar et al. 2015; Alfaki 2013; ElSayary 2018). Consequently, it is important to examine the current status of HEI student STEM majors' enrolments, graduates, and R&D, for new prospects adoption, realization, future programs, and policies application while building Emirati indigenous knowledge (Alfaki 2013; Ahmed & Al-Roubaie 2012)

Moreover, as the UAE endeavours at building its KE, it must ensure that it builds Emirati human-capacity and not sacrifice the long-term aim by implementing short- or medium solutions depending on foreign knowledge, rather than building indigenous Emiratis S&T human-capacity (Alfaki 2013). This should be through strengthening knowledge creation, and transfer through research, and through STI programs, where publicly funded

research drives innovation and S&T knowledge (Ahmed & Al-Roubaie 2012; Gackstatter, Kotzemir & Meissner 2012).

Given HEI contribute to high level productivity of knowledge and human-capital, achieved by mass S&T research workforce. There are few studies investigating knowledge-based economies development based on large-scale education data availability, this study is unique since it will utilize the available data to identify the strengths and weaknesses in terms of UAE HEI STEM majors' enrolments, graduates, and R&D.

2. Literature Review

OECD summarizes KE as an economy based on knowledge production and distribution, while Powell and Snellman base KE as a knowledge-intensive activity contributing to the accelerated scientific and technical advancement pace, with accelerated reliance on intellectual human capabilities rather than natural resources or physical inputs (Rezny, White & Maresova 2019). OECD measures KE through the compilation of S&T, industry and innovation growth concentrating on the four pillars of Knowledge Economy Index (KEI) (Rezny, White & Maresova 2019).

Table 1: The Four Pillars of the Knowledge Economy Index (KEI)

1. 'Economic and institution regime'
2. 'Education and skill of population'
3. 'Information infrastructure'
4. 'Innovation system'

The 'Education and skill of population' is the focus of this study looking at the UAE federal HEI STEM majors' enrolments, graduates, and R&D. It incorporates three indicators such as: gross enrolments rate (tertiary), gross enrolments rate (secondary), and adult literacy rate (Rezny, White & Maresova 2019; Alfaki 2013). Weber (2011) indicates that education a KE pillar does not only contribute to a nation's need of skills and knowledge, enabling knowledge creation and sharing; education plays an important role in nation's innovation system (pillar 4) since HEI generate patents, new ideas, and technologies.

Figure (1): KE Index Model (Adopted from Alfaki 2013)
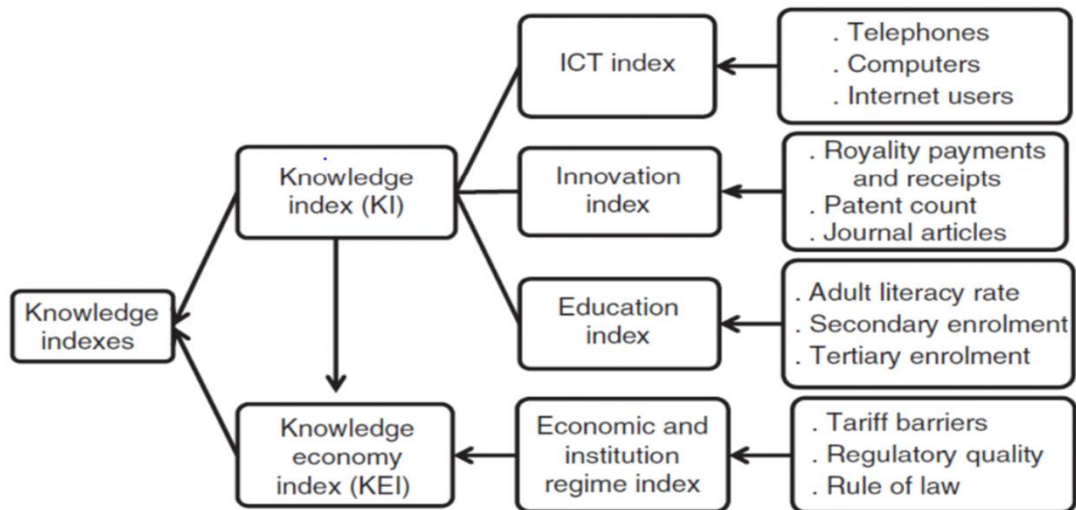
Source: World Bank Knowledge for Development (K4D)

Figure (1) demonstrates KEI constructs such as education and innovation indexes, which rely on human-capital, and R&D (Alfaki 2013; Jung & Mah 2014). Human-capital must engage in 'lifelong learning' to keep pace with labour market fluidity, pacing the

way for HEI reform prominence (Maton 2014; Wiseman 2014; Schneegans 2015). Indicators of KE include knowledge stock represented in STEM workforce, and R&D outputs (ElSayary 2018; Molla & Cuthbert 2018; UNESCO 2010).

2.1 Theoretical Framework

Human-Capital Theory (HT)

Tan (2014) considers education as a basis to human-capital knowledge, leading to economic development. Human-capital refers to the productive embodiment of skills, labour and knowledge, suggesting that education accelerates individual's earning and productivity and country's economic-growth. HT emerging from the neoclassical school, involves individual's skills and knowledge endorsement through education, increasing workplace productivity and incentives (Novak 2010; Tan 2014).

Educationalists use HT to understand education and development policies within KE context. It postulates that higher education is instrumental for the society capacity productivity, thus having an educated society increases employees' efficiency and productivity through cognitive stock and innate skills, leading to greater micro level economic-growth, thus, justifying governmental education expenditure (Tan 2014; Novak 2010). Tan (2014) argue that human-capital investment is based on providing the new population with knowledge that is appropriate that was accumulated by past generations. Secondly, this past knowledge should be presented to the new population in such a way it allows them to develop and introduce new innovations comprised of social products, processes and services through creative methodologies.

Neoclassical Economic Model (NEM)

NEM emphases Methodological Individualism (MI). MI postulates that everything starts from the desires, beliefs of individuals which account for the social phenomena, where individual behaviors are the products of cultural, environmental factors which are pursued to maximize individual's own interest (Tan 2014).

Rational Choice Theory (RCT)

RCT asserts that individuals aim to enhance their interests by making optimal choices in the entire areas of their lives, RCT has some limitations which are termed bounded 'rationality', 'self-interest', 'will power' (Tan 2014). Rationality assumes that individual's cognitive abilities are not endless, individuals have frail memories and restricted computational skills, while willpower refers to the sensitivity to manipulations which may be irrelevant to the individuals decisions and long-term behaviours, self-interest refers to the act of caring about others and being treated fairly as pluralistic individuals, humans are consistently navigating between others' interest and own interests (Tan 2014).

As a result of HT, NEM and RCT, human-capital within the society are increased due to the individual desires in education which is influenced by the society and how it promotes learning and education. Therefore, in the case of the UAE the countries vision 2021 had influenced many individuals in the society to seek knowledge, specifically S&T knowledge in which many initiatives have been developed in the past few years promoting a culture of S&T and innovation, as well as, R&D.

Endogenous Growth Theory (EGT)

Thus far this research paper has focused on the economic-growth resulting from HEI investment, though, there is non-economic impact that is socially oriented, leading to improved health, longevity, asset and household management which are considered externalities contributing to economic and political, innovative stability (McMahon 2018).

EGT assumes that knowledge investment is characterized by accelerated rather than deaccelerated returns, it highlights education's role in human-capital creation and new knowledge production. It discusses that some type of knowledge can be produced at lower cost than other form of knowledge with the difficulty of knowledge transfer highlighting the importance of scientific knowledge (Alfaki 2013). This can be related to STI policy drive to increase R&D contributing to Emirati indigenous innovation and knowledge transfer.

2.2 UAE STI policy and Vision 2021

Policies are encouraging a pressing priority in knowledge acquisition, generation, diffusion, and exploitation in the research and science (Alfaki 2013). STI policy adoption in many countries has focused on STEM education leading to innovation, and entrepreneurship (UNESCO 2011).

One of the pillars of the STI policy is to increase STEM tertiary enrolments, and R&D. Countries such as Singapore, and Korea have increased enrolments and R&D (Jung & Mah 2014). Denmark, Argentina, Sweden and Australia have provided incentives for students who are involved in STEM education (ElSayary 2018). In Canada efforts of improving STEM enrolments was through whole curriculum innovation and

training (Sinay & Ashley 2017). Ireland and Germany increased science instruction, while Norway increased mathematics teaching hours (OECD 2012).

The UAE adopted STI policy to shift away from oil-dependence towards a KE, where it encompasses innovation, human-capital education, and research investment (UAE Vision 2021, 2020). As a result of UAE Vision, a national innovation strategy aiming at making the UAE the most innovative nation in the world by 2021 by focusing on technology, education, sustainable and clean energy (UAE Government 2015). Although different innovation types are included in the policy, this paper focuses on the science-based innovation, which entails the highest expertise caliber providing the greatest economical return. Human-capital and talent development lies at the heart of STI policy focusing on increased S&T enrolments and R&D outputs (Wiseman 2014; UNESCO 2011).

2.3 STI Literature & Studies

During the 21st century, HEI face new challenges, due to global, local/regional, and national challenges (Gidley et al. 2010). Evidence-based policy decision-making is a symbol to a knowledge society, since S&T knowledge has driven labour market, there has been a shift in the education system to increased higher education and greater demand on highly skill S&T workers (ElSayary 2018). Internationally STI policy development has initiated HEI to participate in human-capacity building through STEM programs access and R&D leading to innovation as is the case in Association of South East Asian Nations (ASEAN), Brazil, Russia, India, and China Countries (BRIC).

ASEAN such as Singapore and Korea have envisioned the development of sustainable

communities, capacity building and social empowerment through investment in HEI knowledge development through an interdisciplinary approach and research (Symaco & Tee 2019; Jung and Mah 2014). The ASEAN countries have been ranked second compared to China, with a combined GDP that is seventh in the world (Rodriguez & Soeparwata 2012; Symaco & Tee 2019). BRIC nations have been realized as the upcoming countries with respect to economic-growth due to STI policies adopted within Brazil, and India where major investment in increasing STEM knowledge, and R&D has assisted in improvement in innovation leading to higher KEI (Gackstatter, Kotzemir & Meissner 2012).

STI policy adoption has not been successful world-wide as the case of ASEAN and BRIC countries, in Central America STI has not led to increased STEM majors' enrolments and R&D (Padilla-Pérez & Gaudin 2014). In spite efforts in Middle East and Northern Africa (MENA) region to enhance education access and R&D, it has not been successful due to unawareness of scientific research importance, where minimal collaboration with HEI and industries leading to brain drain (UNESCO 2015), as also see in Iran (Mahdi 2015). In realizing STI goals, often great expenditure on education and R&D has not always yielded an increase in innovation as the case of GCC countries, where monetary investment is less important than appropriate allocation and innovation, and education and technology sectors collaboration as is the case of Saudi Arabia, where in 2011 it was ranked 41 on the Global Innovation Index (GII), however, it was 98 in its innovation output (Iqbal 2011).

Alfaki (2013) explored the role STI policy plays in the transformation of UAE into KE while assessing UAE's STI competence and capacity in knowledge diffusion and

adoption. UAE ranks as part of the top 40 nations according to the latest HDI and the third after Saudi Arabia and Iran in the MENA regions (Ahmed & Al-Roubaie 2012; Alfaki 2013). In the UAE recent growth has been marked by low skills labour force with more than 92% of workforce are foreign workers and only 20% having university diploma, bachelor or masters and PhD degree, making unskilled workers as 80% (Alfaki 2013). The UAE witnessed expansions and investment in HEI, however, the UAE requires higher numbers of STI curriculum majors such as science, technology and engineering (only one third of graduates), in terms of research the UAE ranks 24th worldwide as 37th in terms of university-industry collaboration (Alfaki 2013).

3. Methodology and Results

3.1 Research Approach

The initial stage of data collection employed a sequential mixed method exploratory approach investigating the impact of STI policy on student enrolments, graduates and R&D outputs, involving initial qualitative stage of data collection and analysis exploring to what extent the STEM programs enrolments, graduates, R&D has changed. While the second stage involved the interpretation and exploration of the findings using quantitative data analysis (Berman 2017). Mixed method sequential exploratory case study approach allows us to investigate in-depth relationships among variables, where qualitative methods are utilized to identify critical variables, which are quantified and correlated, triangulating the data (Fraenkel, Wallen & Hyun 2016; Johnson & Christensen 2020).

STI policy impact on three UAE federal universities' STEM programs enrolments, graduates and R&D output was investigated. The UAE is the macro case, while each of

the three federal universities are considered the bounded micro cases, the cases are bounded by activity and sustained time (Yazan 2015).

Sequential exploratory mixed method procedures assist the research to expand one method finding with the another (Berman 2017). In this study the researcher explored and analyzed documents, which involved extracting key data from university documents such as factbooks and websites content using a qualitative document analysis approach, followed with a quantitative approach summarizing a large quantitative data sample in order to generalize the results (Cresswell 2012).

Situational analysis was used since only available key organisation's websites data was utilized for the three federal universities, data included STEM programs enrolments and graduates quantitative information. It is considered situational since not all the data for all the years were found on the websites. In the latter, the least square method was used extrapolating based on available data (Gackstatter, Kotzemir & Meissner 2012). Furthermore, the SCIMAGO website was used to summarize data related to the three universities R&D activities.

Vartinian (2011) asserts that document analysis permits robust data collection and provide realistic overview of the process such as the UAE STI policy impact. The university factbooks were used for summarizing the data, caution should be taken since these factbooks and organizations' websites represent the universities data collection and overreliance on this data should be taken with caution (Vartinian 2011).

Since most of the document are found as open data on the university's website and other organizations website, the data contains quantitative summaries of the enrolments, graduates, and R&D generalizations of findings is possible since the document analysis is

triangulated with the source of this reliable quantitative data.

3.2 Research Design

The main purpose of the research is to investigate STI policy impact on STEM program enrolments, graduates, and R&D outputs in the three UAE federal HEI. Situational mixed method analysis of the online available documents and data were used, similar studies have used this type of approach (Alfaki 2012; Ahmed & Al-Roubaie 2013).

Due to the nature of the study, secondary data consisting of universities factsheets and reports were used. These were available on the universities website and other organisations links presented in Table 2.

Table 2: Secondary Data Sources

Name of University or Organization	Web Address	Type of Data Collected
Higher Colleges of Technology (HCT)	http://www.hct.ac.ae/en/about/open-data/	Open data link provided factbooks and factsheets for enrolments, graduates and other data the years 2010 – 2019
United Arab Emirates University (UAEU)	https://www.uaeu.ac.ae/en/about/data.shtml	Open data link provided factbooks and factsheets for enrolments, graduates and other data the years 2011 – 2016
Zayed University (ZU)	https://www.zu.ac.ae/main/en/open_data.aspx	Open data link provided factbooks and factsheets for enrolments, graduates and other data the years 2010 – 2017
SCIMAGO	https://www.scimagojr.com/countrysearch.php?country=ae	Provided research activity data for R&D indices for the UAE and across the three federal universities being investigated

Only three federal universities were used as micro cases since the scope of the study is to examine Emirati student's enrolments, graduates from STEM programs, and R&D outputs. The three federal universities were Higher Colleges of Technology (HCT), United Arab Emirates University (UAEU), and Zayed University (ZU). Initially, the researcher scanned the three universities websites searching for enrolments and graduate's data, an open data link was found on all three universities, containing university's factbooks some dating back to 2010 until 2018. For the data pertaining to the R&D, the SCIMAGO website was searched for data related to R&D for each of the three universities. For the purpose of this study only the link of open data source and SCIMAGO web was provided in Table 1.

The researcher used the qualitative document analysis approach, where data reports and factbook from the universities were examined and reviewed. First, the documents were analyzed to ascertain the STEM and non-Stem majors within each university. Secondly, the data related to each of the STEM courses such as total number enrolments, graduates, and research related to STEM was compounded into an Excel sheet with relevant numerical statistic from the respective major within the university.

Post a quick revision of the available factbooks data and the SCIMAGO website, enrolments and graduates numbers related to STEM programs and Non-STEM programs enrolments, and graduates were explored and extrapolated. Further analysis of the data focused on emerging themes (Vartinian 2011) associated with enrolments, graduates, STEM programs, and R&D report, creating research experimental knowledge (Vartinian 2011). The extrapolated data was transcribed into Excel worksheets and tables, where

quantitative data analysis and descriptive statistics was used to obtain the results of the study tabulating it into graphs for further interpretation and discussion.

The major limitation of this study is the lack of recent international public data related to the UAE STI policy implementation such as KEI, GERD, FTE, secondary school enrolments and other data which can be further used to analyse the main findings in this study triangulating the evidence and allowing for more correlational study. Also, some universities such as the HCT and UAEU do not provide detailed R&D and patent information allowing for further correlation of innovation and R&D output to Emirati talent, and allowing for comparability among the HEI. Public universities websites were used to collect data used in this study, therefore, there is no requirement for obtaining consents to use this data.

Vartinian (2011) states recently available public reports on organizations website provide secondary data that is reliable and valid as well as trustworthy. In this study, the three federal universities and the SCIMAGO websites are considered to provide public reports that are reliable, valid and trustworthy as stated earlier.

3.3 Results and Discussion

HCT, UAEU, and ZU are federal universities with mostly Emiratis students, these universities have been used due to the scope of this study which is to investigate Emirati STEM enrolments, graduates, and R&D.

Figure (2): Three Federal Universities that will be the Cases Used in the Study (Adopted from Ridge, Kippels & ElAsad (n.d.)

Name	Year Established	Approximate number of students (2016)	About
UAE University	1976	14,000	UAE University is the country's oldest higher education institution. Located in Al Ain (the emirate of Abu Dhabi), it consists of nine colleges. UAE University was the first university in the UAE to institute a Ph.D. program (NAPO, 2013).
Higher Colleges of Technology (HCT)	1988	23,000	HCT's 17 campuses are spread across the country, making it especially popular among female students, who often live at home while undertaking their studies (Higher Colleges of Technology [HCT], 2016b).
Zayed University (ZU)	1998	9,000	ZU has two campuses in Dubai and Abu Dhabi that offer both undergraduate and master's degrees (Zayed University, 2016a). Originally open only to women, starting in 2009 the university opened admission to men (Zayed University, 2016b)

Research Question 1

Figure (3): HCT STEM Program Enrolments Vs. Non-Stem Programs Enrolments Across Academic Years (AY) 2010 - 2019

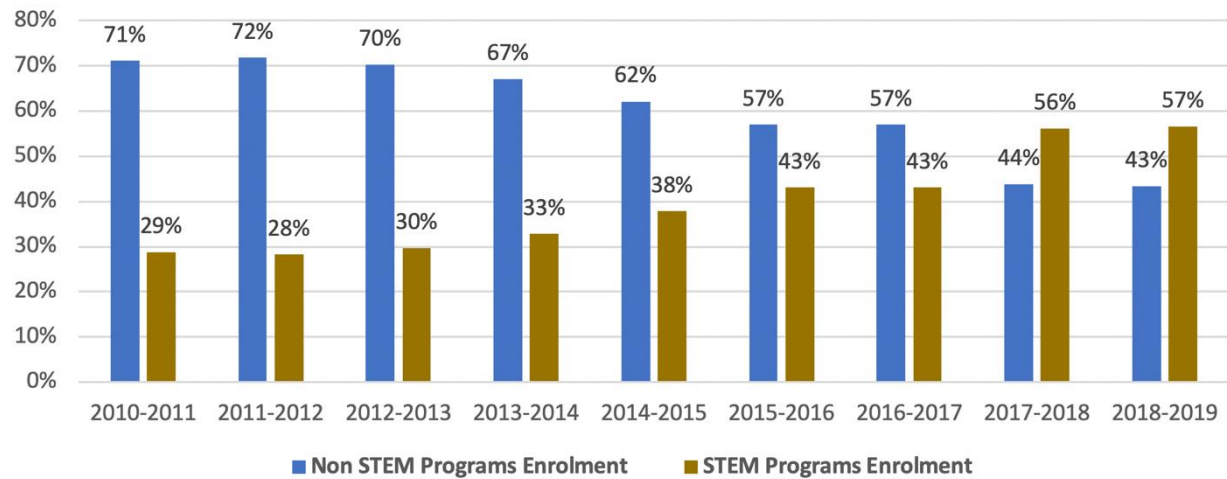Non STEM Programs Enrolment ■   STEM Programs Enrolment ■

Figure (3) shows HCT STEM enrolments during the AY 2010 – 2011 represented 29% of the total, while non-STEM programs enrolments was 71%, this result is like previous studies where STEM program enrolments encompassed one third of the total enrolments compared to two thirds in non-STEM programs (Alfaki 2013; Ahmed & Al-Roubaie 2012). Nevertheless, since 2010 there has been consistent increase in STEM program

51

enrolments reaching 57% for STEM programs vs. 43% for non-STEM program enrolments in the AY 2018-2019, this increase in STEM programs enrolments is expected due to previous research evidence from BRIC countries (Gackstatter, Kotezemir & Meissner 2012).

Figure (4): HCT STEM Programs Student Enrolments AY 2010 – 2019
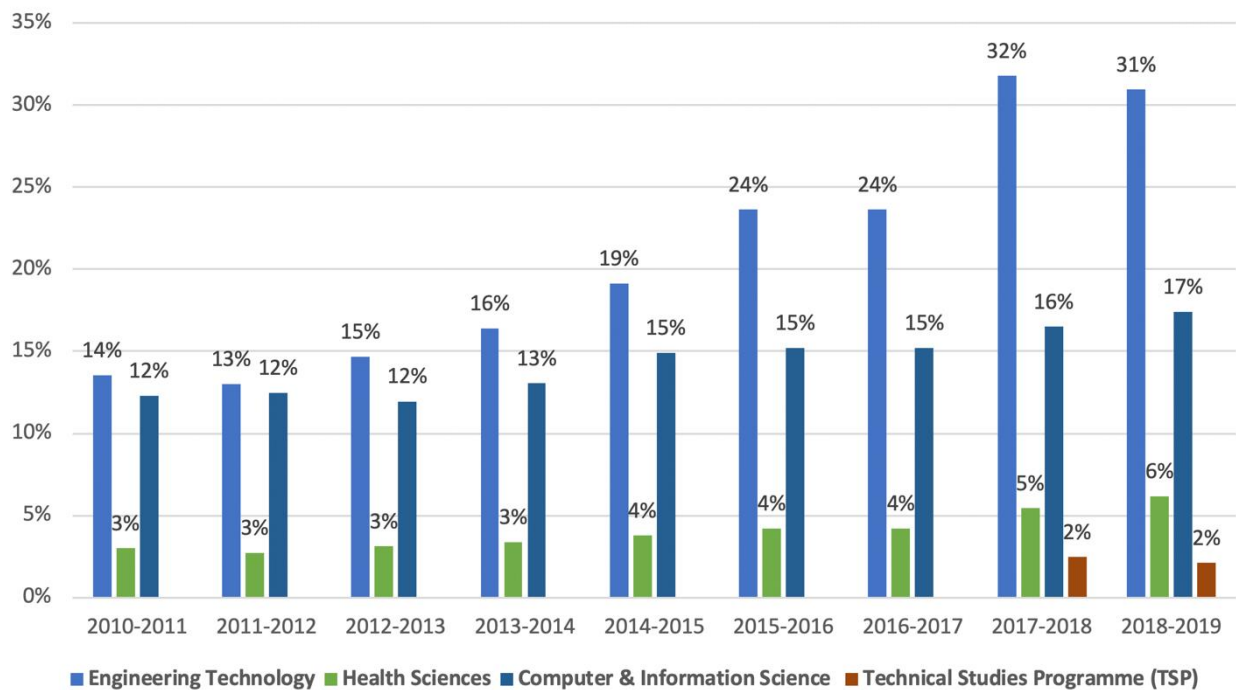
According to Figure (4), student enrolled predominately in engineering, followed by computer science, health science, and technical studies programs respectively. The major shift was in engineering witnessing 17% increase from the years 2010 to 2019, whereas computer science increased by 5%, and health sciences by 3%. Gackstatter, Kotezemir and Meissner (2012) ascertain that for KE key success criteria, the focus in the BRIC and GCC countries should be towards hard sciences such as engineering and information technology, these results support the latter, where hard sciences enrolments has been accelerated throughout the AY in HCT showing that Emirati STEM knowledge is being

52

enhanced towards innovation and KE.

Figure (5): HCT Gender STEM and Non-STEM Program Enrolments for AY Spanning 2012 - 2019
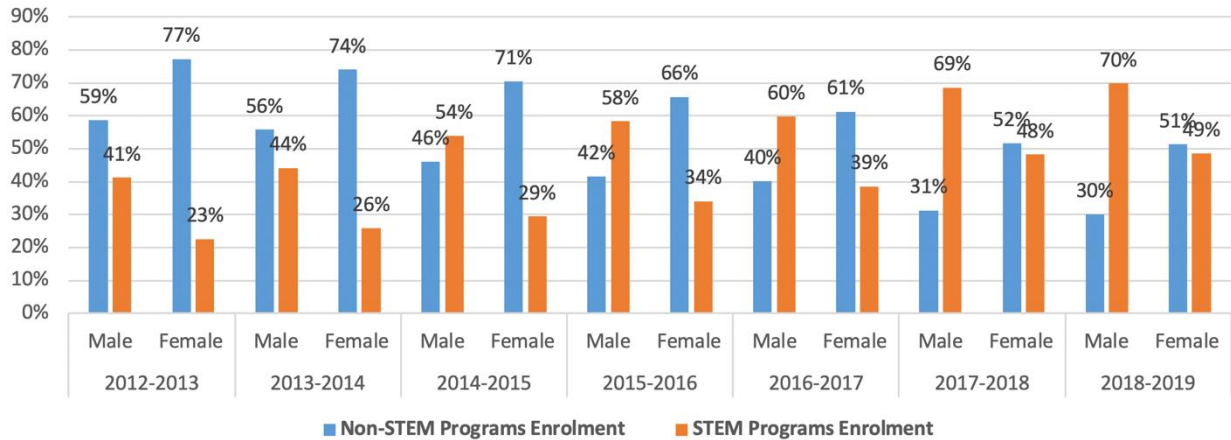
Globally studies show that males enroll in STEM programs more often than females (UNESCO 2010), however, Al Qasmi Foundation (2012) ascertain that there a reverse shift in the case of the UAE where more female's tertiary enrolments. Figure (5) shows that HCT male STEM programs enrolments is consistently increasing from 41% in AY 2012 – 2013 to 70% in AY 2018-2019 with 29% total shift. Similarly, HCT female students have consistently shifted towards STEM program enrolments from 23% in AY 2012-2013 to 49% AY 2018-2019 but at lower rate of 26% shift. The expected results show that male enrolments in STEM programs is higher as often seen worldwide (UNESCO 2010; Levine et al. 2015; Perez-Felkner et al. 2015). Further studies can look at male and female enrolments differences related to the specific STEM majors.

Figure (6): HCT Non-STEM & STEM Programs Graduates Percentage Spanning AY 2010 - 2016
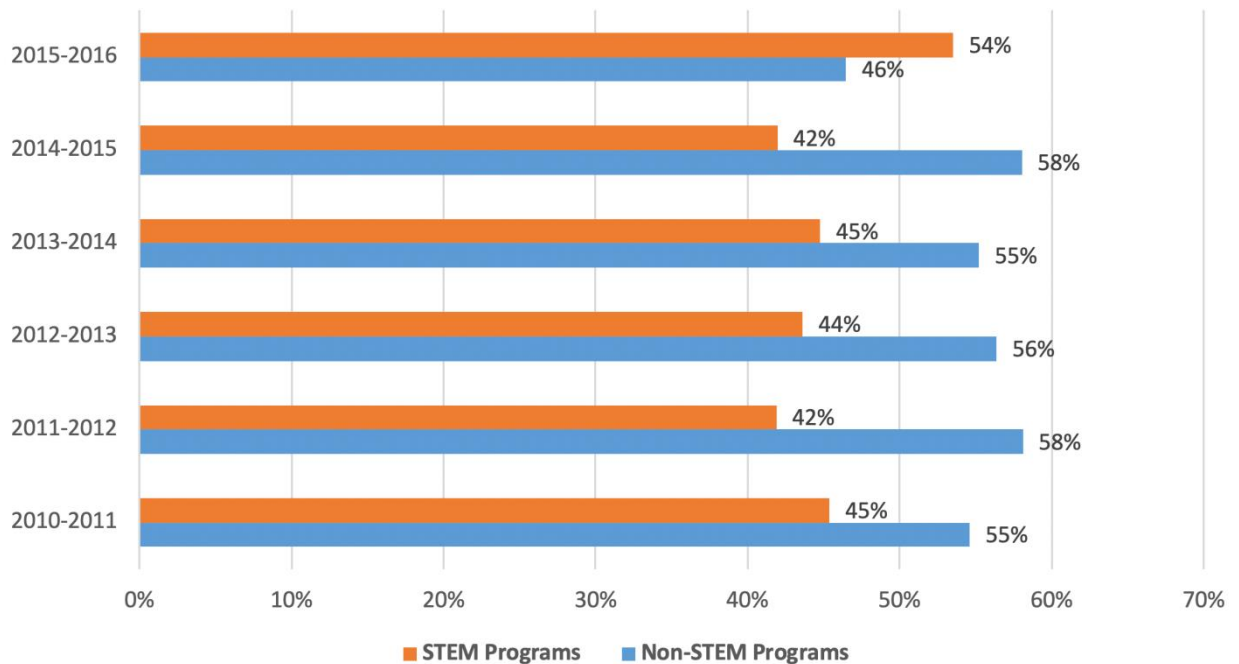

Figure (6) shows HCT STEM programs graduates percentage, which has increased from 45% in the AY 2010-2011 to 54% in AY 2015-2016, this big shift has been observed in the year 2015-2016 since the launching of the new revised STI policy showing an impact of this launch on enrolments as predicted. This difference was not observed in prior years to between 2011-2014. The launching of STI policy and the UAE vision 2021 initiatives aspiring for more innovation showed high affinity of students in grade 8 in one school in Dubai to be interested in STEM programs as future career aspirations (ElSayary 2018) which support the current findings.

Figure (7): UAEU STEM Program Enrolment Vs. Non-STEM Programs Enrolments Across Academics Years (AY) 2010 – 2017
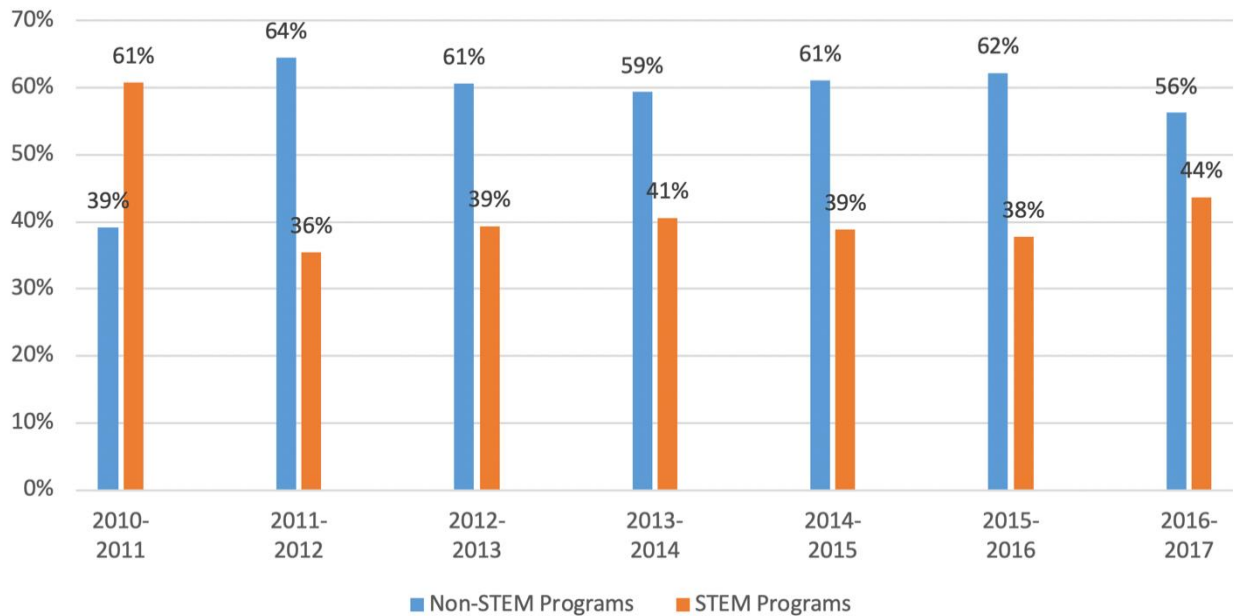

Figure (7) presents STEM program enrolments in UAEU since AY 2010-2011 where the percentage of STEM programs was much higher at 61% compared to 44% in AY 2016-2017 with a difference of 17% deceleration, there has been consistent decrease in STEM program enrolments across the years in UAEU. Although this was not evident in HCT, most previous studies of developing countries such as Central America show scarce influence of STI policy on human-capital and S&T enrolments (Padilla-Pérez & Gaudin 2014).

Figure (8): UAEU STEM Programs Student Enrolments AY 2010 – 2017
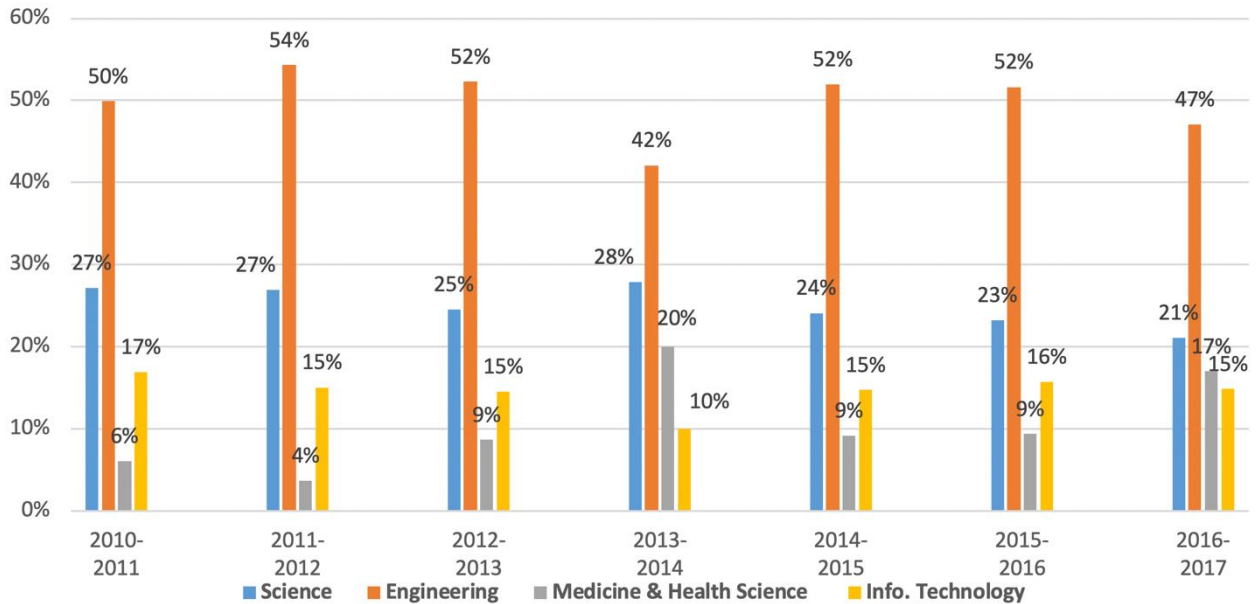
According to Figure (8), engineering has always seen the highest STEM program enrolments throughout the AY, however, there is a decline in engineering since AY 2010-2011 (54%) to AY 2016-2017 (47%), showing a decline of 3%. Science major's enrolments has also declined since 2010 to 2017 at difference of 6%, showing a greater decline than engineering. Also, Info. Technology majors has declined by 2% from 2010 to 2017 showing the least decline. On the other hand, Medicine & Health Science majors have increased in terms of enrolments from 6% in AY 2010-2011 to 17% in AY 2016 – 2017. Mahdi (2015) stated that 67% of S&T majors in Iran were engineering, clinical medicine, and physics, and very low enrolments were evident in statistics and computer science like what has been presented in the results.

Figure (9): UAEU STEM and Non-STEM Program Enrolments for AY Spanning 2016 - 2017
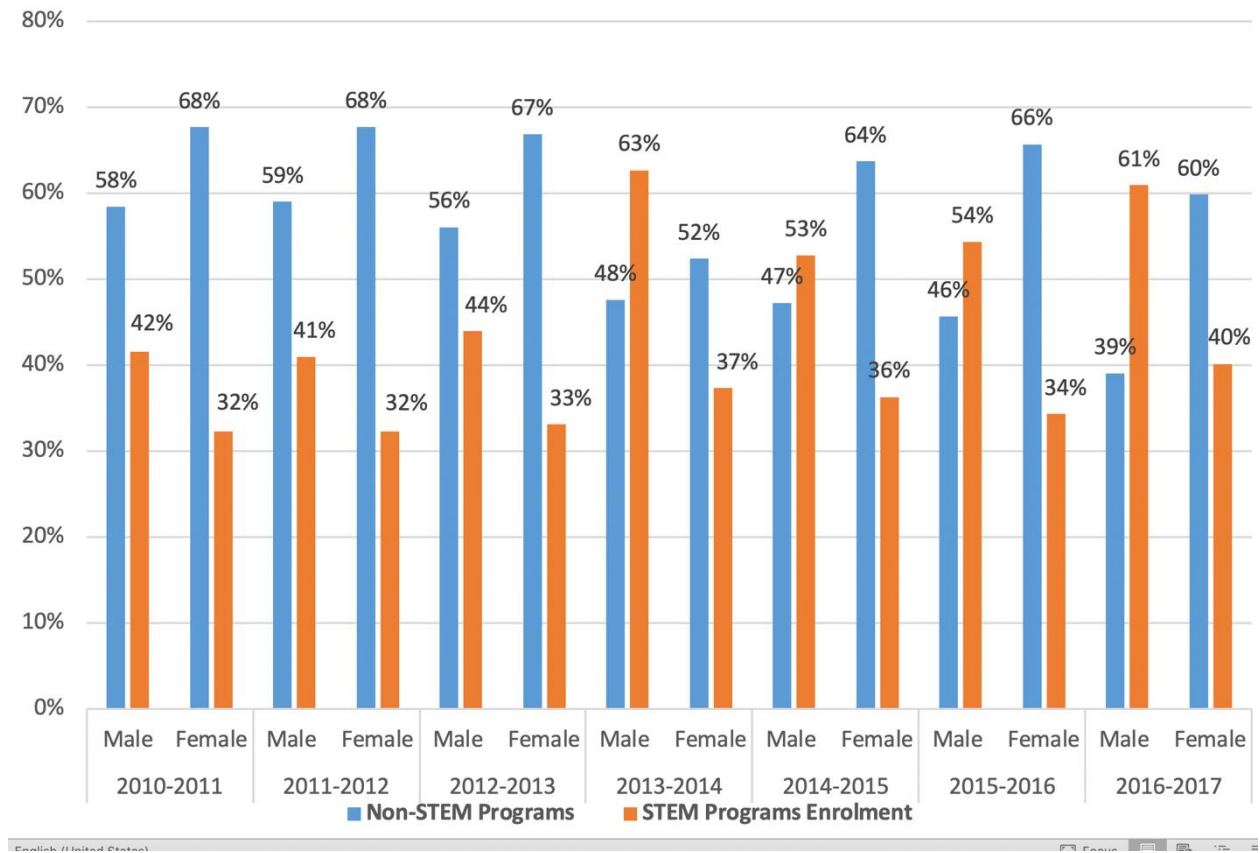
Corresponding to Figure (9) there has been an increase in the percentage of males selecting STEM programs, it shows that in AY 2010-2011 42% of males enrolled in STEM programs, while in AY 2016 -2017 a major increase is evident to 61% showing 19% shift in STEM programs enrolments. Consequently, STEM program enrolments have increased among females however by only 8%, starting at 32% in AY 2010-2011 to 40% in AY 2016-2017. The results align with previous findings showing greater percentage of male students enrolling in STEM programs due to cultural and societal stereotypes (Perez-Felkner et al. 2015).

Figure (10): HCT Non-STEM & STEM Programs Graduates Percentage Spanning AY 2010-2017
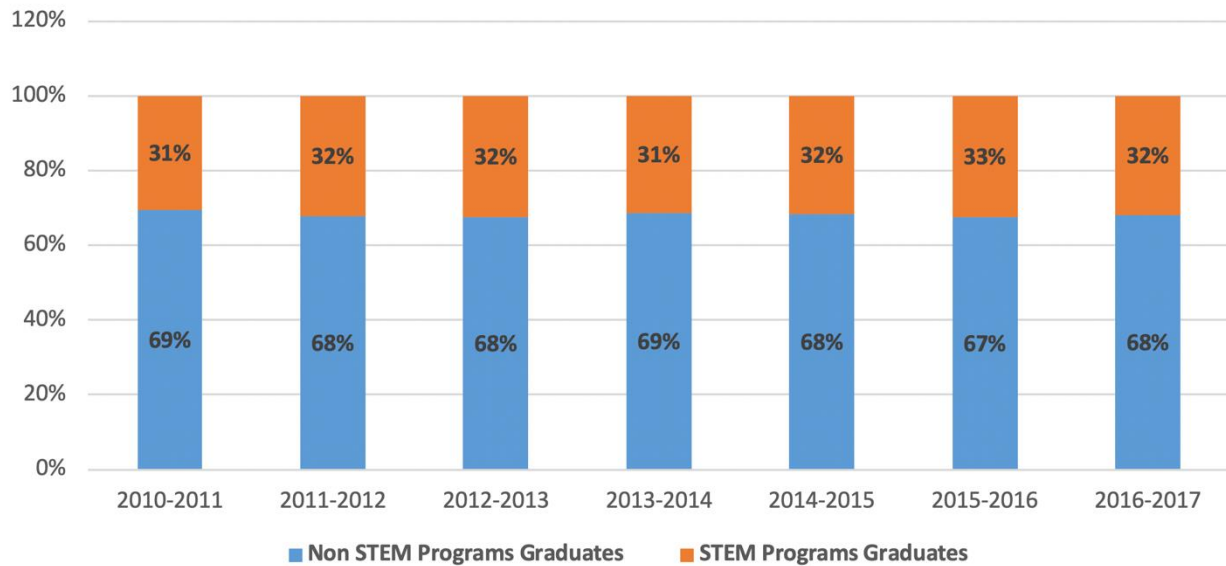

Figure (10) shows there is no significant difference in STEM program graduates from the year 2010 to 2017 where it fluctuated and increased by 1%, although in terms of enrolment STEM majors have decreased by 17% as presented in Figure (7). The results confirm earlier studies concluding that 1/3 of graduates in GCC and UAE are STEM majors' graduates, while the other 2/3 are non-STEM program graduates which has not changes in the case of the UAEU showing minimal impact of STI policy and UAE initiatives on the increase of STEM students' engagement (Alfaki 2013; Ahmed & Al-Roubaie 2012). This result is not expected since UAEU is the oldest and biggest HEI and it should encompass more enrolments, however, further studies investigating types of STEM programs offered and market needs should be investigated to ascertain why there has been no impact of STI on UAEU STEM enrolment.

Figure (11): ZU STEM Programs & Non-STEM Student Enrolments AY 2010- 2017 Across Abu Dhabi (AD) & Dubai (DXB)
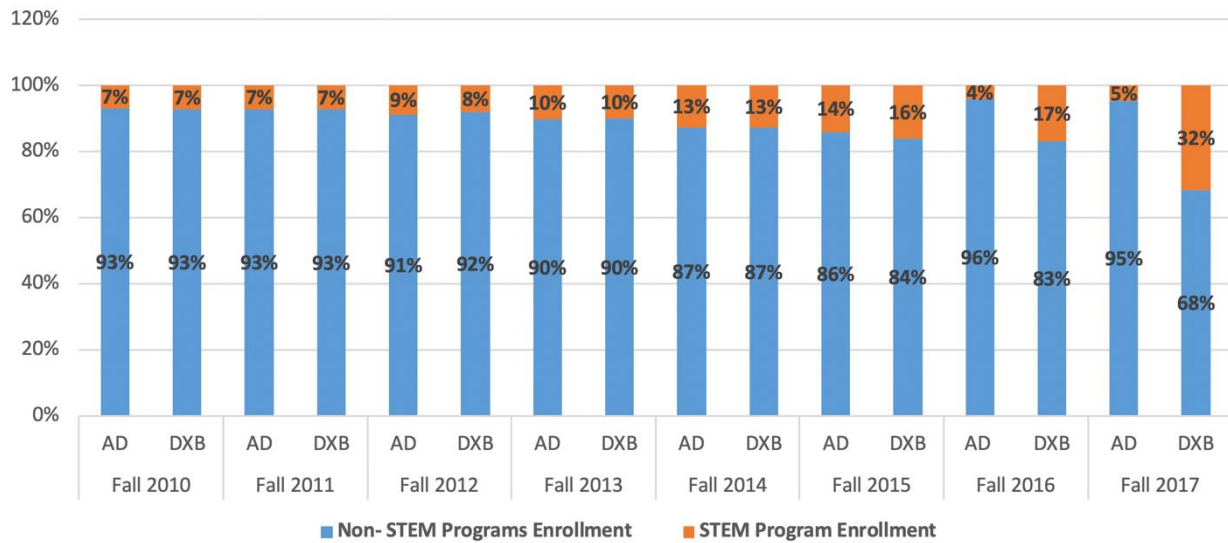

Figure (11) shows that in ZU-AD, STEM enrolments initially increased between 2010 and 2015 by 7%, but in 2016 and 2017 it dropped to 4% and 7% respectively, showing minimal impact of STI policy on enrolments. However, comparing STEM enrolments in ZU-DXB there has been 25% increase from 2010 to 2017, showing greater impact of STI policy in ZU-DXB compared to ZU-AD. The results of ZU-DXB in 2017 show alignment with other studies such as Alfaki (2013) and Ahmed & Al-Roubaie (2012). In terms of ZU, only three-year gender data is present, and there is no graduation data in the factbooks; that is why further analysis of STEM related to gender and graduation was not studied.

Research Question 2

Table 2: Research Ranking of the Three UAE Federal Universities Based on Country, Regional and Global Ranking			
University	**Country Rank**	**Regional Higher Education Rank**	**Global Higher Education Rank**
HCT	6	101	717
UAEU	2	26	592
ZU	7	112	722

Table 2 shows that R&D in the three federal HEI rank is very low on the global rank; UAEU ranks 592, HCT 717, and ZU 722. As expected, although investment in education has been great in the UAE, R&D and innovation remain very low (Gackstatter, Kotzemir & Meissner 2012; Iqbal 2011; Alfaki 2013; Ahmed &Al-Roubaie 2012). Regionally, UAEU ranks 26, but HCT and ZU rank low at 101, and 112 respectively, this is expected due to the low GCC allocation of R&D (Iqbal 2011). The UAEU is considered the second best after MASDAR institute in the UAE when it comes to R&D like findings in Ahmed and Al-Roubaie (2012), while HCT and ZU rank 6th and 7th nationally respectively.

**Figure (12): HCT R&D Ranking – Adopted from SCIMAGO
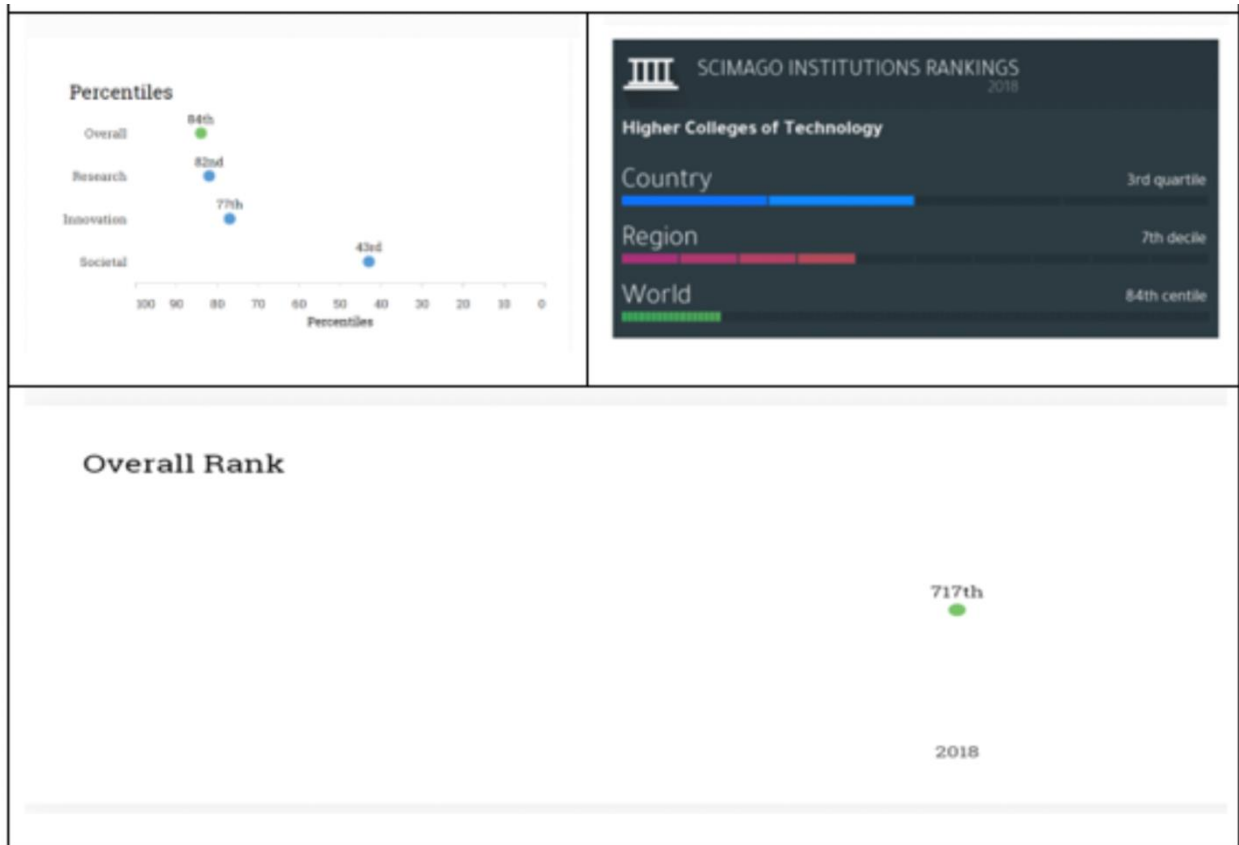"https://www.scimagoir.com/institution.php?idp=9034"**

Figure (12) shows 2018 HCT global ranking data for HCT, it should be stated that this ranking considers a prior 5-year period than the reported year. HCT innovation and research are ranked 82nd and 77th. A 717 global ranking is considered low. This result is expected since Iqbal (2011) and Alfaki (2013) point out that R&D and innovation outputs in the GCC, and UAE remain low compared to other countries such as Korea and ASEAN countries (Jung & Mah 2014; Symaco & Tee 2019).

Figure (13): UAEU R&D Ranking – Adopted from SCIMAGO
https://www.scimagoir.com/institution.php?idp=9038

Figure (13) shows UAEU R&D ranking, since the UAEU is the oldest and most established university among the three federal universities, offering more masters and doctorates it is expected to nationally rank higher as shown in the data with it having 34th in research and 35th in innovation as presented in previous literature (Ahmed & Al-Roubaie 2012). UAEU outperforms ZU and HCT presented in Figures (12) & Figure (14). UAEU global ranking has improved since 2009 where it was 700th to 592 in 2018 showing that there is an impact of STI due to increased doctoral and master majors or collaboration in R&D, this collaboration can be further investigated and related to the UAEU strategic plan in further studies.

Figure (14): ZU R&D Ranking – Adopted from SCIMAGO
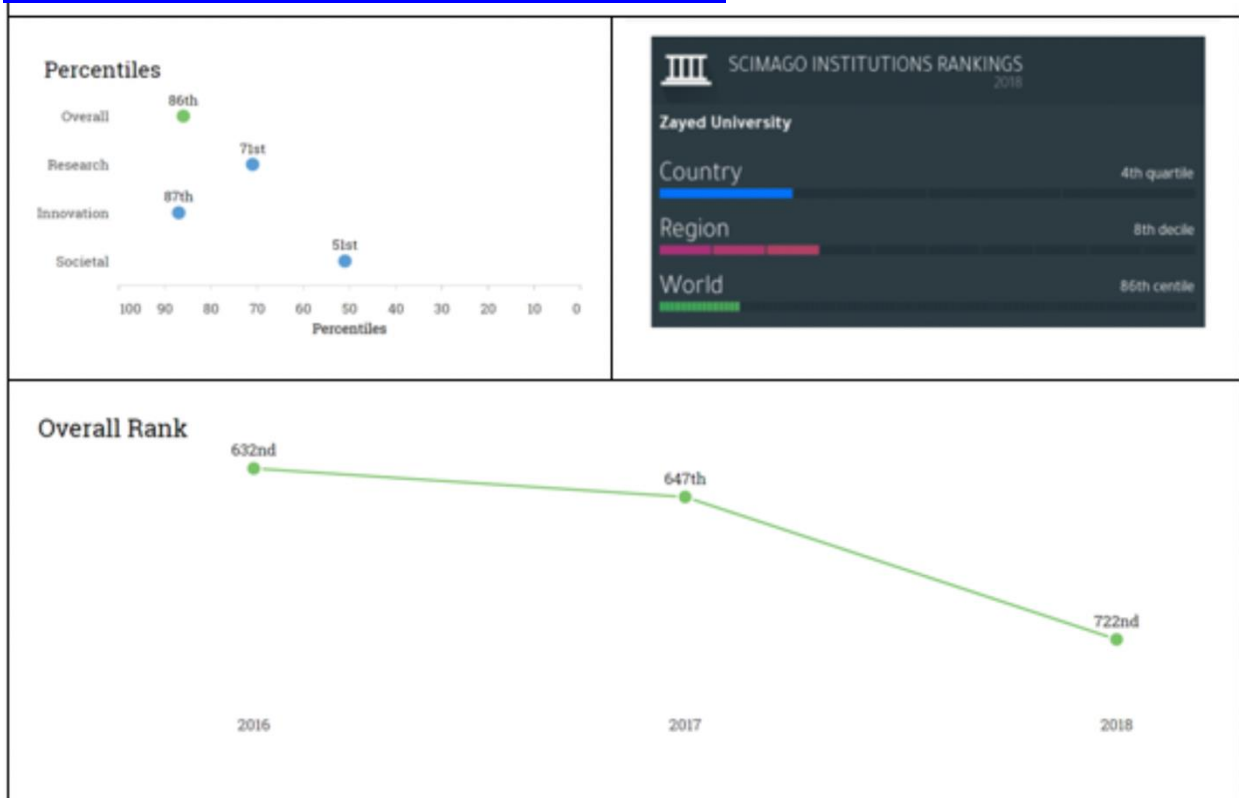**https://www.scimajoir.com/institution.php?idp=8656**

Figure (14) shows ZU global rank as the lowest among the three federal universities at 722 and it has demonstrated a decrease in overall ranking from 2016, which is not expected since STI policy should lead to greater R&D (Weber 2011). In terms of research and innovation output it comes out as 71st, and 87th again lower than UAEU and HCT. The latter is expected since ZU is smaller and the most recently established university leading to minimal research and innovation output and overall ranking (Ridge, Kippels & ElAsad n.d.).

The findings of this study are important since it provides evidence of some impact of STI policy on STEM majors enrolments, graduates and R&D, but this impact is minimal and continued governmental initiatives and investment needs to persist in order to improve

63

STEM majors' enrolments, graduates and R&D in the UAE across all federal universities leading to more Emirati innovators. Further studies can explore the impact in terms of employment skills development and its relation to HEI programs and how HEI R&D can be related to collaboration with industry.

5. Conclusion

The main objective of this study was to investigate the impact of UAE STI policy initiatives on STEM majors' HEI enrolments, graduates and R&D. In summary, the research findings show that STI policy has impacted STEM majors HEI enrolments in two federal universities these are ZU and HCT, where there was an accelerated enrolment like other countries such as ASEAN and BRIC countries (Jung & Mah 2014; Alfaki 2013; Gackstatter, Kotzemir & Meissner 2012; Symaco & Tee 2019). Like prior literature, the major STEM majors' enrolments in STEM were seen in the engineering, and computer sciences (Ahmed & Al-Roubaie 2012; Iqbal 2011). Similar results were found in ZU, however, ZU-DXB had greater STEM majors' enrolments compared to ZU-AD, this calls for further studies to investigate why students in ZU-DXB are choosing more STEM programs compared to ZU-AD.

HCT STEM majors' graduates showed no significant differences from AY 2010 to the AY 2017, the latter shows that although STEM enrolments has increased in HCT, graduates of STEM are consistent and unchanged, meaning that somewhere during their tertiary education, students are not continuing their studies in STEM majors, since it would be expected that graduates in STEM should increase if enrolment has increased. Further study to investigate why STEM enrolments is different than graduation rate in HCT is recommended.

In terms of UAEU there has been a decrease in STEM programs enrolments like the decline witnessed in Central America (Padilla-Pérez & Gaudin 2014), while STEM graduates in UAEU has stayed steady at 1/3 STEM majors compared to 2/3 non-STEM programs as presented in previous studies (Ahmed Al-Roubaie 2012). Although the results presented are not expected, these findings call for further studies looking at the STEM programs choices presented in UAEU and how these programs impacted the results of this study which are different from what has been shown in the other two federal HEI.

Furthermore, the results confirm previous studies findings and expectations where it showed that more male students than female students enrol in STEM programs in both HCT and UAEU (Perez-Felkner et al. 2015; Padilla-Pérez & Gaudin 2014). In terms of R&D, although there has been improvement in UAEU on the global ranking, ZU showed a slowdown in R&D. Therefore, in terms of R&D, the impact of STI policy cannot be ascertained and further investigations are recommended by looking at detailed HEI data to ascertain the type of research outputs.

Although, the study provided evidence of STI impact on STEM programs enrolments and graduates, the lack of impact on UAEU call for further investigations and correlational studies to be done where other forms of UAE international data can be obtained and studied further to investigate this impact such as the KEI, and to generalize the impact on R&D, factors such as GERD, and FTE can be studied. For the purpose of the study the latter data figures were not available for the years of the study and therefore, it was not possible to correlate the findings to this study's data.

Policy makers, practitioners and researcher in the UAE should focus on encouraging STEM enrolments, graduation and research development. Policy makers should work with companies to collaborate on designing STEM majors that are job-oriented, and provide government sponsored internship programs in STEM, which will encourage young people to adopt STEM majors to obtain these jobs. Furthermore, having government sponsored STEM research in collaboration with major universities and organizations would help increase STEM majors enrolments and graduation.

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