Chapter 6
The 'S' and 'T' in STEM: Integrating Science and Technology in Education in the UAE

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Abstract In this chapter, we look at the ways in which STEM (science, technology, engineering and mathematics) has influenced education in the United Arab Emirates (UAE) over the last few decades, focusing in particular on the use and integration of educational technology in schools and higher education institutions (HEIs). Key to the uptake of technology in education is the attitudes, perceptions and self-efficacies of teachers, faculty and administration. We summarize key literature emanating from both school and HEI sectors in the UAE and then discuss technology links to science education in the UAE, and the emirate of Abu Dhabi in particular. Finally, we present four key examples of how science and educational technology can effectively be integrated, and make specific suggestions of ways in which this could be linked to the UAE context. We conclude with some key recommendations for the effective integration of science education and technology.

Introduction

The economy of the UAE has been based predominantly upon oil revenues since oil was discovered in the 1950s. With the growing realization of the short-term nature of dependency upon fossil fuels, the UAE government has placed much emphasis and brainpower into ways in which economic sources in the country could be diversified. Education plays a central role in the UAE Vision 2021. Here, the need for a knowledge economy over oil is highlighted in its aims to 'transition the UAE into a knowledge-based economy which promotes the role of UAE nationals in innovation, research and development, and to be among the best in the world in this' (UAE Vision 2021, 2010).

These three elements of innovation, research and development are directly connected to a need for quality STEM education at all stages starting with primary schools, up to and including HEIs. The emirate of Abu Dhabi in particular has dramatically reformed its schooling systems during the last decade. Two of the most

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salient changes which the past decade has brought to schools include the recruitment of large numbers of native English speaking teachers at both primary and secondary levels, and an alteration of the medium of instruction for both science and information technology subjects from Arabic into English.[1] The increase in large numbers of expatriate teachers was necessary due to the fact that there are small numbers of Emirati teachers of English medium subjects. This is partly due to the relatively small population of Emiratis, and due to the availability of jobs in other employment sectors which are considered to be more lucrative both financially and in terms of societal status (Swan, 2011). There has also been a wide variety of models of in-service teacher training to try to upskill existing teachers to align with the ambitious demands of the new curricula introduced, often with significantly different pedagogical approaches to previously. The characterization of students as autonomous learners was a sharp deviation from the more teacher-centred learning situations in schools of the previous decades (Macpherson, Kachelhoffer, & El Nemr, 2007). In science and information technology (IT) among other subjects, this has included, for example, the need for students to be able to problem solve, work independently using investigatory approaches to learning, and to have the necessary IT skills to be able to integrate these with all of their learned subjects, including Science. When the New School Model (the term used for the new curriculum implemented in schools in Abu Dhabi at that time) was rolled out in 2010, there was a strong emphasis on STEM and twenty-first century skills (Pennington, 2016).

Within the Gulf Cooperation Council (GCC), it is understood that countries now recognize the need to prepare their citizens for tomorrow's employment challenges and that educational technology can be a catalyst to help them move forward (Dini, Markey, & Mohamad, 2015). Wiseman, Abdelfattah, and Almassaad (2016) carried out research in GCC countries to examine the connection between STEM education, citizenship status and expected participation of citizens in the labour market. The authors looked specifically at the dominant effects of ICT-based instruction and concluded that ICT-based STEM instruction helps youths to develop a diverse range of skills including the ability to continually re-educate themselves as well as think critically, which has a major impact in the labour market. According to the 2011 Trends in International Mathematics and Science Study (TIMSS), the development of human capital in GCC nationals and expatriate youth is differently influenced by ICT-enhanced STEM education (TIMSS & PIRLS International Study Center, 2011). It was found that while expatriate youths valued STEM education as an avenue for future employment, GCC nationals did not. The study authors suggested that this may have been due to tendencies to rely more on non-education-related factors (such as social connections), leading students to think they can get the job they want without having to do well in science. So, while it is clear that much progress has been made in a short time in the UAE, a developing nation with a developing educational system, it is also clear that much is still to be done in upskilling human capital, and in perceptions of the usefulness and relevance of STEM.

[1] Personal Communication with Abu Dhabi Educational Council personnel.

We focus our discussion in this chapter in particular around the emirate of Abu Dhabi, for the following reasons: first, for the pragmatic reason that as a team of authors, we have long-term work experience within education in the emirate, and second, because Abu Dhabi is the largest emirate in the UAE and has been in many ways at the forefront of major educational reform since circa 2007. Other emirates at points in the educational history of the country have also taken the capital’s lead on educational reform. The ongoing work of the Dubai government to integrate technology into education has been hugely significant, in particular the innovative Mohammed Bin Rashid SMART learning program which started in 2012. This involved, for example, universal Internet connection, the use of free school-issued tablets for each child, digital textbooks and other innovations (Pennington, 2014). This followed on from another ambitious project over a decade earlier, the Sheikh Mohammed Bin Rashid Education Project which launched in 2000, and included the installation of computing labs in the schools which participated in the project to apparent great effect (Embassy of the UAE Cultural Division in Washington D.C. Report, n.d.).

Perceptions of Technology Use in UAE Institutions

The first step in emphasizing or introducing STEM into institutions is to understand the skills, competencies, perceptions and attitudes of all involved (Corlu, Capraro, & Capraro, 2014). The diversity of educational institutions in the UAE means a diversity of resources, training, qualifications and backgrounds of teachers and administrators, which may contribute to ambiguity towards the implementation of technology. There are also specific challenges to the implementation of technology such as a lack of confidence among teachers, lack of consistency and high turnover of expatriate staff (Nasir, 2018) which may impact successful implementation of STEM in both schools and HEIs. Since the nature of these sectors is different due to factors such as the maturity levels of students, system requirements and likelihood of use of tools such as learning management platforms which are unlikely to be used in schools within the public sector, we next examine the available literature on the two sectors separately. We close this section of the chapter with a segment on students’ perceptions on the use of technology.

Perceptions of Technology Use in Schools

Research studies in the UAE tend to investigate technology integration in K–12 schools by collecting quantitative data about teachers’ attitudes and perceptions. This fact in itself is noteworthy and indicative of the ‘early stages’ nature of STEM in the UAE, and will be touched upon later in the chapter. Almekhlafi and Almeqdadi (2010) showed that teachers were promoting students’ learning by integrating technology in their classes’ activities, by, for example, use of content-specific hardware and software. The authors found that teachers' self-perception of their ability to integrate technology successfully in the classroom was high. Several barriers to technology integration were identified: number of students per class, teacher motivation, negative teacher and parent attitudes about technology impact on the educational process, technical problems and financial support. Despite these barriers, and to different degrees of effectiveness, teachers were integrating technology in their classes. This study did take place in a UAE 'model school' as they were known then, which tend to have a better infrastructure and provide more frequent professional development activities for teachers, so the results may not have been indicative of teacher attitudes across the wider public school sector, even though the authors implied that other public schools had the same advantages in terms of technology resources and teacher training.

Some interesting studies have been carried out into prevailing attitudes amongst school leadership into the use of educational technology in their schools. For example, Serhan (2007) showed that principals in 200 UAE schools (sector not specified in the study article) exhibited overall positive attitudes towards the use of technology in their schools. The study showed that, critically, those school principals were also willing to improve their own knowledge and skills as well as those of their staff, and were enthusiastic about the link between the use of technology and the motivation, interaction and participation of students. This suggested that the will to integrate technology into school environments certainly exists. This is important since the support of leadership is critical to fostering an innovative and STEM-friendly ethos in a school. Other UAE studies have focused on tracking and evaluating e-learning with some positive effects, such as the implementation and use of tablets in a pilot project in the private school sector (Ally, 2013), where some benefits were seen and predicted by teachers and administration alike.

Al-Awidi and Ismail (2014) investigated ESL teachers' perceptions regarding the use of Computer Assisted Language Learning (CALL) in teaching reading to children in the UAE. Teachers reported using computers to enhance children's reading skills, support children's reading, listen to stories being read aloud, recognize letter/sound relationships, and identify letters and beginning sounds of words. Teachers also reported that the technology provided opportunities for active interaction and differentiated instruction. Three main barriers to its successful implementation were cited to be the lack of availability of resources, lack of hardware and lack of suitable programs.

Perceptions of Technology Use in HEIs

In addition to the use of technology for teaching and learning purposes, in HEIs sometimes the impetus is also fuelled by other institutional needs such as scheduling, registration, assessment data management, which inspire interest in a tool which can perform all of these functions in addition to meeting educational needs. An example of this is an all-encompassing learning management system (LMS) which can perform multi-functions, including those mentioned. This is highly dependent upon the institutional infrastructure and technological support which is available, which in turn is highly dependent upon budget allocation for these factors. Teachers also have to feel confident and competent in implementing technology and using devices in their classrooms, particularly in the age of ‘digital natives’ where often, younger students are more comfortable and fluent with technology than their teachers (Salajan, Schönwetter, & Cleghorn, 2010).

In the UAE, a variety of studies have taken place in the way in which technological devices are perceived and received by instructors in HE. Hargis, Cavanaugh, Kamali, and Soto (2014) studied faculty perceptions of the use of iPads and how these were integrated into student learning, following the mandatory introduction of tablets into foundation programs in the federal tertiary institutions. It was found that the iPad deployment was associated with the adoption of a more student-centred pedagogy and greater engagement with both informal and formal professional development. An additional spin-off of the program was that informal professional learning communities began to flourish, which was particularly important given that the study also illuminated that there were faculty with weaknesses in their own knowledge and skills of technology.

On many occasions, it is up to educators to decide if they want to adopt and integrate new technologies. Studies have indicated that ‘educators who do decide to adopt new instructional technologies are frequently not supported [by institutional leadership] with follow-up activities or in-depth staff development, resulting in minor integration of the new technologies into their existing instructional methods’ (Kagima & Hausafus, 2001, p. 35). According to Kagima and Hausafus (2001), this lack of institutional support including professional development in the use of technology remains a significant obstacle to the integration of new technologies in education. In a study designed to investigate how ready UAE educational institutions were for the twenty-first century, three key measurement indices were utilized (Al Blooshi & Ezziane, 2013). One, the identification of twenty-first century tools used in the three educational institutions included in the study, two, an examination of the abilities of students to learn both on and off campus, and three, the type of assessment tools used in the institutions. It was found that each educational institution had a different approach to the twenty-first century vision and was prepared at different levels. There was a relative change in the average scores for the three measures, over time, indicating that progress had been made, but that they stand now at a ‘crossroad’.

In their UAE study of HEIs specializing in teacher training, Al-Awidi and Alghazo (2012) presented results which suggested that an optimal way to train pre-service teachers, which would result in them using the techniques themselves as teachers, is to have opportunities to observe teachers modelling the use of technology. In this way, they would learn vicariously from their teachers or supervisors. Their study also suggested some issues within the program structure of pre-service teacher training programs which might result in teachers not being fully prepared to engage in educational technology in the classroom. Other studies have indicated a large readiness of pre-service teachers to use software and integrate this as part of the curriculum, showing an ability to select appropriate technology resources and a strong willingness to use this (Serhan, 2009). Faculty can indirectly pass on efficacy, knowledge and skills in educational technology by demonstrating the use of a variety of technological techniques themselves and thereby modelling their use (e.g. Smith, 2016). In this way, students become familiar with techniques and witness their use in an environment with which they are comfortable and familiar, and which they might be more easily able to then apply to their own teaching practices.

Finally, Parkman, Litz, and Gromik (2017) studied the extent to which pre-service teachers in the UAE planned to use technology-rich learning environments in their future teaching careers and showed that while there was a strong acceptance of technology-rich environments, the key predictors of intentions of future behaviour were perceived usefulness and computer self-efficacy. Studies of pre-service teachers' beliefs, confidence levels and self-efficacy suggest that there may be some issues of low indices of these in the UAE (e.g. Dickson, McMinn, & Kadbey, 2017; McMinn, Dickson, & Kadbey, 2015) and that sometimes, this appears to be caused by a lack of in-depth understanding of subject matter content knowledge (Tairab, 2013). We know, from our own anecdotal experience as teacher training faculty, that students often use in practicum what they have seen modelled by faculty in their college classroom. We have seen examples of this in particular applications and websites for classroom management, formative assessment, for example, but also in the ways in which the students observe their teachers using their interactive smartboards. All public schools in Abu Dhabi now utilize interactive smartboards, yet not all HEIs do. One research study which took place in a large public UAE University evaluated the effectiveness of the interactive whiteboard technology (IWBT) in teaching (Al-Qirim, 2011). This study attempted to unveil factors influencing IWBT introduction and its use in different departments. The research highlighted different theoretical and professional contributions and raised the need for more research in the IWBT field. Where the use of such technology is ambiguous to faculty, it is easy to see that student teachers are not seeing modelled what they should be putting into practice during practicum.

Students' Perceptions of Technology Use

There is no doubt that students in the UAE are indeed 'digital natives' and that in many cases, they may be more ready to embrace technology than their teachers. One study within a UAE institution showed that students were highly familiar with mobile devices and their uses: 99% of the students had either a smartphone or a tablet, and 81.5% of the students indicated that they were using their mobile devices in their study (Al-Emran, Elsherif, & Shaalan, 2016). Given these statistics, it is critically important that faculty upskill (where appropriate) either by the type of intervention which Hargis et al. (2014) described whereupon iPad deployment led to more student-centred pedagogy, or engage in professional development and work with colleagues to learn how to integrate technology use into their lessons.

At the University of Sharjah in the UAE, Abulibdeh and Hassan (2011) investigated the relationship between students’ self-efficacy in IT and their academic achievement, through the influence of e-learning interactions. Their results indicated that the relationship was not necessarily a direct correlation, since their results did not show that simply stating a high IT self-efficacy alone would lead to academic achievement, but that academic achievement required a host of other factors to interplay with this, such as interactions with other students, e.g. collaborative learning, and interactions with instructors.

Santos (2013) studied the use of mobile devices through the implementation of a mobile quiz activity to enhance student learning and explored the implications of bringing those personal devices to the institution, as well as the impact of using mobile devices on student learning. These mobile devices were used to encourage class discussion and promote formative assessment. This study provided strong evidence to justify the costs of increasing institutional bandwidth to enable Internet access on students’ personal mobile devices. Most students liked the idea of using their mobile devices in class and many recommended the idea to be used by other instructors too. Students found the process of accessing the quizzes easy, demonstrating their status as ‘digital natives’ and the study indicated that students may only need IT support regarding the distribution of applications.

Integration of Technology with Science Education

We now turn our attention to the ‘S’ in STEM, the ways in which science and technology can and should be, clear partners in the STEM movement. The science curriculum currently in use in Abu Dhabi government schools has strongly emphasized science and inquiry skills, as the following excerpt from the Grade 5 science curriculum[2] for science skills demonstrates in the ‘Investigating Scientifically’ strand of the curriculum:

- Construct a scientific question to investigate and predict the outcome.
- Outline how to investigate a scientific question.
- Identify the variable(s) to change, measure and keep the same.
- Select equipment for carrying out an investigation.
- State the obvious hazards in an investigation.
- Carry out a fair test.
- Make at least three suitable observations/measurements.
- Record and organize data from observations or measurements.
- Draw a simple bar chart.
- Describe observations and simple patterns in data.
- Draw conclusions from patterns in data.
- Suggest two improvements to an experiment.

[2]Earmarked for change in September 2018.

Each of these skills is intended to be achieved by each student by the end of the year, but the intention is that teachers integrate the skills throughout the science curriculum content of the particular grade level. The content of the Abu Dhabi curriculum at the time of writing is divided into four segments, denoted 'Matter' (linked to chemistry elements), 'Earth and Space' (linked to geological elements), 'Living World' (linked to biology elements) and 'Physical World' (linked to physics elements).

Inquiry-Based Learning

The science skills are closely tied to inquiry-based learning and give opportunities for the fostering of critical thinking and for students to deeply engage. Students are likely to gain depth of understanding when involved in their own learning, such as through inquiry-based pedagogies (Healey & Roberts, 2004). Inquiry-based learning has the ability to 'improve science teaching by engaging students in authentic investigations, thereby achieving a more realistic conception of scientific endeavor as well as providing a more learner-centred and motivating environment' (Kubieck, 2005, p. 1). Within the curricula used in the UAE (using the Abu Dhabi model as an example), there is ample scope for inquiry-based learning using the designated science skills.

We now outline four key examples of ways in which technology can be integrated with science teaching and learning, and how this has been used to effect in other contexts, or is being used in the UAE, where applicable.

Use of Photography and Video Acquisition Devices in Science

Research has shown the effectiveness of the use of mobile technology including iPads in lessons involving investigative and inquiry-based approaches. As an example, students can work in small groups to design simple moving vehicles from available materials, collecting time and distance data during experiments, and the groups can use an iPad to take photos and videos using the camera app of their construction process of the prototypes, as well as at least one video of an experimental trial. They can also instal apps which connect to force and motion (Wilson, Goodman, Bradbury, & Gross, 2013). There are pedagogical advantages to students using iPads to take photos or videos of themselves performing experiments. These include creating a dialogue alongside observing an experiment, recording predictions before the experiments and drawing conclusions afterwards. These kinds of activities also create opportunities for students to work together in teams, both collaboratively and cooperatively, with each member contributing and working together towards a common goal. There are numerous ways in which the current science curriculum can be implemented to integrate technology, not only in Abu Dhabi, but across the emirates, e.g. force and motion, Newton’s Laws, etc., concepts which form an integral part of the physics curriculum.

One UAE study by Awani, Senteni, Singh, Bin, and Smart (2016) aimed to explore teachers’ and students’ perspectives on the impact of digital videos in teaching. The authors also wanted to investigate teachers’ practices, strategies, difficulties and beliefs about the use of video in their classes. The study focused on the impact videos have on students’ learning, motivation and satisfaction. A strong relationship was found between students’ learning and engagement, and the use of videos. This research stressed the need for the curriculum to be supported by a web-based video sharing platform that could showcase the best teaching practices. It also shed light on the need for effective integration of video technology with curricula as well as pedagogical knowledge and skills on how to create videos suitable for the current educational systems.

Still on the theme of using technology as visual aids, Tamim (2013) used a mixed methods approach to conduct a study on school teachers’ use of YouTube videos in the UAE, and concluded that integrating YouTube videos into lessons had perceived advantages including supporting the learning process, increasing interest and efficiency, and enriching content, but that the majority of participants were using videos for presentation purposes in teacher-led classrooms. There seemed to be a lack of knowledge about the potential of visual pedagogies and how they could support students’ understanding and involvement. However, allowing students the flexibility to search for and upload movies of their own experiments for teaching and learning purposes proved very useful.

Use of Data Sensors and Data-Gathering Probes

Increasingly, schools are attempting to incorporate technology into the acquisition of science skills involving collecting data, using data probes and associated hardware. Examples of these might include using a range of sensors to measure temperature, wind speed, humidity, in investigations connected with weather, sensors which measure time, speed, force, in mechanical experiments, pH and CO_2 levels in chemistry and biology experiments. Even though these topics are normally associated with middle and high school science work, there are also ample opportunities in primary science for the use of data probes. Handheld-based data collection probes can be used to extend inquiry-based investigations with real-time data and visualizations. Sensors can capture data, create visualization (e.g. on small screens connected to the probe, laptops or on iPads if the correct app is installed) (Maldonado & Pea, 2010). Students have also been shown repeatedly to favour mobile devices in learning both their class subjects and outside of the class (Looi et al., 2011). Tablets and other handheld devices are also very helpful in field-based science. There are numerous examples of possible field-based activities where students could gather data using probes, for example, checking water quality, plant samples, in ecosystems in the UAE such as the mangroves, or measuring temperatures of various turtle breeding grounds which exist along the UAE and Oman coastlines. In these ways, the use of data-gathering devices can be closely integrated into science curricula. Looi et al. (2011) give examples of how students can embark on 'authentic missions that can be completed through constructive and productive learning activities' (p. 271). Guided by a socio-scientific question, students can work both individually and collaboratively to carry out their 'mission'.

For faculty who are not confident or skilled in the use of technology, the idea of integrating a full science lesson using probes, data loggers and iPads may be too overwhelming. We have previously mentioned the value of having faculty model by use, a variety of techniques which students could then use, but this is not always possible. Planning for students to have more flexibility to use the technology they are familiar with shows that faculty are willing and interested, if not skilled. For example, giving students opportunities to self-direct their learning, or to gather and access course information and present information using any technology they wish to, might overcome some of these issues.

Geographical Information Systems

The UAE is a country with diverse (given its relatively small size) topographical, geological and weather conditions, which lends itself very well to connecting science of Geographical Information Systems to track and model this terrain. From 2011 until 2014, Abu Dhabi Education Council (ADEC) science curriculum development was focused on integrating inquiry-based learning as a core methodology in all phases (cycles) alongside context-based science education and a cooperative learning approach. This strategy was an implementation of the guidelines produced by prior work in this field (Lowe, 2004) in which students in New Zealand experienced cooperative, inquiry-based group work and assessment methodologies resulting in a significant improvement to science-related attitudes. Further to this, the aim was to develop the role of technology in science education to enable students to explore authentic scientific phenomena interactively and perform complex, inquiry-based learning activities (Hanif & Al-Ahmadi, 2009). The inquiry-based learning activities developed for the cycle 2 (middle years) curriculum are of particular interest as they were implemented in a number of schools and iteratively developed through a piloting process. These innovative inquiry units included the use of geographical information systems (GIS) software and various other technologies.

One such example of an inquiry-based learning unit was titled, 'Endangered Species: The Asian Houbara' (Abu Dhabi Education Council, 2011a). The Asian houbara is a migratory bird that is used as a quarry for falconry, which is an important aspect of UAE culture and heritage. Upon noticing the decline in the number of the Asian houbara, Sheikh Zayed bin Sultan Al Nahyan established a breeding program in 1982 at Al Ain zoo (International Fund for Houbara Conservation, 2017). The International Fund for Houbara Conservation (IFHC) was established to continue and extend this project in 2006. This inquiry unit linked the conservation work carried out by the IFHC with a number of outcomes in the science curriculum. Learning experiences in the unit were diverse and engaging, and included visits to the National Avian Research Centre (NARC) where students studied with scientists working in captive breeding and release programs. The unit also integrated the *Partnership for 21st Century Learning’s Skills Framework* (Partnership for 21st Century Learning, 2016) which was developed by professionals from the business world and educational experts to outline the skills and knowledge required for students to successfully contribute to society, both at work and in the wider community. One key element of this framework is the development of information, media and technology skills. Students developed their technology skills in authentic, inquiry contexts by carrying out GIS related tasks, such as mapping GPS data using GIS software, in order to establish the conditions experienced by the houbara on their migratory routes.

A second curriculum-linked inquiry-based learning unit involved the study of the mangrove forests around the main Abu Dhabi islands (Abu Dhabi Education Council, 2011b). Development projects, such as the construction of a new island, had led to concern regarding the conservation of mangrove areas as important ecological resources. In this unit, students were expected to plan a media campaign to promote the conservation of the vulnerable mangrove forests. The inquiry unit began with students accessing GIS software and using pre-uploaded geographical data to assess the changes that had taken place in the Abu Dhabi area since the 1970s. Students also learned, through online research, that mangrove forest conservation actions, such as plantation and seed dispersal channel construction projects, were already underway. Immersive activities then took place, such as touring the mangrove swamps in kayaks and using portable devices with integrated cameras, GPS systems and mobile Internet capabilities, to collect environmental data and audit the wildlife in the area. The resulting data was uploaded by the students, in situ, to a live web map using the GIS software and analysed and interpreted to illustrate the ecological importance of the mangrove forests. Students were then required to communicate their findings, in the style of a multimedia campaign, as part of the end of unit assessment. Although the focus of curriculum development in the emirate of Abu Dhabi shifted focus away from an inquiry-driven approach in 2015, the use of inquiry-based activities integrating GIS technologies continued until 2017. The *Houbara and Mangroves* projects continued to be offered to all government schools in the emirate, on an optional basis, and teachers used the outcomes of these projects as assessment evidence for the students’ coursework component of their final science grade. To date, no formal assessment regarding the effectiveness of these GIS projects has been carried out but, in 2015, GIS technologies were formally added to the curriculum as an elective, inquiry-based subject termed ‘Geoscience’ in Abu Dhabi government schools (Abu Dhabi Education Council, 2015).

3D Printing

Currently, 3D printing is something of a ‘hot potato’ in educational technology, with various research teams internationally working on training both teachers and students alike in the skill of using and applying 3D printing. Lecturing and other teacher-centred practices are becoming outdated because they cannot cope with the demands of a world increasingly dominated by technologies (Hilbert & Lopez, 2011). Memorization and rote learning are being replaced by other skills such as industrial skills, creativity and innovation which aim to prepare students for their future careers. One of the emergent technologies that can foster this creativity and innovation is 3D printing. During the printing process, objects are created by adding layers which is why 3D printing is considered an additive manufacturing type of technology (Kaur, 2012). As 3D printing has become more user-friendly and readily available to non-commercial users (Griffey, 2017), schools have begun to use 3D printing as a way to promote interdisciplinary and enhanced educational experiences (Sansing, 2015).

In the UAE, an example of Project Based Learning (PBL) has been used in Higher Education as an additional teaching practice. Students presented their assignments in different ways including printed 3D objects. The results of this experience, performed by students from a higher education institution in the UAE, were presented by Mohammed (2017) as providing a 'catalyst for an effective and efficient process-oriented quality education where students are active individuals managing their own learning and having fun in the process' (p. 1). Another project being developed in the UAE attempts to create 3D printing objects from 3D reconstructed models using a low-cost Kinect sensor. This 3D system, named *From Sense to Print,* aims to 'generate ready-to-print 3D models of objects without manual intervention in the processing pipeline' (Figueroa, Dong, & El Saddik, 2013, p. 4897).

In the UAE, 3D printing is being introduced in selected schools by the educational authorities with the aim of integrating this emerging technology into school subjects. A research project conducted in four primary schools in Abu Dhabi explored the impact, strategies and efficacy of 3D printing in those schools. In the project, 3D printing opportunities were identified and integrated into existing science, math and English curricula. Teachers were asked to create lesson plans that included 3D printing activities with the aim of improving students' spatial ability, performance, motivation and STEM perceptions (Khine, Ali, Santos, Gromik, & Hill, 2017).

STEAM (Science, Technology, Engineering, Arts and Mathematics)

STEAM is an educational approach to learning which goes a step beyond STEM to include the creative arts. Menano and Fidalgo (2017) describe the ways in which art and technology 'go hand in hand enhancing creativity and their relationship is often integrated in the educational setting', (p. vii) espousing the underlying philosophy of STEAM processes. There are a multitude of ways in which the arts can be linked to the other elements of STEAM. The emerging domain of robotics offers creative play strategies for engaging young children with the technology and engineering components of STEM. Sullivan, Strawhacker, and Bers (2017) wrote about the way in which robotics can facilitate the integration of engineering and technology. They also found that 'when implemented thoughtfully, robotics is a creative medium with the power to engage young children in the arts and humanities' (p. 231). A study by Grant and Patterson (2016) detailed a partnership involving a natural history museum and art gallery, where upon an STEAM learning program integrated science and art, and resulted in a number of STEAM events which merged the two. The writers gave strongly scientifically driven examples such as allowing students to deepen their ‘understanding of caterpillar defences, fish ecomorphology, and pollinator biology’ (p. 144). The potential of such work to develop skills in, for example, critical thinking, was examined. Others approach the implementation of STEAM through a more structured lens, using visual and art analysis as core program aspects with the tools of mathematical and scientific thinking used in the service of goals (Glass & Wilson, 2016). Glass and Wilson wrote about the way in which integrating these subject areas becomes collaborative through combining strengths of the different fields, with their aptly entitled article ‘Collaboratively learning our way to improved STEAM integration’. Although we were not able to find significant literature on the use STEAM in schools the UAE, other than some examples of using 3D printing devices to create art, anecdotally and from school experiences, we believe that this is occurring sporadically. Higher education institutions can help by partnering with school practitioners in order to document and publish research in this new field. This brief literature review hints at the STEAM possibilities for UAE schools. This is particularly true given the huge emphasis on arts and culture in the UAE; a wonderful example of which was the opening of the Louvre Abu Dhabi in 2017. With other museum and galleries planned in the near future, links between these art institutions and schools hold great potential for STEAM opportunities in the UAE.

Implications and Recommendations for STEM Integration in the UAE

While researching the use and integration of educational technology in the UAE, it was apparent that there is a dearth of published academic work on the actual implementation of technology in UAE schools, i.e. specific ways in which technology was integrated into education and published results on these projects. Where there are publications, as the previous sections have shown, these tend to focus on attitudinal, perception or awareness factors in connection with technology use, often as part of a wider needs analysis after which key suggestions are made. This is in part, presumably, due to the relative youth of the country’s educational system and the even younger technology sector, which is still very much in the planning and development stages.

In the previous section, we demonstrated some key examples of good practice in STEM-related work which particularly link science and technology, and put forth suggestions for how these could be integrated into the science curriculum used within the UAE national context. Effective technology integration is based on a combination of different factors such as training, support, investment in infrastructure (e.g. high-speed Internet connectivity) and technological resources. It also depends on the stakeholders’ perceptions of technology usefulness and their willingness to participate in the change process. Several approaches can be used when integrating technology, such as making sure that technology has value and relevancy to subjects and curriculum, and working closely with teachers to ensure that suitable applications are available and used. It is suggested fairly frequently in the available literature that the involvement of faculty to raise and discuss technological needs and support was sometimes inadequate, i.e. that decisions were being made *for* faculty, rather than *with* them. This might be, therefore, an area in which institutions have to develop and improve in order to increase the effective use of technology. Almekhlafi and Almeqdadi (2010) suggest a few steps to increase effective technology integration in schools, including holding regular professional development workshops, increasing collaboration between schools across the country, and giving teachers some freedom and autonomy in the selection and coverage of curriculum resources.

A dynamic whereby the teacher feels less competent and knowledgeable than his or her own students may be a major factor in resisting the application of devices in the classroom. This is where an effective framework for professional development and training becomes critical in supporting teachers to be able to effectively integrate technology into their teaching. In the institution in which the authors work, for example, an e-buddy scheme was piloted in 2016 whereby faculty identified themselves as being highly proficient and knowledgeable in the use of educational technology. They volunteered to partner up with faculty who identified themselves as being less comfortable or skilled. In addition to direct training, this type of initiative could complement and add to a faculty's general sense of comfort and competence, and so more initiatives like these could be taken up by both schools and higher education institutions.

Initiatives to increase the use of technology in schools and higher education must critically fit into an overall vision or mission of curriculum for a particular sector, since it cannot be expected that standalone subjects such as science and IT can carry the task alone. It is this cross-disciplinary communication which we suggest would lead to the successful integration of the 'science' and 'technology' in STEM, in particular.

References

Abu Dhabi Education Council. (2011a). *Endangered species: The Asian Houbara*. Retrieved from https://maps.adec.ac.ae/GISatSchools/Documents/Exercises/Science/Science%20Houbara%20Project.pdf.

Abu Dhabi Education Council. (2011b). *Mangroves—A sustainable future*. Retrieved from https://maps.adec.ac.ae/gisatschools/documents/exercises/science/Science%20Mangroves.pdf.

Abu Dhabi Education Council. (2015). *Grade 11 student electives guidelines for 2015/16*. Retrieved from https://planning.adek.abudhabi.ae/C3Electives/Documents/C3_Grade_11_student_elective_guidlines_English_Final.pdf.

Abulibdeh, E. S., & Hassan, S. S. S. (2011). E-learning interactions, information technology self efficacy and student achievement at the University of Sharjah, UAE. *Australasian Journal of Educational Technology*, *27*(6).

Al-Awidi, H. M., & Alghazo, I. M. (2012). The effect of student teaching experience on preservice elementary teachers’ self-efficacy beliefs for technology integration in the UAE. *Educational Technology Research and Development, 60*(5), 923–941.

Al-Awidi, H. M., & Ismail, S. A. (2014). Teachers’ perceptions of the use of computer assisted language learning to develop children’s reading skills in English as a second language in the United Arab Emirates. *Early Childhood Education Journal*, *42*(1), 29–37. http://doi.org/10.1007/s10643-012-0552-7.

Al Blooshi, A., & Ezziane, Z. (2013). Technological readiness of the UAE HEIs for the 21st century. *Journal of Education and Learning*, *2*(4), 123–139. http://doi.org/10.5539/jel.v2n4p123.

Al-Emran, M., Elsherif, H. M., & Shaalan, K. (2016). Investigating attitudes towards the use of mobile learning in higher education. *Computers in Human Behavior, 56,* 93–102.

Al-Qirim, N. (2011). Determinants of interactive white board success in teaching in HEIs. *Computers & Education, 56*(3), 827–838.

Ally, M. (2013). Mobile learning: From research to practice to impact education. *Learning and Teaching in Higher Education: Gulf Perspectives*, *10*(2).

Almekhlafi, A. G., & Almeqdadi, F. A. (2010). Teachers’ perceptions of technology integration in the United Arab Emirates school classrooms. *Journal of Educational Technology & Society, 13*(1), 165–175.

Awani, A., Al, Senteni, A., Singh, A. D., Bin, H., & Smart, M. (2016). An investigation about the usage and impact of digital video for learning. In *Proceedings of the European Conference on E-Learning*, 1–9.

Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Education and Science, 39*(171), 74–85.

Dickson, M., McMinn, M., & Kadbey, H. (2017). Science anxiety levels in Emirati student teachers. *Learning and Teaching in Higher Education: Gulf Perspectives*, *14*(1).

Dini, L. A., Markey, J., & Mohamad, G. (2015). Education, technology, and the Middle East. *Journal of Applied Learning Technology, 5*(2), 35–41.

Embassy of the UAE Cultural Division in Washington D.C. Report. (n.d.). *K-12 education in the UAE; Embassy report*. Retrieved May 25th, 2018 from http://www.uaecd.org/k-12-education.

Figueroa, N., Dong, H., & El Saddik, A. (2013). From sense to print: Towards automatic 3D printing from 3D sensing devices. In *2013 EEE International Conference on Systems, Man, and Cybernetics—SMC* (pp. 4897–4904). Manchester, United Kingdom: Institute of Electrical and Electronics Engineers. http://doi.org/10.1109/SMC.2013.833.

Glass, D., & Wilson, C. (2016). The art and science of looking: Collaboratively learning our way to improved STEAM integration. *Art Education, 69*(6), 8–14.

Grant, J., & Patterson, D. (2016). Innovative arts programs require innovative partnerships: A case study of STEAM partnering between an art gallery and a Natural History Museum. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 89*(4–5), 144–152.

Griffey, J. (2017). 3D: A status report. *American Libraries*. Retrieved from https://americanlibrariesmagazine.org/2017/09/01/3d-printing-status-report/.

Hanif, M., & Al-Ahmadi, F. (2009). *Computer based teaching and learning of physics at undergraduate level by using multimedia*. Paper presented at the Multimedia in Physics Teaching and Learning, University of Udine, Italy.

Hargis, J., Cavanaugh, C., Kamali, T., & Soto, M. (2014). A federal higher education iPad mobile learning initiative: Triangulation of data to determine early effectiveness. *Innovative Higher Education, 39*(1), 45–57.

Healey, M., & Roberts, J. (Eds.). (2004). *Engaging students in active learning: Case studies in geography, environment and related disciplines*. Cheltenham: Geography Discipline Network and School of Environment, University of Gloucestershire.

Hilbert, M., & Lopez, P. (2011). The world’s technological capacity to store, communicate and compute information. *Science, 332,* 60–65.

International Fund for Houbara Conservation. (2017). Retrieved from http://www.houbarafund.org/en/info/asian_houbara.

Kagima, L. K., & Hausafus, C. O. (2001). Faculty: The central element in instructional technology integration. *Journal of Family and Consumer Sciences, 93*(4), 33–36.

Kaur, S. (2012). How is "Internet of the 3D printed products" going to affect our lives? *IETE Technical Review, 29*(5), 360–364. http://doi.org/10.4103/0256-4602.103164.

Khine, M. S., Ali, N., Santos, I. M., Gromik, N., & Hill, A. (2017). Integrating 3D printing in the curriculum to support STEM education. In *Proceedings of International Symposium on Education and Psychology (ISEP 2017)* (pp. 284–292). Kyoto, Japan.

Kubieck, J. P. (2005). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, *31*(1).

Looi, C. K., Zhang, B., Chen, W., Seow, P., Chia, G., Norris, C., et al. (2011). 1:1 mobile inquiry learning experience for primary science students: A study of learning effectiveness. *Journal of Computer Assisted learning, 27*(3), 269–287.

Lowe, P. (2004). *The effect of cooperative group work and assessment on the attitudes of students towards science in New Zealand* (Unpublished doctoral dissertation). Curtin University, Australia.

Macpherson, R., Kachelhoffer, P., & El Nemr, M. (2007). The radical modernization of school and education system leadership in the United Arab Emirates: Towards indigenized and educative leadership. *International Studies in Educational Administration, 35*(1), 60–77.

Maldonado, H., & Pea, R. D. (2010). LET'S GO! To the creek: co-design of water quality inquiry using mobile science collaboratories. In *Proceedings of the Sixth International IEEE Conference on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE 2010)* (pp. 81–87). IEEE.

McMinn, M., Dickson, M., & Kadbey, H. (2015). Emirati Science Teachers' beliefs, self-confidence, challenges faced and their reported practice. *International Online Journal of Primary Education (IOJPE), 4*(1). ISSN: 1300-915X.

Menano, L., & Fidalgo, P. (Eds.). (2017). *Art and technology: The practice and influence of art and technology in education*. Berlin: Springer.

Mohammed, N. (2017). Project-based learning in higher education in the UAE : A case study of Arab students in Emirati Studies. *Learning and Teaching in Higher Education: Gulf Perspectives, 14*(2), 1–14. http://doi.org/10.18538/lthe.v14.n2.294.

Nasir, S. (2018, March 11). Teacher turnover is taking a toll on quality of instruction in the UAE. *Khaleej Times*. Retrieved May 25th, 2018 from https://www.khaleejtimes.com/news/education/teacher-turnover-is-taking-a-toll-on-quality-of-instruction-in-uae.

Parkman, S., Litz, D., & Gromik, N. (2017). Examining pre-service teachers' acceptance of technology-rich learning environments: A UAE case study. *Education and Information Technologies*, 1–23.

Partnership for 21st Century Learning. (2016). *Framework for 21st century learning*. Retrieved from Washington, DC. http://www.p21.org/storage/documents/docs/P21_framework_0816.pdf.

Pennington, R. (2014, January 13). Smart Learning Program transforms education in UAE's government schools. *The National*. Retrieved May 25th, 2018, from https://www.thenational.ae/uae/education/smart-learning-program-transforms-education-in-uae-s-government-schools-1.320112.

Pennington, R. (2016, August 29). Sweeping reforms in UAE schools overhaul. *The National*. Retrieved May 25th, 2018, from https://www.thenational.ae/uae/sweeping-reforms-in-uae-schools-overhaul-1.137303.

Salajan, F. D., Schönwetter, D. J., & Cleghorn, B. M. (2010). Student and faculty inter-generational digital divide: Fact or fiction? *Computers & Education, 55*(3), 1393–1403.

Sansing, C. (2015). *3-D printing: Worth the hype?* Retrieved March 11, 2018, from https://www.slj.com/2015/05/technology/3-d-printing-worth-the-hype-the-maker-issue/.

Santos, I. (2013). Integrating personal mobile devices in teaching: the impact on student learning and institutional support. *Learning and Teaching in Higher Education: Gulf Perspectives*, *10*(2), 1–15. Retrieved from http://lthe.zu.ac.ae/index.php/lthehome/article/view/149.

Serhan, D. (2007). School principals' attitudes towards the use of technology: United Arab Emirates technology workshop. *TOJET: The Turkish Online Journal of Educational Technology*, *6*(2).

Serhan, D. (2009). Preparing pre-service teachers for computer technology integration. *International Journal of Instructional Media, 36*(4), 439–448.

Smith, C. (2016). A framework for understanding and gauging faculty change and evolution in teaching. *Faculty Development in Developing Countries: Improving Teaching Quality in Higher Education*, 174.

Sullivan, A., Strawhacker, A., & Bers, M. U. (2017). Dancing, drawing, and dramatic robots: Integrating robotics and the arts to teach foundational STEAM concepts to young children. In *Robotics in STEM education* (pp. 231–260). Berlin: Springer.

Swan, M. (2011, June 21). Universities need more Emirati teachers. *The National*. Retrieved on May 25th from https://www.thenational.ae/uae/education/universities-need-more-emirati-teachers-1.607234.

Tairab, H. (2013). Assessing Science Teachers’ Content Knowledge and confidence in teaching science: How Confident are UAE Prospective Elementary Science Teachers? *Florida Journal of Educational Research, 51,* 1–20.

Tamim, R. M. (2013). Teachers’ use of YouTube in the United Arab Emirates: An exploratory study. *Computers in the Schools*, *30*(4), 329–345. http://doi.org/10.1080/07380569.2013.844641.

TIMSS & PIRLS International Study Center. (2011). *TIMSS 2011: Trends in International Mathematics and Science Study, Lynch School of Education, B. C*. Retrieved March 20, 2018, from https://timssandpirls.bc.edu/timss2011/index.html.

UAE Vision 2021. (2010). *UAE Vision 2021*. Retrieved from https://www.vision2021.ae/en/our-vision.

Wilson, R., Goodman, J., Bradbury, L., & Gross, L. (2013). Exploring the use of iPads to investigate forces and motion in an elementary science methods course. *Contemporary Issues in Technology and Teacher Education, 13*(2), 105–126.

Wiseman, A. W., Abdelfattah, F. A., & Almassaad, A. (2016). The intersection of citizenship status, STEM education, and expected labor market participation in gulf cooperation council countries. *Digest of Middle East Studies, 25*(2), 362–392. https://doi.org/10.1111/dome.12087.

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