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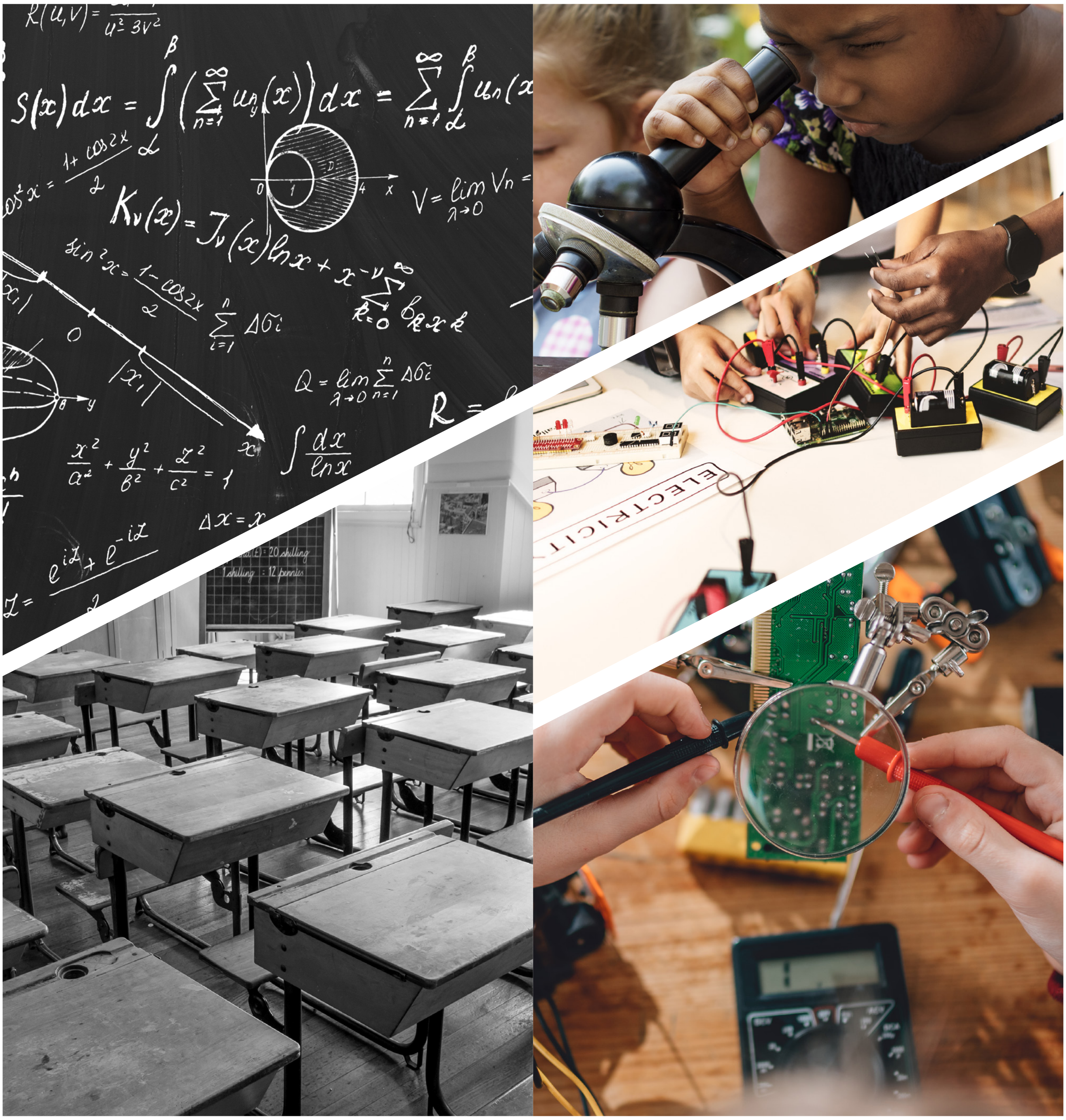
THE STEAM DILEMMA

Advancing Sciences in UAE Schools – the Case of Dubai



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THE STEAM DILEMMA

Advancing Sciences in UAE Schools – the Case of Dubai

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Acknowledgements

The authors would like to thank the teachers and principals of Dubai private schools for their generosity, time and candidness. The insights offered by teachers, administrators and principals were invaluable to this work. In particular we would like to acknowledge and thank the following schools for their participation, enthusiasm and contributions to our research:

Al Mawakeb School - Barsha

Al Mizhar American Academy School

American School of Dubai

Dubai British School

Emirates International Private School

GEMS International School- Al Khail

GEMS New Millennium School

GEMS Modern Academy

International School of Arts & Sciences

JSS Private School

Nord Anglia International School

Repton School

Springdales School

We hope that the insights offered here might drive policies that will advance the good work being done by many of Dubai's educators.

The Mohammed Bin Rashid School of Government

The Mohammed Bin Rashid School of Government (formerly Dubai School of Government) is a research and teaching institution focusing on public policy in the Arab world. Established in 2005 under the patronage of HH Sheikh Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of the United Arab Emirates and Ruler of Dubai, in cooperation with the Harvard Kennedy School, MBRSG aims to promote good governance through enhancing the region's capacity for effective public policy.

Toward this goal, the Mohammed Bin Rashid School of Government also collaborates with regional and global institutions in delivering its research and training programs. In addition, the School organizes policy forums and international conferences to facilitate the exchange of ideas and promote critical debate on public policy in the Arab world. The School is committed to the creation of knowledge, the dissemination of best practice and the training of policy makers in the Arab world. To achieve this mission, the School is developing strong capabilities to support research and teaching programs, including:

- applied research in public policy and management;
- master's degrees in public policy and public administration;
- executive education for senior officials and executives; and,
- knowledge forums for scholars and policy makers.

The MBRSG Research Department focuses on the following six priority policy areas:

1. Future Government and Innovation
2. Education Policy
3. Health Policy
4. Public Leadership
5. Social Policy, Wellbeing and Happiness
6. Sustainable Development Policy

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Education Policy

This research area focuses on issues related to education access and reform in the UAE and the region. Research in this area explores some of the main challenges facing education in the region including access to higher education, skills gaps, building capacity for the knowledge economy, technology integration in education and unemployment among youth. Education policy research at the MBRSG pays special attention to global trends impacting education such as globalization and the rise of the digital classroom, while focusing on local issues such as the youth bulge, unemployment, emiratization and dropout rates among youth.

EXECUTIVE SUMMARY

Integrative curricula, particularly for science, mathematics and technology subjects, have the potential to enhance learning experiences for students by connecting classroom learning to real world issues. What curriculum integration means is still hotly debated, but some have argued that true curriculum integration blurs and minimizes disciplinary boundaries (Bean, 1995; Berlin and White, 1994). STEAM (science, technology, engineering, arts and mathematics) is a form of interdisciplinary and integrated learning. STEAM education has become the go to educational solution for countries preparing their students for technological changes and their consequences. The Next Generation Science Standards developed by the National Research Council of the United States reflect the tenets and principles of STEAM education. Countries such as Singapore, Hong Kong, Australia and Korea have made a push for integrating STEM and STEAM in their national curricula.

In the United Arab Emirates, the government has pushed STEM (science, technology, engineering and mathematics) through educational reform as well as through national strategic measures such as the Advanced Sciences Agenda and the Fourth Industrial Revolution strategy. Educational reform starting with Abu Dhabi and then Dubai and the Northern Emirates has focused on integrating creativity and innovative thinking into school curricula. The national agenda and the UAE Vision have set goals for the UAE to be among the top 20 highest performing countries in PISA and the top 15 highest performing countries in TIMSS.[1] Over the past decade, government agencies have organized numerous activities to support this agenda. For example, the Ministry of Education has launched multiple events to encourage students to partake in STEM activities including an annual national science fair named the National Science, Technology and Innovation Festival (NSTIF) and an Artificial Intelligence and

1. PISA (Program for International Student Assessment) is a worldwide study by the Organisation for Economic Co-operation and Development (OECD). TIMSS (Trends in International Mathematics and Science Study) is a series of international assessments of the mathematics and science knowledge of students around the world by the International Association for the Evaluation of Educational Achievement (IEA).

Robotics series (AIR) which took place in late January of 2019. Since 2012, the Emirates Foundation has been running “Think Science”, an annual youth-focused program in partnership with the UAE Ministry of Education and Abu Dhabi Department of Education to develop knowledge in the fields of science, technology and innovation.

However, there has been limited assessment of how Schools in the UAE are adopting these educational trends. In this report, we explore STEAM adoption in private schools in Dubai focusing primarily on five key challenges and opportunities that emerged from our fieldwork. Based on extensive empirical findings, the report argues that as the 4th industrial revolution transforms the employment landscape in the region, a focus on educational reform is critical to combat the negative consequences of technological revolutions, and take advantage of rising opportunities.

As governments and educators all over the world debate how STEAM and STEM education might prepare students for the future of work, it is important to interrogate how their educational objectives are being implemented on the ground. Our study shows that while there might be a consensus around the importance of STEAM education, there are no standards as of yet on its implementation and adoption or indeed, on what counts as ‘integrated’ education and how to achieve it. The findings highlight the following challenges and opportunities that private schools face in aligning their educational systems with the STEAM agenda.

Challenges of STEAM Education in Dubai:

1. **Integrating Curricula:** Curricular integration posed a difficulty for teachers because of the time constraints and curricular limitations in which they operate. For many, translating curricular integration as a concept into lesson plans that can be easily delivered to students was difficult and required a lot of coordination across departments. Even then, what integration meant on the level of lesson delivery was not clear.

2. **Teacher Capacity:** Teacher workloads in all of the schools interviewed were high. Most post-service teacher training was peer to peer[2] with many teachers reporting that they did not receive enough professional development. While all teachers interviewed had degrees in their subject matter areas and most had pre-service training and certifications, only a very small number said they were trained in STEAM methods and tools.

3. **Resource Allocation:** Resource allocation was an issue for schools whose funding was limited. Despite enthusiasm for STEAM, resources in some schools were stretched thin or were limited to a certain grade level. The funding available for resources determined what schools were able to access and which of their students benefited from these resources.

4. **Incorporating Technology:** All of the schools studied integrated technology into their teaching practices. In most cases, textbooks included online equivalents that linked to the web and offered online worksheets and presentations to students. Moreover, technology integration was limited to electronic versions of traditional teaching resources such as books, worksheets, and videos. Some teachers reported difficulty in using online resources.

5. **Balancing Curricular Requirements with STEAM Objectives:** In some school systems which were described as rigid, teachers reported that it was difficult for them to follow the required curriculum and also integrate STEAM into their teaching plans. There was a tradeoff between achieving curricular goals that ensured that students performed well on standardized exams and teaching exploratory and inquiry based integrated STEAM. It was difficult to achieve both goals at once.

2. It is worth noting that, since the conclusion of our fieldwork, GEMS schools have partnered with the TELLAL institute to offer training for their teachers and staff.

Opportunities of STEAM Education in Dubai:

1. **Culture of Interdisciplinary Learning:** All of the schools visited for this study demonstrated a commitment to STEAM education. Awareness of the importance of STEAM and its integration into extracurricular activities creates school cultures and a learning ethos that values interdisciplinary learning and that emphasizes inquiry based collaborative learning.

2. **Emphasis on Project Based STEAM:** While STEAM was primarily integrated into extra-curricular rather than curricular activities, STEAM integration took the form of inquiry and project-based learning that emphasized cognitive and 21st skills such as critical thinking, problem solving, communication skills, leadership skills and information and media literacy.

3. **Integration of Robotics:** Robotics kits were enthusiastically adopted by students and teachers. Even while teachers faced challenges in understanding the best ways to use robotics for STEAM instruction, those schools with qualified engineering teachers and teachers trained in the use robotics kits found them to be highly impactful for students.

4. **Collaboration between Schools:** Efforts have been made by schools to share experiences and best practices. This is done primarily amongst schools which belong to the same corporate umbrella such as Taaleem or GEMS. However, other schools reported sharing experiences and some resources with schools that were in close proximity to them. Large conferences such as GESS offer another example of ways in which schools can share practices and resources and experiment together.

5. **Extracurricular STEAM:** Extracurricular activities offer a testing ground for STEAM integration. While teachers may not have much latitude to integrate or experiment with STEAM in the curriculum, teachers and students are able to explore and experiment with STEAM concepts, methods and tools outside the curriculum. This form of experimentation creates a space where successful teaching methods can be slowly integrated into the classroom.

INTRODUCTION

Breakthroughs in the fields of artificial intelligence (AI), Internet of Things (IoT), big data and computing, and robotics, among others are changing how industries do their work. From logistics, to manufacturing, to banking, economic systems and labor markets are being irreversibly changed by emerging technologies. We argue that educational reform and preparing future generations for an unpredictable and unstable future of work is an ethical imperative.

Governments are not only being transformed by technological changes, they must also respond to these changes by reforming their education systems, regulatory frameworks, and social safety nets.

> **“Governments must, not only, adapt to the changes technology imposes on the ways in which they provide services and engage with citizens, but also put in place the correct policy enablers to ensure that the 4IR and the rise of AI do not destabilize societies.**

Education reform is one the most important responses to this new world. Education reforms that prepare students for the future of work achieve the dual goal of enabling an innovative and productive economy and ensuring that the Fourth Industrial Revolution (4IR) does not lead to unwanted levels of unemployment.

Curricular reform to advance science, technology, engineering, arts and mathematics (STEAM) education has been a popular response to the needs of the new labor market. This paper uses insights gained from over 35 interviews in 13 Dubai based private schools to understand the challenges facing educators as they incorporate STEAM education into their curricula.

Our findings show that the most prevalent challenges facing schools as they transition from traditional science and math curricula to STEAM curricula are: (1) Developing integrated teaching programs that include science, math, and arts subjects, (2) Training and preparing teachers to deliver integrated curricula, (3) Distributing resources to ensure access to STEAM education for all students, (4) Adopting technological solutions for teaching objectives, and (5)

Achieving current curricular objectives and exam targets while also achieving the goals of STEAM education.

While there are challenges, there are also opportunities. Our study shows that, in general, even when facing challenges in integrating STEAM into curricula, (1) Schools have developed and promote interdisciplinary cultures, (2) Schools and teachers understand the value of and integrate project based learning, (3) Schools are making a special effort to invest in and promote tools, such as robotics, that assist teachers to achieve STEAM objectives, (4) There is a nascent effort to cross-pollinate and share experiences across schools, and (5) Extracurricular activities have successfully attracted students to STEAM and offer a testing ground for STEAM integration.

These challenges indicate the difficulties inherent in preparing students for a complex world in which disciplinary boundaries are blurred and in which problem solving and creative thinking skills are taking precedence over knowledge accumulation. A discussion of these challenges and opportunities opens up avenues for discussing the necessary policy responses that might enable schools and curriculum developers to overcome resource, capacity and regulatory barriers.

This report begins with a discussion of the impact of the 4IR and the AI revolution on the future of work and the skills needed to address future challenges. We then discuss the steps taken by the UAE to address the challenges of the 4IR and the strategies it has developed to promote STEAM and advanced sciences in the UAE. The third section of the report discusses the main findings of our case study of Dubai private schools. Finally, we provide policy recommendations aimed at promoting STEAM education in schools based on the rich findings of the research.

THE FUTURE OF WORK, THE FUTURE OF EDUCATION

Digital technology has changed the way we communicate, live, learn and work. It is not only changing the ways we create and consume, but also who we are. The ubiquity of the internet and the affordability of modern technologies has led to hyper-connectivity and an integration of technology into all aspects of daily life. This integration is a feature of the Fourth Industrial Revolution. While there is debate around the 4IR and how to define its temporal boundaries, there is some consensus that we have entered into a new era that is different from those that preceded it. The 4IR is marked by disruptive trends and interdisciplinary utilization of technology while the First Industrial Revolution depended on water and steam to operate machines, the Second Industrial Revolution used electric power to increase production and the Third Industrial Revolution used technology and automation to enhance productivity.

The velocity of change in the current era is unprecedented and is only accelerating and the nature of change is becoming increasingly disruptive, making it harder to predict the future of work. The 4IR is marked by the emergence of a new disruptive business model in which new technologies reshape the way we produce, consume, transport, and deliver (Schwab, 2016). This disruptive nature of today's technology has eliminated major market players because they could not adapt. The emergence and fusion of technologies across physical, digital and biological domains forced corporations either to collapse or reinvent themselves in order to survive, a phenomenon often described as "Digital Darwinism" (Schwab, 2016). With more disruptive technologies expected to emerge in the near future, what will the job landscape be like?

Children who will enter the formal educational system in 2019 will be ready to join the workforce by 2031. While we can't say for certain what the future of work will look like in 2031, there is consensus that tremendous changes will take place in terms of job elimination and generation. The debate regarding the future of work is complex and multilayered. Between pessimism and optimism, it is noted by world economists that there has never been a time of greater promise or potential peril (Schwab, 2016).

The reality of the disruptive and exponential growth of technology and the consequences it brings mean that all stakeholders of global society- governments, business, academia, and civil society need to work together to shape the 4IR in a way that is empowering and human-centered (Schwab, 2016). The increasingly ubiquitous and mobile internet, connectedness across all sectors, smaller, cheaper and more powerful devices, and artificial intelligence and machine learning represent an inflection point in the history of the world's economies and societies due to the unique challenges and choices they bring (Brynjolfsson & McAfee, 2014). The UAE government is clearly aware of future challenges and is preparing for the 4IR.

Employment and education are two of the fields most impacted by the 4IR. The role of education is crucial in unlocking the future potential of the 4IR through implementing the right educational reforms and policies to reskill and upskill the future labor force.

The Future of Jobs

As the 4IR unfolds, many uncertainties envelope the future of work, and experts are divided between optimists and pessimists. Some predict that our rapid and accelerated shift into automation and AI will eliminate a significant proportions of today's jobs, which will leave millions of people jobless. Others maintain a positive outlook that views change as an opportunity that will create new categories of jobs. The common ground among all of these experts is that major changes are approaching and the job landscape will be revolutionized, as many jobs will be automated and other jobs generated.

There are four main drivers that are set to determine the reality of business in the period between 2018 to 2022: ubiquitous high-speed mobile internet, artificial intelligence, big data analysis, and cloud technology. Businesses are moving faster into digitalization and constantly seeking to reap the benefits of emerging technologies to achieve higher levels of productivity and efficiency. This competitive pattern resulted in increasing demands on workers equipped with skills and abilities that allow them to navigate and adapt to the uncertainties of the 4IR market.

Experts are trying to imagine the job landscape in the coming decades. From the perspective of multinational employers, the job landscape will witness increased adoption of emergent and disruptive technologies and clusters of emerging roles will gain in importance, while other clusters will be eliminated due to automation (see table 1[3]). By 2022, there will be clusters of emerging jobs, while other clusters will become increasingly redundant. Half of today's jobs will remain stable to some degree in 2022. Established roles pertinent to disruptive technology and data analysis are on the rise. Also on the rise are jobs that require human skills and cannot be done by AI yet.

Table 1: Examples of stable, new and redundant roles, all industries.[4]

Stable Roles	New Roles	Redundant Roles
Managing Directors and Chief Executives	Data Analysts and Scientists*	Data Entry Clerks
General and Operations Managers*	AI and Machine Learning Specialists	Accounting, Bookkeeping and Payroll Clerks
Software and Applications Developers and Analysts*	General and Operations Managers*	Administrative and Executive Secretaries
Data Analysts and Scientists*	Big Data Specialists	Assembly and Factory Workers
Sales and Marketing Professionals*	Digital Transformation Specialists	Client Information and Customer Service Workers*
Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	Sales and Marketing Professionals*	Business Services and Administration Managers
Human Resources Specialists	New Technology Specialists	Accountants and Auditors
Financial and Investment Advisers	Organizational Development Specialists*	Material-Recording and Stock-Keeping Clerks
Database and Network Professionals	Software and Applications Developers and Analysts*	General and Operations Managers*

3. Table was sourced from the WEF 2018 report on the Future of Jobs

4. Note: Roles marked with * appear across multiple columns. This reflects the fact that they might be seeing stable or declining demand across one industry but be in demand in another

Supply Chain and Logistics Specialists	Information Technology Services	Postal Service Clerks
Risk Management Specialists	Process Automation Specialists	Financial Analysts
Information Security Analysts*	Innovation Professionals	Cashiers and Ticket Clerks
Management and Organization Analysts	Information Security Analysts*	Mechanics and Machinery Repairers
Electrotechnology Engineers	Ecommerce and Social Media Specialists	Telemarketers
Organizational Development Specialists*	User Experience and Human-Machine Interaction Designers	Electronics and Telecommunications Installers and Repairers
Chemical Processing Plant Operators	Training and Development Specialists	Bank Tellers and Related Clerks
University and Higher Education Teachers	Robotics Specialists and Engineers	Car, Van and Motorcycle Drivers
Compliance Officers	People and Culture Specialists	Sales and Purchasing Agents and Brokers
Energy and Petroleum Engineers	Client Information and Customer Service Workers*	Door-To-Door Sales Workers, News and Street Vendors, and Related Workers
Robotics Specialists and Engineers	Service and Solutions Designers	Statistical, Finance and Insurance Clerks
Petroleum and Natural Gas Refining Plant Operators	Digital Marketing and Strategy Specialists	Lawyers

The GCC and the UAE

In the Middle East and North Africa region (MENA), the current wave of emergent and disruptive technologies will have a profound impact on the labor market, but the pace of change will vary from one country to another (WEF, 2017). There is a number of leading drivers that will shape the job landscape in the GCC countries (WEF, 2017)- Ranked base on impact, the drivers are:

1. New energy supplies and technologies
2. Mobile internet and cloud technology
3. Flexible work
4. Young demographics in emerging markets
5. Geopolitical volatility
6. Climate change and natural resources
7. Women's economic power and aspirations
8. Consumer ethics and privacy issues.

As a result of these drivers and many new ones to emerge in the region, change will revolutionize the job landscape as we know it now.

The quest for new and clean energy supplies has already started to drive change in the UAE. The plan to shift to a more ecologically sustainable economic model has the potential to create many jobs. It is suspected that the energy efficiency sector will be the single largest generator of new jobs within the UAE, creating more than 65,000 by 2030 (WEF, 2017). Also The UAE's broader Green Growth Strategy aims to create 160,000 new jobs and boost GDP by 4-5% by 2030 (WEF, 2017).

In the UAE, the human capital optimization rate is 68% (Bahrain at 73% and Qatar at 69%) (Human Capital Index, 2016). The country is one of the leaders in the availability of high-skilled jobs in the MENA region. However, the percentage of jobs that will be lost to automation in the UAE is estimated to be 47% by 2030 (WEF, 2017). A decline in jobs is not the only outcome of automation, there will be serious changes to the skills profile, where the market will witness emergent roles in a variety of sectors. By 2020, 21% of core skills needed in the GCC will be different from those needed in 2015 (WEF, 2017). If approached effectively, this will offer an opportunity to create high value-adding formal sector jobs, high skill profiles, and work platforms.

Recent research found that concerns about innovation leading to higher unemployment is especially pronounced among business leaders in MENA (WEF, 2017). Global market research shows that the demand for jobs in the STEAM sector has increased rapidly in the past decade and continues to do so (OECD, 2018). Smart and sustainable economic growth requires graduates who are innovative, problem solvers, and engaged in the challenges facing our world today. Experts in the Arab region stress the urgency of developing the skills of Arab youth and preparing them for the 4IR. This urgency is particularly relevant in a country like the UAE that aspires to be a hub for innovation and technology. Knowledge and skills in STEAM are essential to respond to future challenges and address the issues students will face.

Artificial Intelligence

The term Artificial Intelligence (AI) is often associated with science fiction but in reality, the applications of AI have existed for decades and are utilized on a daily basis. The term AI was coined in 1955 by a computer scientist named John McCarthy and popularized at a conference at Dartmouth College. In definition, AI refers to intelligent "agents" (or programs) that are able to learn, adapt, and deploy themselves successfully to overcome the challenges of changing and uncertain environments (Miailhe & Hodes, 2017). From virtual assistants at

5. As John McCarthy stated once, "As soon as it works, no one calls it AI anymore." https://cacm.acm.org/blogs/blog-cacm/138907-john-mccarthy/fulltext

customer services to self-driving cars, AI has been integrated on a wide scale with the help of the exponential advancement of computing power and accessibility to data feeding algorithms and machine learning. Thousands of AI applications have been used on a daily basis, without our even realizing it.[5] Despite the advancements made in AI, its applications are still in progress and often imperfect which means that there is still much work to be done by scientists and engineers.

The promise for economic growth aided by AI and automation is a target for many governments and businesses. Based on Mckinsey's scenario modeling, it is estimated that automation could raise productivity growth globally by 0.8 to 1.4 percent annually (Mckinsey, 2017). Governments around the world have devised strategies and allocated budgets for AI development, as in the US, China, Japan, South Korea, France, among others. National governments' emphasis on AI stems from a desire to reap the potential benefits of making better predictions about the future, making informed decisions, increasing efficiency in different sectors, gaining status in a competitive digital market, and triggering optimization across domains. But the quest is more complex than it appears for policymakers. While policymakers aim to embrace the economic opportunities and foster market growth, they must evolve and innovate policies that help workers and institutions adapt to the impact on employment which is likely to involve rethinking education and training (Mckinsey, 2017).

The consequences of automation on the job landscape is debated between optimism and pessimism. Optimists predict that global productivity could be raised by automation, as it will balance the decline in productivity caused by decreasing birthrates and aging populations (McKinsey, 2017). It must be mentioned here that the wave(s) of automation will be absorbed differently in different regions and countries, based on various demographic, economic, political and social factors. So how can the AI revolution work for everybody? Serious reforms should be made to education and skill development systems in order to prepare future workforces to make repeated and viable professional transitions (Miailhe & Hodes, 2017). The urgent need to invest in developing a capable AI-related workforce and enabling interdisciplinary AI research is imperative, as AI will be an essential component in all domains (Miailhe & Hodes, 2017), especially with the emergence and fusion of technologies across physical, digital and biological spheres (Schwab, 2016). The interdisciplinary nature of AI provides insights into the type of education that students should receive. There is tendency to focus on computer science in STEAM education curricula which is not adequate to address the challenges of future AI market.

> "An enhanced and diversified approach to STEAM that includes computational thinking, data science, creativity, innovation and entrepreneurship, in addition to civic education, to equip future citizens with AI literacy and understanding of the potentials and threats of AI, as well as ethical and political debates
>
> (Miailhe & Hodes, 2017).

The Future of Education

From the discussion above, we can conclude that the future presents inherent opportunities (WEF, 2018), however, bold and urgent educational reforms are needed in order to capitalize on those opportunities and avoid devastating economic consequences induced by shifting job patterns. Engaging stakeholders has never been more crucial to prepare the future workforce for jobs that have not yet been created or technologies not yet invented to solve world problems that have not yet occurred. As the 4IR unfolds, education encounters an inflection point where it has to rethink and reinvent itself in order to respond to the rising challenges. Education is not about accumulating knowledge or creating knowledge anymore. Skills like memory, reading, and writing are declining (some of the core skills of conventional education). On the other hand, skills such as analytical thinking, creativity, problem-solving, reasoning, technology design and programming are on the rise in future markets.

Table 2: Comparing skills demand, 2018 vs. 2022, top ten[6]

Today, 2018	Trending, 2022	Declining, 2022
Analytical thinking and innovation	Analytical thinking and innovation	Manual dexterity, endurance and precision

6. The table was sourced from Future of Jobs Survey 2018, World Economic Forum (2018).

Complex problem-solving	Active learning and learning strategies	Memory, verbal, auditory and spatial abilities
Critical thinking and analysis	Creativity, originality and initiative	Management of financial, material resources
Active learning and learning strategies	Technology design and programming	Technology installation and maintenance
Creativity, originality and initiative	Critical thinking and analysis	Reading, writing, math and active listening
Attention to detail, trustworthiness	Complex problem-solving	Management of personnel
Emotional intelligence	Leadership and social influence	Quality control and safety awareness
Reasoning, problem-solving and ideation	Emotional intelligence	Coordination and time management
Leadership and social influence	Reasoning, problem-solving and ideation	Visual, auditory and speech abilities
Coordination and time management	Systems analysis and evaluation	Technology use, monitoring and control

Experts in education and curriculum design are calling for a shift from knowledge and content based education to education that focuses more on knowledge use and synthesis, building useful skills and positive character qualities. In an attempt to reinvent educational systems in a way that addresses the demands of the 4IR, a four-dimensions model was proposed that rethinks knowledge, skills, character qualities, and meta-learning (Fadel, Bialik & Trilling, 2015). Each dimension is explained below[7]:

Knowledge dimension

Teaching of traditional knowledge usually includes the following subjects: math, science, languages (both domestic and foreign), social studies, arts, and physical activities. Teaching these subjects takes up most of the students' school time, and leaves little time to introduce new topics, character building activities, or 21st century skills, most of which end up as extracurricular activities that burden the already crowded students' school schedule. Moreover, the problem with the traditional model of knowledge teaching is that it encourages quantity over quality, and depends heavily on testing the knowledge and content students acquire. An important question to ask here is how can the educational system upgrade itself to prepare student for the 4IR and

7. The explanation of each dimension is based on the following reference: (Fadel, Bialik & Trilling, 2015)

the uncertainties of the coming times? One suggestion would be to redesign the components of the curriculum to pare back declining skills and advance those that are demanded for the 21st century.

Experts in curriculum design provide four ways of reexamining disciplines to identify its essential components of traditional and modern knowledge: differentiating between concepts and meta-concepts, dividing the learning experience into processes, methods and tools, slicing disciplines into branches, subjects and topics, and devising ways to transfer knowledge across disciplines.

The purpose of the ways mentioned above is to help focus school curricular on what matters for future generations. However, redesigning school curricular needs to be done under the light of new, modern interdisciplinary subjects, branches, and topics needed to equip students with the knowledge necessary for the 21st century. There is a number of the suggested topics and themes for a 21st century school curriculum: human lifespan extension (e.g. personal health and career pathways), connected world (e.g. emotional intelligence, global literacy, and system thinking), smart machines and systems (e.g. digital literacy, design thinking, synthesis and integration, and ethical mindset), big data and new media (e.g. big data analysis, media literacy, and information literacy), Environmental issues (e.g. environmental literacy and systems thinking), and finally amplified humans (e.g. physical skills, empathy and collective responsibility, mindfulness and metacognition).

Educational systems around the world have started to introduce modern disciplines to enrich students' learning experience, however, the main challenge is finding time in the curriculum to focus on them. Because the traditional disciples take the largest share of available time, these efforts seem insufficient in comparison to the increasing demand on 21st century skills. In order to make effective changes, traditional disciplines need to be reexamined in terms of their relevance and utility.

Skills dimension

As discussed above, knowledge is essential for education, and making the right choices about what to teach shapes the future of graduates. Traditional transition of knowledge emphasizes listening, reading, and performing routine exercises to learn content. On the other hand, unconventional methods allow learners to exercise their higher level thinking skills by investigating, creating, debating and synthesizing knowledge. While knowledge is learned concepts, skills are learned behaviors that allow students to apply their knowledge and use it as tasks require. Equipping students with the right skills to prepare them for higher education, workplace, and citizenship in the 21st century is essential for building a sustainable future.

There is a lesson to be learned from employer survey studies. Almost all such surveys report skills mismatch between the skills recent graduates have and those needed in the workplace. This skills gap has been highlighted for many years, and employers have been raising the issue of under-preparedness of fresh graduates constantly. When this problem is examined in light of the 4IR, where volatility, uncertainty, complexity, and ambiguity dominate the future, the need to respond to it through educational reform has never been more urgent. The skills required for workplace change with time. As technological advances are made, some skills decline, while others become more important. As Table 2 showed above, skills such as problem-solving, critical thinking, analytical thinking are gaining importance.

Under the skills dimension, educators highlight a number of skills that are crucial to the 21st century education:

- **Creativity:** a creative person can be defined as someone who is able to think about a problem differently (divergent-thinking),produce original solutions and show fluency and flexibility in handling their ideas. Teaching models that are built around problem-solving and project-based approaches is more likely to encourage students to think creatively about solutions.

- **Critical thinking:** A critical thinker is someone who questions and does not take ideas for granted. In definition, critical thinking is "actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action" (Scriven & Paul, 1996). Critical thinking in education has existed for hundreds of years, however, traditional education has not encouraged students to develop that skill adequately and actively. In a classroom, critical thinking can be taught explicitly or can be integrated in projects that involve analyzing, synthesizing, and evaluating of evidence (Greenstein, 2012).

- **Communication:** good communication skills are essential for a workplace where interactions with clients and colleagues happen on a daily basis. It is often expressed by employers that good communication is a desirable trait in potential hires. A good communicator is someone who is able to negotiate, give instructions, advise, build relationships, resolve conflicts, and if the jobs requires, be able to report, speak publicly, and communicate with different audiences. Through group collaboration and peer tutoring, students can learn to communicate effectively.

- **Collaboration:** simply, collaboration happens when a group of individuals join their efforts to work towards a common goal. The best solutions are not produced in isolation. In today's connected world, bringing together multiple perspectives and experiences to solve problems is made easier and more accessible through smart devices and the ubiquity of the internet.

Character dimension

The knowledge dimension helps students acquire relevant and useful content, and the skills dimension will aid them to apply that knowledge in meaningful ways. But the picture is not complete with only these two dimensions, because students are expected also to engage and behave in the world as members of their local communities and in the bigger global society. So, in education, character qualities are teachable qualities that can be nurtured to ensure individual growth, as well as, societal engagement. Proponents of teaching character qualities identify 6 major qualities:

- **Mindfulness:** rooted in Eastern philosophy, mindfulness is being present in the moment, and paying purposeful attention to experiences. Educators have used mindfulness as way to help students reduce stress and anxiety. Mindfulness is also associated with enhanced focused attention and improved memory, self-acceptance, self-management, and self-understanding. So, mindfulness is a practice. Students can be guided and trained to mediate and practice mindfulness, even if for short periods of time. Managing stress and anxiety is crucial for students, especially that testing can be overwhelming for many students, and mental health issues are common among young people.

- **Curiosity:** as research suggests, curiosity can be both an innate trait and a response to environmental cues. Observing children at play shows how curious children are naturally to investigate and find solutions. But when does curiosity reach a peak? The optimal arousal model suggests that curiosity peaks when children know enough to be interested, surprised by their experience, and uncertain of how to make sense of the situation. This model shows that challenging students is important to make them curious enough.

- **Courage:** can be described as an ability to act despite fear or uncertainty, in risky situations, or when we are feeling vulnerable. This quality has to be encouraged in healthy doses, because overdoing it might lead to damaging consequences. A healthy dose of courage can help students loosen up negative burdens and make students more open to new experiences. However, it is worth noting that traditional education which is heavily based on performance and testing might inhibit courageous behavior because of the fear of losing grades. In these situations, students tend to choose the path to success that is tested and guaranteed.

- **Resilience:** a resilient person is someone who does not give up easily, someone who keeps trying to overcome obstacles to reach their goals. Working towards long-term goals no matter what obstacles come in the way is associated with the notion of grit. Building resilience in young people is also important for mental health, as it teaches students not to breakdown under pressure.
- **Ethics:** teaching ethics and morals is not new. Because students belong to a local and global communities, ethics are an integral part of their being. Educators believe that providing students with situations which allow them to participate in groups, share decision-making process, and assume responsibility for their actions is the best way to teach them about ethics.
- **Leadership:** traditionally speaking, leaders are individuals who are identified based on their innate ability to control and manage others. This definition implies a hierarchal order where leaders are at the top, while other team members act like subordinates. A more flexible definition of leadership focuses on the processes, practices and interactions, where leaders just like any other member in a team are constantly making sense of the situations, while executing their communicative skills such as negotiation, conflict resolving, and motivating others. This model of leadership is more fitting for uncertain and changing times.

The Meta-learning dimension

The three dimensions discussed above, knowledge, skills and character qualities, are incomplete without adding the enveloping meta-learning dimension. In short, meta-learning is “learning how to learn,” or reflecting on ones’ learning. It helps students understand where they stand in terms of their own progress and their future goals. Moreover, the importance of metacognition stems from the importance of giving students opportunities to transfer skills and knowledge across disciplines. Traditional education has encouraged students to be aware of their own learning through traditional methods like note-taking, summarizing, and testing, while more modern methods encourages students to monitor their own progress, set short and long term goals, be resilient in the face if obstacles and build a growth mindset. A growth mindset, as opposed to fixed mindset, is based on the belief that success cannot be handed and abilities can be developed through hard work (Dweck, 2007).

What is STEAM Education?

The origin of contemporary STEM goes back to 1990s at the National Science Foundation, when the acronym SMET was proposed, later the term was changed into STEM for science, mathematics, engineering, and technology (Bybee, 2013). Some educators re-conceptualized STEM to STAEM, where "A" stands for the arts (Quigley, Herro & Jamil, 2017). The addition of the arts to STEM comes from the need to increase innovation and creativity thorough integrating artistic design, artistic expression, and multi-sensory appeal in the curriculum (Daughetry, 2013). The term STEAM education is now widely used by educators and policymakers around the world to refer to a pedagogical approach meant to prepare future generation to face the challenges of the FIR. There is no consensus on the definition of STEAM till this day. Even within education, the definition of STEAM varies according to the areas which are meant to be highlighted. Some highlight the interdisciplinary aspects of STEAM and promote an integrative model of instruction (Merrill, 2009), while others see STEAM as an opportunity to highlight subject-specific content. Whether STEAM highlights interdisciplinary directives, subject-specific focus or integration of arts and design, STEAM education is not meant to produce more engineers, scientists, or mathematicians, but rather develop highly capable students who can respond to the challenges of the 21st century. STEAM education is aimed at making students better problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate (Morrison, 2006).

Learning in STEAM education happens when different disciplines intersect. Adding arts to STEM broadens the spectrum of learning, as it helps make disciplines more relevant to a larger number of students (Kang et al., 2012). Despite the recent interest in integrating arts in STEM education, experts highlighted the lack of clear conceptual framework or guidelines for educators on how to integrate arts (Quigley, Herro & Jamil, 2017). There are many educational models of STEAM, where arts can mean the integration of aesthetic elements, liberal arts or a combination of both (Quigley, Herro & Jamil, 2017). Through the inclusion of authentic problems, disciplinary integration, and problem-solving approaches, STEAM teaching can be enriched (Quigley, Herro & Jamil, 2017). STAEM should intentionally include the arts. The integration of disciplines in STEAM should include some form of arts (e.g. media, visuals, language) to foster better integration and engage students (Yackman, 2008). Creative skills include designing, patterning, play, performing, modeling, and connecting ideas, and in a STEAM classroom, this translates into opportunities to explore a variety of solutions and ways to demonstrate understanding (Quigley, Herro & Jamil, 2017).

In order to reach the full potential of STEAM education, students must acquire STEAM literacy which refers to four major pillars (Bybee, 2013): 1) knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEAM related-issues; 2) Understanding of the characteristic features of STEAM disciplines as forms of human knowledge, inquiry, and design; 3) Awareness of how STEAM disciplines shape our material, intellectual, and cultural environments; and 4) Willingness to engage in STEAM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen. Increasing STEAM literacy should target all students, regardless of their career path (National Academy of Sciences, 2011). The reason for including all students in STEAM literacy goals is to prepare a generation of qualified and responsible citizens who can apply scientific and technological skills in solving their personal and societal decisions.

Although there is no consensus on defining STEAM, there are several components which are identified in the literature as essential for fostering STEAM education in schools. A conceptual framework of STEAM instruction based on a bottom-up approach, LaForce et al. (2016) identified eight categories according to STEM school leaders and stakeholders of inclusive schools that are crucial to STEM school identity: problem-based learning, rigorous learning, personalized learning, career, technology and life skills, school community, external community, staff foundations, and supporting factors.

In the literature, there is no magical formula to promoting effective STEAM education, and there is no "one size fits all" approach. The components discussed in the literature vary based on different contexts, available resources, and school types. However, there are some core components often highlighted in the literature that are considered essential: some of them are instructional, some are non-instructional, and others target support systems around STEM education.

The following sections will discuss some of these components:

Integrative Approach to STEAM

For many years, science, technology, engineering, arts and mathematics have been taught as separate subjects in educational institutions. Traditional approaches to learning depend on breaking problems down into smaller parts and teach them separately. Many educators have argued against creating artificial boundaries between these subjects, and called for more connectedness and coordination (Dewey, 1966). There is a growing realization nowadays among educators that teaching separate subjects or "layer cake" approach to knowledge and skills is one of the fundamental issues in the educational system (Furner & Kumar, 2007). On the other hand, integrative approaches to learning stress transfer of knowledge and skills across disciplines. The main idea behind integrative approaches is that children naturally use multiple cognitive skills simultaneously to solve problems. In curriculum design, the integrated model is used to arrange interdisciplinary topics around overlapping concepts and patterns which can be described as a kaleidoscope model (Fogarty, 1991).

There are three types of STAEM integration: multidisciplinary, interdisciplinary and interdisciplinary (Quigley, Herro & Jamil, 2017). These three types differ in the degree of integration of STAEM disciplines. Multidisciplinary is the least integrated, since it involves using knowledge, processes and skills from more than one discipline. Interdisciplinary integration involves using knowledge, processes and skills of one discipline within another which makes it more popular in solving real world problems. However, the inquiry to investigate each of the disciplines relies within each discipline. Lastly, intradisciplinary integration is also oriented towards problem solving. It brings the content of one discipline and uses the context of another discipline to make the content more relevant (Quigley, Herro & Jamil, 2017).

Creating barriers between STEAM subjects denies students the opportunity to apply their knowledge and skills across disciplines to overcome challenges. Adding to that, the world today faces numerous economic, environmental, and societal challenges and that dictates developing future citizens that are capable of solving problems through rich, engaging, and powerful experiences, and STAEM integration helps them to do so (Moore, Roehrig, Lesh, and Guzey, 2010).

Personalized Learning

The personalization of learning is student-centered approach, based on the belief that children have different needs, interests and capabilities. Personalized learning is seen as tailoring instruction to help students engage in learning experiences that suit their needs and interests. One core attribute of personalized learning is that learning should always be student-centered, not curriculum-centered. Other key features of a personalized learning approach are "strong emphasis on parental involvement, smaller class sizes, more one-on-one teacher and student interaction, attention to differences in learning styles, student-driven participation in developing the learning process, technology access, varied learning environments, teacher and parent development programs, and choices in curriculum programs" (Personalized Learning Foundation , 2012).

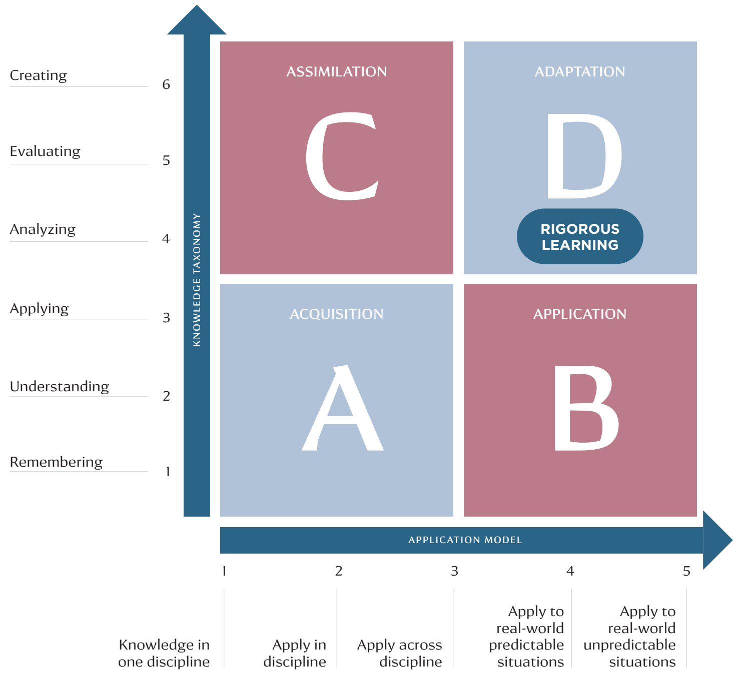
Problem-solving Learning

Based on the idea that young children are naturally driven by exploration and problem-solving behavior, STEAM education fosters these skills and integrates problem-solving as a core component. Teaching that relies on problem-solving is not exclusive to STEAM, but rather has a long history in pedagogical theory (Glancy & Moore, 2013). Relying on problem-based approach to learning invokes high process skills instead of rote learning. There are three main types of problem-solving skills: cognitive, interactional and creative (Quigley, Herro & Jamil, 2017). The cognitive skills include, abstracting, analyzing, applying, classifying, formulating, interpreting, perceiving, modeling, synthesizing, and questioning (Quigley, Herro & Jamil, 2017). Students who use cognitive skills to solve problems are more likely to succeed in transferring knowledge to new situations (Hmelo-Silver, 2004). The interactional category involves any skills that are used to collaborate and work in groups. As mentioned before in the skills dimension, teaching interactional skills is essential for the future of education. The last category is the creative which includes designing, patterning, play, performing, modeling, and connecting ideas (Quigley, Herro & Jamil, 2017).

Rigorous Learning

Rigorous learning, often used interchangeably with academic rigor, is difficult to define. Since it involves many varied components, there is no common definition that all educators agree on; however, it can be generally described as education that challenges students and develops in them high-level skills, knowledge, attitudes, and aptitudes that are essential to live and work in the increasingly complex world (Daggett and Gendron, 2015). Although rigorous learning is hard to pinpoint, it involves some core characteristics that educators can use to recognize students' high engagement (Daggett and Gendron, 2015), including: Rigor (indicated through thoughtful work, asking high-level questions, and engaging in rich academic discussions), Relevance (indicated through meaningful and relevant real-life lessons, using authentic sources, and making connection with global applications), and Engagement (indicated by active participation, fostering learning environments based on commitment and respect, and using formative tools and processes tailored for differentiated learning). So rigorous learning does not mean asking students to do difficult homework or overwhelm them with many tasks. It is crucial to encourage students to reflect on their learning, through "considering alternative arguments or explanations, making predictions, interpreting their experience, analyzing data, explaining their reasoning, and supporting their conclusions with evidence" (LaForce et al., 2014, p.4).

To help educators further understand what rigorous learning is and how to assess it, the International Center for Leadership in Education developed the rigor/relevance® framework (Figure 1). The vertical axis in the framework is based on Bloom's Taxonomy (the lower three levels are straightforward and fundamental, while the upper three are more complex and involve higher thinking skills) (Bloom, 1956). The Framework is meant as a tool or guide for educators to devise learning experiences that fully engage students. As Figure 1 shows, when learning occurs in Quadrant D, students interact analytical and creatively with their learning tasks, and use complex skills to do so. Examples of classroom questions belong to Quadrant D include, "how would you design a… to…?" or "What would be different today, if that event occurred as…?" with a focus on real-life situations (Jordan, 2014). The point here is to stimulate complex thinking processes to find creative solutions to both predictable and unpredictable real-life situations.



Source: The International Center for Leadership in Education, Daggett and Gendron (2015)

Cooperative Learning

Cooperative learning is often contrasted with competitive learning and individualistic learning. Although cooperative learning is an ancient learning method, it is relatively recent in contemporary education. Maintaining that social interdependence theory has been validated by hundreds of research studies, Johnson and Johnson (2007) listed five core elements under which cooperative learning should be implemented: positive interdependence, individual and group accountability, promotive interaction, interpersonal and small group skills, and group processing.

These elements shape the ways in which students create their individual and shared learning experiences and aid teachers in fostering positive cooperative learning environments. Social interdependence happens when the actions of others impact the accomplishment of each individual's goals in a group (Deutsch, 1949; Johnson and Johnson 2005). The emphasis in cooperative learning is on fostering positive social interdependence[8] which occurs when each group member perceives that they can accomplish their goals only if the other team members achieve theirs (Johnson and Johnson, 2007).

8. As opposed to negative social interdependence which exists when team members perceive that they can achieve their goal only if the other team members fail to reach their goals (Johnson and Johnson, 2007).

UAE VISION AND THE FUTURE

The UAE has long recognized the importance of innovation in determining the sustainable future of the UAE. The UAE Vision 2021 identifies innovation as key for the development of a diversified economy and a competitive country with a high standard of life. In 2015, a UAE National Innovation Strategy was launched that identified education as a key pillar and enabler of innovation. Since then, the UAE has taken some important steps not only to drive innovation, but also to meet the challenges of the future.

In response to disruptive technology and the 4IR, the UAE launched a number of initiatives and strategies including strategies for the 4IR, Artificial Intelligence and an agenda for the advanced sciences which are also aligned with the targets of the UAE Vision 2021 and the UAE Centennial 2071. The UAE appointed the world's first Minister of Artificial Intelligence, H.E. Omar Al Olama, who is responsible for boosting the government's performance through the use of innovative tools and artificial intelligence. The UAE also appointed a Minister of State for Advanced Sciences, H.E. Sarah Al Amiri, who is also the Chairperson of the UAE Council of Scientists and the Deputy Project Manager of the Emirates Mars Mission at the Mohammed Bin Rashid Space Centre. H.E. Sarah Al Amiri is also responsible for the implementation of the National Advanced Sciences Agenda 2031 and the Advanced Sciences Strategy 2021.

UAE Fourth Industrial Revolution Strategy

The UAE's Fourth Industrial Revolution strategy was launched in September 2017 during an annual government meeting. It aims to position the UAE as a global hub for the Fourth Industrial Revolution. The plan urges innovative education and research in advanced sciences and artificial intelligence in order to meet the requirements of the future. The UAE also aims to invest in national research on human enhancement and neuro science.

The UAE plans on becoming a global healthcare center and boosting medical tourism. It will invest in medical research and introduce wearable and implantable medical solutions. The strategy aims to transform the health and medical industry by using nanotechnology, providing robotic health services and adopting intelligent genomic medicine.

The plan also focuses on improving environmental stability and ensuring food security and water security through bioengineering and advanced renewable energy. Economic security is also highlighted and the UAE plans to adopt a digital economy and use blockchain technologies for financial transactions.

The UAE plans to focus on 3D printing, designing and manufacturing technologies. It will also focus on robotic construction and producing self-driven cars. It also aims to become a global hub for space exploration and space entrepreneurship.

UAE Artificial Intelligence Strategy

The UAE launched the Artificial Intelligence Strategy and appointed the world's first Minister of Artificial Intelligence, H.E. Omar Al Olama, in October 2017. The strategy aims to improve the government's performance through the use of new smart technology tools, to become the first in AI investments in different sectors, and create a new vital market with high economic value. The national plan's objectives are to assist the transport sector by reducing accidents and operational costs, improve health by minimizing chronic and dangerous diseases, assist with conducting accurate experiments for the purpose of space exploration and decrease the rate of costly mistakes, manage renewable energy facilities, cut education costs and increase the desire for education, use technology to increase productivity, conduct studies to provide water sources, preserve the environment by increasing forestation rate and growing suitable plants, develop new traffic policies that will reduce annual costs by 50% and create tools to assist with traffic jam management and traffic accidents .

Moreover, the strategy covers five main themes which focus on forming the UAE Artificial Intelligence Council, organizing workshops, fieldtrips, and field visits to government entities, providing government officials with training courses, providing government services through AI and developing the skills of all staff operating in the technology field, integrating medical and security services with AI, issuing a government law on the safe use of AI and launching a leadership strategy.

In March 2018 the UAE Artificial Intelligence Council was formed and is chaired by HE Omar Al Olama. The council consists of ten members with representatives from each Emirate and its main focus will be on integrating AI in the government and education.

UAE National Science Agenda

In April 2018, the UAE government launched the National Science Agenda 2031 which includes the Advanced Sciences Strategy 2021. The 2031 Agenda aims to utilise advanced sciences in the development and creation of solutions for the challenges of the future and to support the objectives of Vision 2021 and Centennial Plan 2071.

The agenda highlights eight priorities for 2031 and 30 targets for 2021.

The eight scientific priorities are:

1. national capacity-building
2. promoting the sustainable energy sector
3. enhancing water security using advanced and clean technology
4. developing advanced scientific food security system
5. addressing health challenges in the UAE through a national scientific system
6. developing advanced industries sector
7. building a system of logistical support based on scientific studies and data
8. creating a strategic industries complex.

Furthermore, the agenda aims to develop four enablers which are:

1. economic information services
2. a coherent scientific community
3. a supportive technology
4. an entrepreneurship in science and technology.

Role of Education in the UAE Vision 2021

The UAE Vision 2021 was announced in 2010 and was developed by over 300 officials from both federal and local government entities. The aim of UAE Vision 2021 is for the UAE to be considered as one of the best countries in the world. One of the national agenda's indicators is focused on education. The UAE aims to have a 'First-Rate Education System' by transforming teaching methods and the current education system. Schools and universities also need to be facilitated with smart technologies that will assist in teaching, research and projects. The agenda aims for students to be amongst the top-ranking students in reading, mathematics, science and Arabic skills. Furthermore, the agenda aims to increase secondary schools' graduation rates, ensure an exceptional level of leadership in all schools and have internationally accredited teachers.

The Ministry of Education Strategy 2017-2021 is aligned with the UAE Vision 2021. One of the six core values of the Ministry of Education is to encourage science, innovation and technology in UAE society.

Table 3. Related Vision 2021 Targets and Current Progress (vision2021.ae) :

	Indicator	Progress
1	The average TIMSS score to be among the top 15 countries	Average TIMSS Score Grade 4 – Mathematics Rank 35 (2015 Report) Average TIMSS Score Grade 4 – Science Rank 35 (2015 Report) Average TIMSS Score Grade 8 – Mathematics Rank 19 (2015 Report) Average TIMSS Score Grade 8 – Science Rank 22 (2015 Report)
2	The upper secondary graduation rate to be 98%	97.86% (2017 Report)
3	Have a 95% enrolment rate in preschools in both public and private schools	92.55% (2017 Report)
4	The average PISA score to be among the top 20 countries	Average PISA Score Mathematics Rank 38 (2015 Report) Average PISA Score Science Rank 36 (2015 Report) Average PISA Score Reading Rank 36 (2015 Report)

5	Ensure that 90% of students have high skills in Arabic based on National Tests	68% (2017 Report)
6	To have the enrolment rate in foundation year down to 0%	44.80% (2017 Report)
7	Ensuring that 100% of schools in the UAE have high quality teachers	27% (2018 Report)
8	Ensuring that 100% of schools have highly effective leadership	27% (2018 Report)
9	Spend 1.5% per GDP on research and development	-

The UAE Context

The UAE's unique context presents opportunities and challenges for advancing STEAM education and science in general. The UAE's political stability offers a conducive environment for piloting and delivering STEAM related initiatives and policies. In particular, the stability of the UAE and its strong federal system have created an environment in which policies are quickly and easily adopted and rolled out across the country and where there are strong inter-agency relationships and collaboration.

Additionally, the country's economic and political stability, as well as the high standard of living, attracts talent from all over the world. This ability to recruit globally ensures that the UAE can tap into technical professional networks from all over the world to fill its human resource needs.

Furthermore, the UAE is at the forefront of technological development in the region investing heavily in IoT and Artificial intelligence technology. This strong thrust toward the knowledge economy presents a skills challenge for the UAE in which students and young people must be prepared for future of work in a technology driven knowledge economy. At the same time, these investments create ample opportunities for synergies and collaboration across the education sector and the technology sector in order to upskill and educate students whether at the secondary or tertiary levels.

The UAE faces the risks of climate change in an area that will be most affected by rising global temperatures. Water scarcity and food security are already priority issues for the UAE. As such, a capable cadre must be educated and trained to respond to these challenges with technological innovations and solutions. The large expatriate population of the

Emirates creates yet another risk which requires the UAE to develop national talent but also develop resource, education, and other incentives to ensure that expatriate talent remains in the country.

Current efforts to advance science and technology education in the UAE are nascent and have seen some success. The UAE's strong strategic direction and leadership support for STEAM education

Table 3: PESTLE Related to Advancing Science in the UAE

Political	• Internal stability • Strong policy implementation • Strong federal system • High trust in government • Strong global ties • Positive diplomatic relationships with global players • Strong strategic directions • Emphasis on global competitiveness • Regional Instability – impacts: hires, mobility of human capital, investments
Economic	• High income per capita • Reliance on foreign labor • High dependence on oil • Economic volatility • Majority of Emiratis still work in the public sector • Skill gap • Nascent alternative energy sector • Oil and gas, aviation, transportation and the healthcare sectors will still be central to the future market • Low unemployment rate
Social	• Gender pay gap • A high number of highly educated national female graduates with a low rate of employment • Gender employment gap – closing the gap will raise the UAE's GDP by more than 12% • Large expatriate population • Social cohesion challenges • Happy population • Multicultural environment

Technological	• Disruptive technology – uncertainty of future of jobs. As the 4IR unfolds, and disruptive technology is being introduced, the workforce of the future needs to be equipped with flexible STEAM skills in order to adapt to the uncertainty of the future. • Businesses reinvent themselves in the 4IR which means there will most likely be a higher demand for STEAM graduates • Technology shifts the delivery and the content of school curriculum • The UAE aims to be a hub for smart technology and innovation that attracts investment in technology and creates new jobs
Legal	• UAE has compulsory secondary education for all citizens • By law all citizens are entitled to free education at the secondary and tertiary levels • The UAE has strong regulatory and legal frameworks to which schools abide
Environmental	• Climate change • Water Scarcity Challenges • Food Security Challenges

has created high awareness amongst the population about the importance of STEAM. This awareness has also incentivized educators, whether in secondary schools or tertiary institutions, to encourage STEAM education in their schools and universities. The UAE strong and stable policy environment and its speedy implementation of policies presents opportunities for launching experimental pilot programs in STEAM education.

The UAE's global connections and status as a regional hub gives educators and STEAM professionals access to global best practice and technological resources from across the globe. Diplomatic and other connections have also ensured that national talent can receive training in some of the world's most successful STEAM institutions whether in East Asia, Europe or the United States. Despite a predicted increase in technical or research and development related STEAM jobs, the current market presents a dearth of such opportunities in the private sector. However, the public sector has been leading STEAM related areas. Despite this, investment in research and development is still inadequate across all disciplines and fields.

The UAE presents an attractive market for private education providers. The private education sector, though offering a diversity of options and offerings suffers from excessively high tuition fees. Tuition fees and resource allocation impacts the kinds of STEAM initiatives and programs that are available in schools. As a result, accessibility to quality STEAM education becomes determined by a student's household income level. This leads to an inequality of access to STEAM education. Further exacerbating this problem is the dearth of STEAM resources in the Arabic language which leaves a portion of the population unable to access quality online and offline resources and the shortage of qualified national teachers.

Table 4: SWOT Analysis related to STEAM education in the UAE

Strengths	Weaknesses
AI Strategy	High tuition fees make quality education inaccessible for many
4IR Strategy	Unavailability of Arabic language resources for STEAM
National Advanced Sciences Agenda	English as a lingua franca disadvantages Arabic speaking students and students graduating from Arabic medium schools.
Support from leadership for the advancement of science	A nascent innovation and technology sector leads to a dearth in employment opportunities in STEAM in the private sector
Educational reforms in AD, Dubai and the Northern Emirates focusing on science	Shortage of qualified national teachers in STEAM subjects.
Educational initiatives and policies are implemented quickly	
Encouraging science through national competitions and science fairs	
Initiatives such as the Space Center increase interest and awareness of advanced sciences	
UAE attracts scholars and teachers from all over the world which leads to multiple opportunities for knowledge sharing	
Being a business and economic hub, the UAE has access to technology and resources for science instruction from all over the world	
High per capita GDP and high investments in education	
High foreign education investment	
Attractive market for education providers	
A hub for growing sectors such as artificial intelligence, alternative energy, etc.	
High awareness and dissemination of methods and philosophies in education	
High rates of literacy and education amongst Emiratis	
Strong education quality regulations	

Opportunities	Threats
Growing sectors are leading to a rise in future jobs	Transitory population could lead to migration of experts
The period between formulation and policy implementation is short	Disruptive technology may make particular education programs and requirements obsolete
High trust in government and high adherence to government policies provides a conducive environment for experimentation and pilot STEAM programs	Large expatriate workforce can lead to high risks in core sectors that require advanced levels of expertise
Rise in number of Arabs and Emiratis in STEAM provides opportunities to highlight role models in the STEAM fields	A low investment in research and development puts the UAE at risk of falling behind global trends in innovation
Willingness to share experience and expertise between schools can lead to productive cross-pollination	
Multiple opportunities for exchange and collaboration with global counterparts	
High GDP and world class universities present a conducive environment for STEAM research and development	

STEAM EDUCATION: THE CASE OF DUBAI PRIVATE SCHOOLS

THE DUBAI CONTEXT

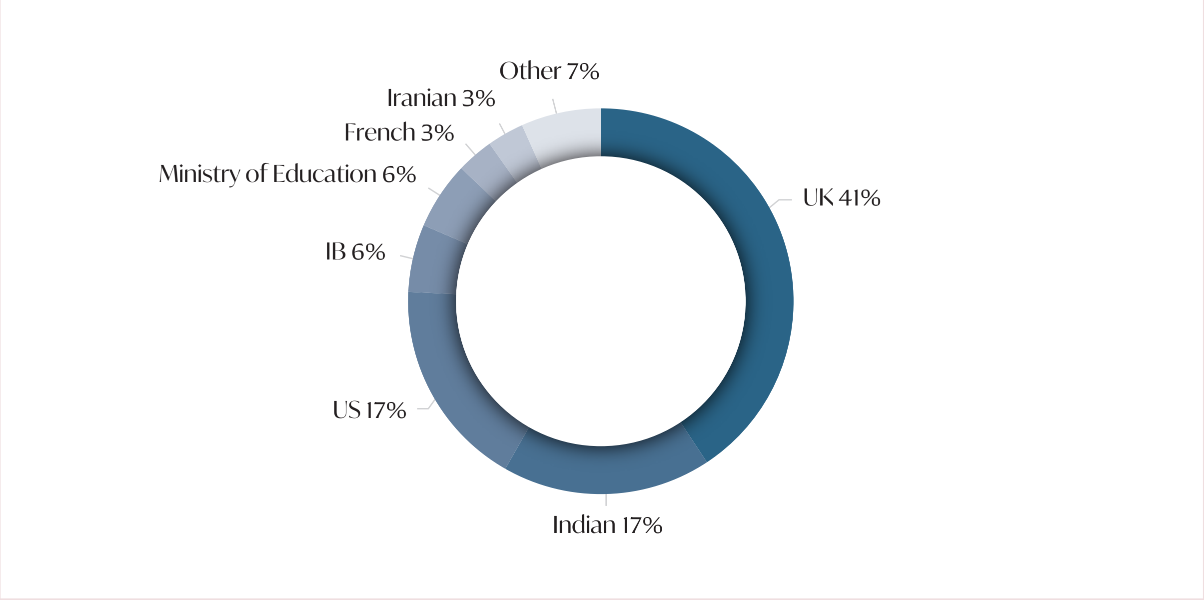
Based on the KHDA's open data for 2017/2018, there are 194 private schools in Dubai with 281,432 students belonging to 182 nationalities. 57% of Emirati Students in Dubai go to private schools and the other 43% attend public schools. There are 32,911 Emiratis attending private schools which makes up 11.7% of all private school students in Dubai.

The study shows that the most preferred curriculum in Dubai is the British Curriculum. 41% of schools in Dubai offer the UK curriculum and a total of 101,402 students were enrolled in these schools in the 2017-2018 academic year. The second and third preferred curricula are the Indian Curriculum with 34 schools and 79,705 students enrolled and the American curriculum with 34 schools and 48,282 students enrolled.

Table 5: Number of students attending schools by curriculum:

School Curriculum	Number of Schools	Number of Students
UK	79	101,402
Indian	34	79,705
US	34	48,282
IB	11	13,794
Ministry of Education	11	13,121
French	6	6,047
Iranian	6	2,485
SABIS	2	6,910
Philippine	2	4,594
Pakistani	2	2,830
Canadian	2	275
German	1	733
IAT	1	724
Russian	1	269
Japanese	1	135
KG	1	126

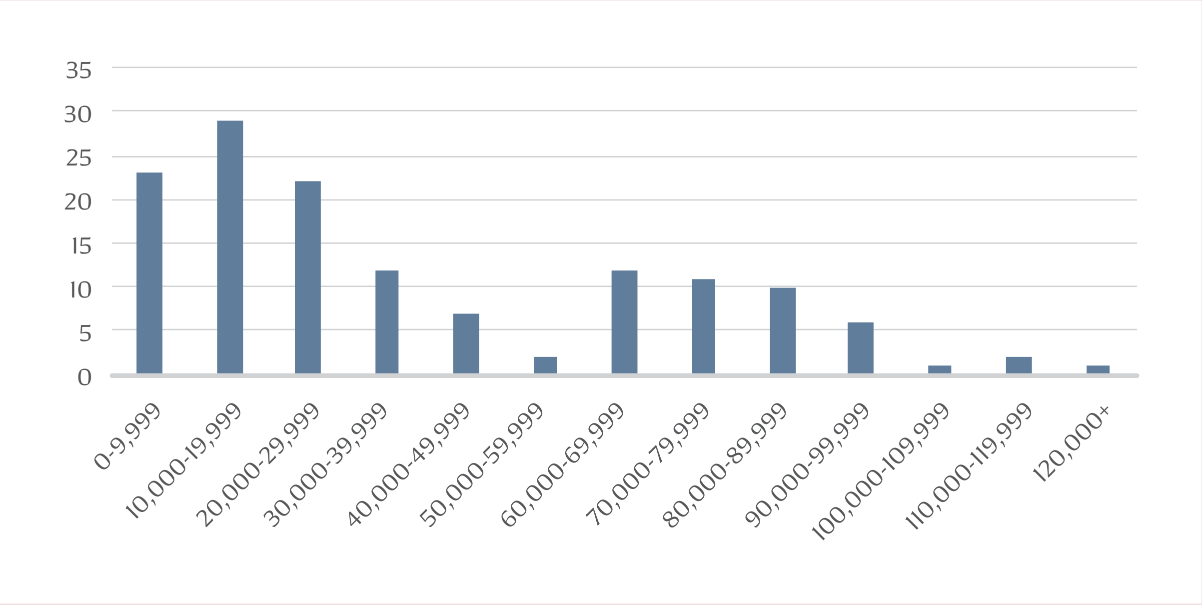
The following chart shows the percentages of each curriculum offered in private schools in Dubai:



Secondary Private Schools in Dubai

There are 134 private schools in Dubai providing education for grades 9 and above. The average tuition fee per student attending G9-G12 in a private school in Dubai for the year 2017/2018 is 39,287 AED a year.

Table 6: Tuition Fees for grades 9-12:



Below we can see the average annual tuition fees for each curriculum in Dubai's private schools. Schools offering an IB curriculum have the highest tuition fees with an average cost of 84,007 AED.

Table 7: Average Annual Tuition Fees per Curriculum

School Type	Average Tuition (AED)
IB	84,007
Canadian	75,750
German	64,625
UK	49,826
French	48,296
SABIS	38,701
American	37,420
Russian	21,963
Indian	17,111
Iranian	11,820
MoE	11,043
Philippine	10,497
Pakistani	6,225

Table 8: Number of Schools Offering High School Education per Curriculum

Curriculum	Number of Schools
UK	49
US	29
Indian	23
IB	11
MoE	8
Iranian	6
French	3
Philippine	2
Pakistani	2
SABIS	2
German	1
Russian	1
Canadian	1

It is clear that there is a relationship between school ranking and school fees. Schools that have a higher ranking by the KHDA appear to have higher tuition fees.

Table 9: Average High School Tuition Fees by Ranking

School Ranking	Average High School Tuition Fees (AED)
Weak	9,280
Acceptable	20,840
Good	39,071
Very Good	60,252
Outstanding	76,895
Not Inspected Yet	39,160

Teaching in Dubai Schools

There is a set of minimum requirements that teachers in the UAE need to meet to qualify to teach in the country. These requirements are set by the Ministry of Education. Every teacher should have earned a bachelor's degree or a 4-year university degree or higher within their area of specialization. All their certifications must be attested by the Ministry of Foreign Affairs and International Cooperation and the embassy of the country issuing the university degree.

In 2017, the Ministry of Education launched a licensing system for teachers in the UAE. In order for a teacher to obtain the license, he/she has to take an exam which evaluates their pedagogical skills and knowledge of the subject of their specialization. In the case of teachers failing the exam, they are given customized training based on their demonstrated level of performance in order to be able to meet the ministry's criteria.

By the year 2020, It will become compulsory for all education professionals to be licensed. The exam will not only be required for teachers, but also principals, vice-principals and managers.

This system was co-developed by the Ministry of Education (MOE), National Qualifications Authority (NQA), the Knowledge and Human Development Authority (KHDA), Department of Education and Knowledge (ADEK) and Abu Dhabi Centre for Technical and Vocational Educational Training (ACTVET) and aims to ensure good quality teaching which is in line with the national agenda indicator for 'First-Rate Education'.

Popular Secondary School Curricula in Dubai

American Curriculum

There are 34 private schools in Dubai offering the American curriculum with 48,282 students enrolled.

Students who attend American Curriculum schools attain an American High School Diploma. The American Curriculum is a credit-based system and each school requires a different number of credits in order to graduate high school, typically a minimum of 25 credits. There is no centralized national curriculum, but schools make sure they follow the American Common Core State Standards for English Language Arts/Literacy and Math and the Next Generation Science Standards (NGSS) for science education and often choose to follow the curriculum of a particular state. This is meant to set a minimum standard for K-12 education in all American curriculum schools.

When students graduate high school, they receive their Grade Point Average (GPA) which is an average score of their course work of their past four years. Students at the high school level are required to take a variety of courses without any specialization and also choose from a range of electives.

Some schools offer Advanced Placement (AP) courses for grades 11 and 12 which prepare students to take the AP Exams. There are 38 different AP exams offered that students could choose from and the exams are administered by the College Board.

UK (British) Curriculum

There are 79 private schools in Dubai offering the British Curriculum with 101,402 students enrolled. British Curriculum schools in Dubai follow the National Curriculum of England. It consists of four key stages, Key Stage 1 for grades 1-2, Key Stage 2 for grades 3-6, Key Stage 3 for grades 7-9 and Key Stage 4 for grades 10-11.

The International General Certificate of Secondary Education (IGCSE) offers mandatory courses in the core subject groups of mathematics, science, English language, English literature and modern foreign language. Students can then take courses from a broad range of electives which depend on the subjects that a school chooses to offer. Students take the IGCSE exams and are then awarded certificates in the subjects they complete. The IGCSE prepares students for the Advanced Level Qualifications (A-Levels). Students might also opt for the Business and Technology Education Council National Diploma (BTEC) which is equivalent to the A-Levels. Students who choose to take the BTEC exams typically are planning on fulfilling a university degree in business.

A very common practice in British schools is 'The House System'. Students are divided up into houses with the purpose of having them compete in either athletic or academic competitions. Students are also awarded on their behavior and extra-curricular participation by receiving house points.

Indian Curriculum (CBSE)

There are 34 schools in Dubai offering the Indian curriculum with 79,705 students enrolled.

These schools follow the national curriculum of India which is developed by the Central Board of Secondary Education (CBSE). At the senior level, the Indian curriculum has a core that consists of two languages and mathematics. Students then choose from a number of electives ranging from science to history and geography. The updated CBSE curriculum now offers vocational education options as electives which become mandatory for students who fail a subject elective.

The CBSE system is highly structured a relies on standardized textbooks. Assessment of students happens throughout the year. These formative assessments are mandated by the curriculum. Students can take the board exams in the 10th grade or the 12th. The board exams are optional in the 10th grade but mandatory in the 12th.

International Baccalaureate Curriculum

There are 11 schools in Dubai offering the IB curriculum with 13,794 students enrolled.

Schools offering the IB curriculum divide students into 3 programs: The Primary Years Program (PYP) for ages 3-12, The Middle Years Program (MYP) for ages 11-16 and The Diploma Program (DP) for ages 16-19.

The DP contains six academic subject groups which are (1) Studies in Language and Literature, (2) Language Acquisition, (3) Individuals and Societies, (4) Sciences, (5) Mathematics and (6) The Arts.

At the secondary level the IB curriculum has five mandatory subjects: Mathematics, Physics, Biology, Chemistry and Arts. Students then take electives of their choosing.

IB curriculum students have both internal and external assessments. The external assessments are written exams that include essays, written response questions and case study questions. Exams are scored on a scale of 1 to 7 with 7 being the highest. Internal assessments are prepared by teachers and taken in class. Depending on the topic, students do fieldwork, laboratory work, oral exams and artistic performances.

THE STUDY

Methodology of the Study

This study utilized a qualitative methodology. 10 School principals and 24 science and math teachers were interviewed in a total of 13 private schools in the city of Dubai. Where possible, participants were interviewed on an individual basis. Where this was not possible, one to three teachers were interviewed together. In all but two cases, principals were interviewed separately.

Interviews with principals interrogated the following topics: (1) school structure, (2) resource and funding sources, (3) resource allocation, (4) teacher recruitment, (5) teacher training and evaluation, (6) school strategies and strategic directions, (7) policies regarding curricula and instruction, (8) policies regarding parent engagement.

Teacher interviews interrogated the following topics: (1) school curricula, (2) curricular development, (3) classroom instruction and STEAM practices, (4) student motivation, (5) extracurricular activities, (6) student support, (7) teacher support and training, (8) teaching loads, (9) integration of online and digital resources and technology, (10) facilities and resources.

Of the schools we visited, four offered an American curriculum, two offered an Indian curriculum, three offered a UK curriculum, one offered an International Baccalaureate (IB) curriculum and two schools combined both the UK and IB curriculum into their program giving their students the choice of either one.

In addition, eight of the schools we interviewed were ranked good, one was ranked very good, and four schools were ranked outstanding.

The average cost of school fees for secondary school students in the selected schools ranges from 19,000AED to 115,000AED a year. Five of the interviewed schools were within the range of 20,000AED to 39,000AED, one school was within the range of 40,000AED to 59,000AED, four schools were within the range of 60,000AED to 79,000AED, two schools were within the range of 80,000AED to 99,000AED and one school was within the range of 100,000 to 119,000AED.

FINDINGS

Our research has indicated that there is a large diversity in school practices as they relate to STEAM education in Dubai. This is the result of a variety of factors starting with the diversity of school curricula in the city as well as the variety of school infrastructures and resources. As a result, we have found that STEAM education varies between schools, though schools share a number of practices and understandings of STEAM education.

STEAM Education as a Philosophy in Dubai Schools

Our interviews have indicated that all of the schools that we visited have developed an emphasis on STEAM education that results in part from the KHDA focus on STEAM and innovation and the National Agenda PISA and TIMSS indicators.

By and large, teachers and principals understand STEAM as an integrated practice of teaching and learning in which science, math and arts subjects ought to be taught together so that students incorporate concepts and skills found in each of these subjects. Teachers and principals understand STEAM as being an important component for preparing students for the future – whether for the surge of technology in the workplace or for a dynamic labor market that places a high premium on 21st century skills.

While teachers and principals understand very well that STEAM includes integration of skills and integrated teaching through hands on projects, the specifics of what makes a STEAM education different from, say teaching multiple science, math and design subjects is still missing. This can be attributed to the vagueness of the term and to the debates that are still ongoing in education about how such a concept is implemented in lesson plans and projects.

As a principle, STEAM is understood as the thematic integration of multiple subjects such as mathematics, physics, biology, chemistry and art or the practical integration of multiple skills into science and technology-oriented projects such as robotics and engineering. Other forms of integration were not easily identified by teachers. Few teachers were able to articulate integration beyond a sequenced model, where topics in one or more disciplines were taught in parallel such that students can make connections between them, or a shared thematic model, in which two lessons with shared organizing themes can be taught together with teachers coordinating a single lesson.

The common understanding between teachers that we interviewed is that STEAM requires project-based learning that emphasizes and enhances 21st century skills such as critical thinking and problem solving, creativity and innovation, teamwork and communication and adaptability. Laboratories and STEAM spaces are understood as spaces in which this kind of project-based learning can occur.

When asked if schools have a STEAM curriculum, all the schools interviewed for this project responded that they employ a STEAM curriculum. However, when describing their curricula, all of the schools interviewed still appeared to teach subjects separately.

STEAM as a philosophy that integrates multiple conceptual, cognitive and practical skills is largely implemented in extra-curricular or co-curricular projects that are developed outside of the classroom in science and technology clubs or in robotics, 3D printing or Lego labs.

Teachers and Teacher Training

Due to KHDA guidelines and regulations, all of the science teachers interviewed for this study held science degrees in areas somewhat related to the subjects they teach though those who taught middle school also taught science subjects unrelated to their area of specialization.

Not all teachers interviewed held international teaching certificates or education degrees. Eight out of the thirteen schools required international teaching certifications to consider teachers qualified and requested such certification during the hiring process. However, schools where not all teachers were certified reported assisting new teachers with receiving teaching certifications as well as assisting teachers with preparing for upcoming national teacher licensing requirements.

At the time of the interviews, all of the teachers we talked to reported receiving training though not in relation to STEAM in particular. While training was offered to all teachers it was largely occasional and peer to peer. In some schools, professional development seminars, however brief, occurred on a regular basis, per quarter or per month. However, many teachers reported training being rare and only in relation to changes in curriculum or new technical resources. Schools that belonged to large conglomerations of schools such as GEMS and Taaleem had larger peer to peer training seminars, workshops and conferences where teachers and school leaders are able to share their experiences.

In addition, some teachers reported attending national education conferences such as the GESS conference. Schools reported sending one or two teachers, usually heads of department to such conferences and required those teachers to share the insights they gained with colleagues.

A major hindrance to teacher training, as reported by teachers and principals, was the availability of resources on the one hand and the availability of time on the other. While not all teachers were able to accurately report the number of hours they worked in addition to their in-classroom teaching time, on average, our interviewees reported working 50 to 70 hours a week. This included several hours of class preparation and grading that teachers did at home or after school hours. Teachers involved in coordination or administrative roles typically had a lower teaching load; however, the average full-time teacher interviewed in this study taught 5 class periods a day across multiple grades or sections[9].

These time commitments made it very difficult for teachers to receive outside training or to dedicate enormous amounts of time to class preparation or to developing new and innovative teaching plans that required coordination between teachers or a great deal of research. Many teachers suggested that they considered their teaching load to be burdensome. For many, the number of hours required to grade assignments, plan for classes and mentor students outside of class hours lead to a reliance on lesson plans and activity plans from past years.

Seasoned teachers in particular reported that they used the same lesson plans and power point presentations several years in a row. When they have time, they reported updating some aspects of their materials but rarely changing much.

Teachers who belonged to schools that utilized online teaching resources, such as pre-prepared presentations, online textbooks and worksheets, and online lesson guides found that their teaching loads were significantly improved.

STEAM in the Curriculum

STEAM in Dubai private schools was dependent almost entirely on the curriculum offered by the school. Due to accreditation and other requirements, teaching the curriculum on offer was the number one priority for teachers and principals. Many did try to incorporate STEAM principles and practices into their teaching even when abiding by this or that curriculum.

9. These estimates are based on the estimates provided by teachers during interviews. They provide only a rough estimate and are not to be considered statistical data.

Students in secondary school across the UAE have a choice of learning basic to advanced science and mathematics ranging from Algebra II, Geometry and basic Science to Calculus II, Trigonometry, Physics and Chemistry. Typically, the range of classes that a student can choose from and whether they are considered mandatory or elective depends on the curriculum.

By and large, global curriculums such as the ones taught in Dubai private schools do not mandate that students learn science subjects in their senior years of high school, though they might have to learn at least one science or math subject in their first two years of high school (See table 10 below).

Curriculum	Courses	Compulsory or elective (High School)
IGSCE	Mathematics Science (General) Physics Chemistry Biology Arts	Compulsory Compulsory Compulsory Compulsory Compulsory Elective
A Levels	Mathematics Physics Biology Chemistry Arts	Elective Elective Elective Elective Elective
American Common Core	Mathematics Physics Biology Chemistry Arts	Compulsory Elective Elective Elective Elective
Indian CBSE	Mathematics Physics Biology Chemistry Arts	Elective after grade 10 Elective after grade 10 Elective after grade 10 Elective after grade 10 Elective
International Baccalaureate	Mathematics Physics Biology Chemistry Arts	Elective after grade 10 Elective after grade 10 Elective after grade 10 Elective after grade 10 Elective after grade 10

On the whole, teachers in Dubai schools reported that math and science subjects, even when considered electives, were popular with students and their parents and that students tended to opt into these subjects.

All curricula teach science and mathematics subjects separately at the high school level. Often times this is to fulfill testing requirements and other curricular standards. Teachers reported that curricula at the elementary and middle school level tended to be more interdisciplinary and taught the sciences and maths together where mathematics skills were used to enhance science skills and vice versa. At the lower levels the arts were consistently used to engage students in learning and to demonstrate concepts.

All of the schools we visited had a strong emphasis on lab work and understood the importance of practical hands on science learning. However, the degree to which students had access to or an ability to partake in hands on learning depended on the resources available to the school. Some of the schools we visited had weekly lab sessions for each science subject while others visited the lab once a month.

STEAM in Extra Curricular Activities

STEAM in Dubai schools is implemented largely as an extracurricular activity. All of the schools we visited had at least one form of STEAM extra-curricular activity and often more.

The most popular forms of extracurricular activity were science fairs and science clubs in which students worked in groups to solve a real-world problem. All the schools we visited implemented some form of this particularly for early high school and middle school students. These clubs and fairs were intended to activate students' curiosity and creativity and engage their entrepreneurial skills. Students were expected to develop a solution to a problem by using engineering, scientific principles and design principles. After developing a solution, students developed a marketing scheme for their invention and were expected to pitch it to business people, parents and teachers at their science fairs.

Other common extra-curricular activities included STEAM competitions in which students responded to one or more prompts and worked in teams. One such competition is a robotics design competition in which students engaged in robotics design, basic coding, and engineering. Other competitions include such things as the F-1 competition in which students are expected to design a car based on engineering and physics principles such that it will beat other designs in a race. Students are also encouraged to seek out sponsorship for their designs from local businesses.

Facilities and Laboratories

Laboratories designed for STEM projects and experiments were available in all of the schools interviewed for this report. All schools had a minimum of two laboratories that were shared among middle school and high-school students. However, almost half of our sample reported having at least 6 labs, around one third of our sample reported having 3D printing labs, and all of the schools in the sample reported having robotics or Lego labs or used robotics kits.

Lab facilities were designed for student group work and were equipped with things like microscopes, basic chemicals for chemistry experiments, biology charts and models, and weights and measures for physics. The amount and variety of equipment varied between schools. In around 30% of the schools visited, teachers said that their labs were not well equipped or that they did not have enough equipment for each child or each two children to work on a single experiment.

Science and math labs were used primarily used to implement project and experiment-based learning for science and math classes. In some cases, these spaces also doubled up as STEAM labs in which students were encouraged to use robotics kits and other STEAM related resources in after school activities. In the cases where STEAM labs existed, those were used for project-based learning, science and robotics clubs, and for programming, robotics and Lego based learning.

Integration of Technology

All of the schools visited for this study either provided their own devices to students or requested that students bring their own devices to school (BYOD). BYOD policies encourage students to purchase personal devices based on a set of guidelines provided by the school. These devices are then used by the child in school and at home to complete assignments, access supplementary materials, and utilize the internet inside and outside the classroom.

These devices are registered onto the school network where schools have control over Wi-Fi access and internet access. In addition, teachers in many schools can access the devices of students during lessons to ensure that students are using their devices as necessary.

The primary function of technological devices in schools was to access online materials. Those were in the form of:

- eBooks
- E-exercises based on ability and progression through the material

- Presentations
- Multi-media such as videos and sound clips
- Internet sources such as YouTube and webpages
- Search engines such as google

Student Centered Learning

All of the schools visited for this study said that they practiced student centered learning. This was understood as a teaching method and philosophy that focuses on the individual student, his or her abilities and his or her needs. Student centered learning is intended to produce independent students who are able to learn autonomously with the teacher acting as a guide.

Schools that taught the UK curriculum employed CAT 4 or the Cognitive Abilities Test to determine a student's ability and skill level across (1) verbal reasoning, (2) non-verbal reasoning, (3) spatial reasoning and (4) quantitative reasoning. The CAT 4 is used to determine the learning goals set for each child which take into account his or her starting point. Teachers have access to each student's CAT 4 test and profile and can adjust their teaching style to suit each student.

The frequency of CAT 4 testing differed between schools with some schools giving students the test on a yearly basis and others doing so less frequently. Schools that did not employ this kind of testing still have personalized education methods such as student passports or ability assessments that teachers make on a case by case basis.

Teachers then differentiate students based on their ability level whether through formative assessments in the classroom or formal assessments. Only around one third of schools that we visited employed formal streaming or had a gifted and talented track. However, all schools differentiated students in each lesson by ability level. Based on these assessments, teachers differentiated students by:

- Task – where different ability levels are given different tasks
- Group – where team work groups are determined based on skill sets and how students will work together
- Resources – level of complexity of experiments, online resources, or ever exercises
- Pace- some students are given more time to complete a task than others
- Outcome – where some students are expected to achieve different kinds of outcomes than others

This, teachers believe, allows all students, irrespective of their ability level to learn in the same classroom.

CHALLENGES

Our interviews showed that there were five main challenges that faced Dubai Schools in implementing STEAM education. First, schools implemented STEAM primarily as an extracurricular activity that was delivered through clubs and science fairs. Second, teachers who teach science or math subjects reported that they either did not have the necessary time or the training to deliver integrated course material which requires considerable planning of content and activities. Third, while all of the schools we visited either were currently utilizing resources like robotics kits or had at some point utilized them, resource allocation and adequate use of these kits and labs was still an issue. Fourth, while all the schools we visited encouraged the use the internet and online resources for learning and accessing information technological integration was still limited to the use on e-books/e-worksheets or internet search engines and online multimedia. Finally, Schools felt a difficulty in meeting curricular and accreditation standards while also meeting the goals of integrated STEAM education.

Integrating Curricula

Teachers and heads of science and math departments that were interviewed for this study acknowledged the importance of integrated curricula for advancing student understanding of STEAM subjects and for connecting STEAM learning to real world issues. This, teachers acknowledged, raised student interest and motivation and ensured engagement by students irrespective of their ability or performance. As principals and teachers were aware of the trends globally but also in schools in the city and the country more broadly, there was a strong push among all schools toward interdisciplinary or integrated instruction. However, these efforts ranged from purely extracurricular in the form of science fairs and science clubs to a few classes a week that were 'integrated'.

While all of the schools we visited had a strong emphasis on math, science and technology and encouraged STEAM in their extra-curricular activities, only 5 out of the 13 had an explicit emphasis on integrated STEAM education within the classroom such that teachers were encouraged to consistently incorporate other disciplines in their teaching as a matter of school strategy.

Some curricula posed more difficulties for teachers than others. Teachers who taught in British and Indian curricula schools were especially concerned with the rigidity of curricular requirements that culminated with standardized tests. Many of those teachers reported integrating STEAM subjects in extracurricular activities which incorporated multidisciplinary projects, experiments and challenges, but adhering to the curriculum in all other ways in order to ensure that students were prepared for exams.

Teachers in one Indian curriculum school reported teaching classes, even within curricular requirements, that were co-designed with teachers from other disciplines and in which lessons from that week were incorporated. This however, was subject to the time available to teachers to prepare and to the progress they had already made within the traditional curriculum. Teachers who taught in IB system schools reported more flexible teaching standards that enabled them to develop their own teaching plans that may or may not contain STEAM activities. This was left up to the teacher. Additionally, teachers reported that, in general, the American, British, IB and Indian curricula were moving towards interdisciplinary learning though, for now, these moves appeared to be primarily reflected in worksheets or side notes that children could read about in their text books.

In general, when teachers related to us the methods they used to integrate curricula, they were primarily describing topic centered integration in which one common theme, like climate change, was discussed from the perspective of many different subjects – chemistry, physics, environmental science, geology etc. In these cases, the independence of each subject is maintained, even if the lines are somewhat blurred. Teachers come together on one theme but discuss different concepts that enhance the student's understanding of a single phenomenon. Art and design were usually integrated as a way to visualize concepts but not as a subject matter in and of itself.

By and large, teachers reported great difficulty in delivering truly integrated curricula where a teacher can teach common or overlapping concepts from within a variety of disciplines. This is because, while nice in theory, the practical elements of curricular integration were not yet thought out. Primarily, teachers complained that integrating curricula required a great deal of time and coordination between sections and teachers. First, teachers would have to meet on a weekly basis to plan classes together and likely even co-teach. Second, integration as a concept is still ill-defined, meaning that teachers still did not have reliable guidelines or measures for successful curricular integration. This posed a major problem for teachers as they tried to translate the concept of integration to lesson plans and day to day practices.

Overall, while heads of departments encouraged curricular integration and teachers made attempts to integrate STEAM education into their curricula, these efforts were not standardized and indeed standards that defined integration were non-existent. This meant that curricular integration was largely ad hoc and depended heavily on every individual teachers' capacity, knowledge, and creativity.

Teacher Capacity

All teachers interviewed for this study reported engaging with STEAM education in one way or another. Where curricula were not acknowledged as multidisciplinary in nature, teachers felt that they had to take an initiative to introduce multidisciplinary lesson plans and practical activities that encouraged creativity and problem solving. While the broad learning objectives of STEAM education might be widely understood, translating these objectives into enhanced lesson plans proved to be a challenge for teachers.

For those teacher and others who made an explicit effort to integrate curricula, aligning lesson plans with STEAM objectives posed a challenge. While 10 out of the 13 schools offered teacher training, primarily in house, curricular integration and training teachers on the tenets of STEAM education was not offered. However, schools did train teachers on the use of technology, teaching with robotics or Lego kits, and on general practices of personalized education and project-based learning. Training was largely peer-to-peer in the form of Training and Development or informal mentoring.

Teacher loads, which consisted of teaching an average of 5 classes a day in addition to administrative duties, hindered teachers' abilities to develop their skill sets or design new lesson plans. Additionally, teachers reported that teaching an interdisciplinary curriculum that taught shared concepts required teachers to re-educate themselves in the concepts and methods of other sciences, which they may not be familiar with.

Overall, and also due to the lack of a formalized understanding of STEAM education measures and standards, training in STEAM teaching methods and in strategies for developing STEAM lesson plans and projects, there was a shortage of training opportunities for teachers in STEAM. While many teachers improvised STEAM lessons, teachers who were less confident did not take such risks. A lack of formalized training in STEAM teaching methods creates a problem in which STEAM education is left entirely up to the individual teacher's capacity and creativity.

Resource Allocation

Resource allocation was an issue for schools whose funding was limited. In one school, the principal reported that, while there was enthusiasm and support for funding innovation and STEAM labs, there were not enough financial resources to provide these kinds of resources to all grade levels. As a result, the school opted to offer this resource to only middle school children. In addition, the school reported having to fundraise additional funds to purchase these resources. Other schools, while having adequate funding, reported a lack of expertise and experience with the market for things such as robotics kits and other similar resources.

Indeed, heads of science departments faced issues in differentiating between vendors and in understanding the costs and benefits of different providers. One teacher told us that, because the market was so saturated with buzz words, sales representatives for STEAM teaching and learning resources, particularly those related to design and engineering, and specifically robotics kits, all sounded the same. Schools and science departments are spending school funds on these resources that seem to them, at the moment, to be indispensable. However, teachers report that guidance on their appropriate use and on how to integrate them in a holistic way into classroom instruction was lacking.

Many, but not all, of the schools we visited had 3D printers, robotics labs, and break out spaces for STEAM activities. These resources were open and available to all students. However, students used them primarily in dedicated classes, for example for design and 3D printing, or during extra-curricular activities.

By and large, the funding available for purchase of such resources played a determining role in whether these resources were available and to whom. The way they were used depended heavily on what was purchased in the first instance and on whether teachers received the appropriate training on how to use these resources. This training, we were informed, was usually delivered by the solutions provider.

Incorporating Technology

All of the schools we visited used computers in their teaching practices. Some schools had a Bring Your Own Device (BYOD) policy and others offered devices to their students. In all cases, students were encouraged to bring their own personal devices to school and teachers incorporated digital presentations and online resources into their teaching plans.

In most cases, student textbooks included an online equivalent that linked to the web and offered online worksheets and presentations to students. These resources were invaluable to teachers and they reported that such resources facilitated their lesson planning and allowed students to partake in more personalized and self-guided learning.

However, there were also reports of teachers facing difficulties with online resources, though all schools reported that those teachers were offered training to improve their computer and digital skills, these challenges still existed. Our interviews did show, however, that the implementation of online resources and technological integration varied from school to school and was largely inconsistent.

In some schools, teachers had the choice of whether to make use of online resources or not. As these choices were left up to teachers, some students benefited from them while others did not. Additionally, not all schools had online resources. In large part, as was explained to us, this was because textbook manufacturers did not always have updated online resources for all of the science and mathematics textbooks. Additionally, some textbook manufacturers did not provide online resources at all. This left digital resource integration inconsistent even in the same school or from year to year.

Where these resources were not readily available and provided by the textbook manufacturer, teachers were compelled to prepare their own presentations, and find their own online resources on the web and on YouTube. This increased the lesson planning burdens on teachers. Online resource provision, which often included premade presentations, lightened the load on teachers considerably and encouraged even the technologically reluctant to incorporate online learning in the traditional classroom.

By and large, with few notable exceptions, technology was used to digitize what might be considered traditional teaching materials but was not used to encourage experiential learning. Some notable exceptions include one school which reported using simulation technology for teaching anatomy in biology classes as well as piloting the use of gaming in science teaching.

Balancing Curricular Requirements with STEAM Objectives

Finally, a major challenge that was already touched upon was balancing traditional curricular requirements with STEAM objectives. Due to the variety of curricula that are employed in Dubai schools, these challenges varied in intensity. Teachers in only around one third of the schools we visited said that their school curricula facilitated integrated STEAM course delivery. Others took it upon themselves to deliver integrated coursework but felt it often times fell outside of their curriculum.

In general, American and IB schools reported some flexibility in the methods that teachers chose to deliver their lessons. IB teachers in particular, reported that the IB curriculum encouraged interdisciplinary learning and therefore it was not difficult for them to follow the curriculum and achieve STEAM objectives. However, teachers in UK and Indian system schools found that completing the content required for examinations and ensuring that students were prepared for standardized exams was a priority and that STEAM educational methods did not always facilitate exam performance.

Indeed, examinations and standardized testing were a major component in school ratings and rankings and in how schools assessed their own success. In many cases, student performance on standardized exams such as the A Levels and Indian university entrance exams, or Advanced Placement (AP) tests determined their college and university admittance and attendance.

Teachers viewed integrated curricula as important for student motivation and their engagement with and understanding of STEAM related subjects and concepts. However, because testing and other curricular assessment strategies had not caught up with STEAM teaching methods, teachers preferred to limit STEAM to extra-curricular activities where they had more freedom to instruct students and develop activities and projects without having to mitigate any risks in the process.

OPPORTUNITIES

Culture of interdisciplinary learning

The schools we visited appeared to have a clear understanding of the importance of interdisciplinary learning that was demonstrated by students, teachers and principals. The combination of curricular and extracurricular activities as well as the parental involvement and external partnerships has led to an ethos of hands on learning that is embedded in the school community. Teachers and students enjoyed a form of learning and teaching, whether inside or outside the classroom that sought to relate learning to the real world and therefore make it meaningful to students.

Furthermore, the push toward personalized learning has created a sense of teaching and learning as a collaborative partnership between faculty and students that is based in a growth mentality that encourages students to learn at a pace that is comfortable for them.

This was achieved by:

- Moving away from teacher directed projects to self-directed collaborative work in STEAM. This was true primarily with STEAM activities that took place outside of the curriculum or that supplemented the curriculum.
- Developing inquiry-based exercises and projects inside and outside the classroom.
- Efforts to create engaging lab experiences through purchasing latest resources and using household and other relatable items to discuss and explain scientific concepts.
- Encouraging faculty to engage in STEAM activities that engage teacher's own creativity and initiative.
- Raising awareness about the importance of STEAM subjects and collaborative, interdisciplinary learning.

Emphasis on Project-based STEAM Activities

While STEAM was primarily integrated into extra-curricular rather than curricular activities, it took the form of inquiry and project-based learning that emphasized cognitive skills. Project based learning as a method of teaching valuable skills was well understood and articulated by teachers that saw themselves as designing tasks, whether in traditional physics experiments, or more complex robotics projects, that required students to demonstrate independence, explore possibilities, research on their own, respond to a problem or task, and work together. Projects were the primary way in which teachers viewed themselves as implementing STEAM and in which they related subjects to the real world.

In most cases, students were offered a complex real-world challenge by their teachers and asked to respond to it as a team. According to our teacher interviews, this form of inquiry-based learning required students to first:

- Research a problem and learn more about it
- Understand the complexities of an issue and communicate their understanding to one another
- Plan a solution and agree amongst each other
- Divide roles and collaborate
- Design a solution and test it
- Present their solution to their friends and teachers

This form of active learning by doing enables students to develop a number of 21st century skills including information literacy, media literacy, social skills, leadership skills, flexibility, collaboration, creativity and problem solving.

Integration of Robotics

All of the schools visited in this study had employed robotics or Lego kits for teaching STEAM. Teachers utilizing robotics did so, often, because integration of this resource was seen as a best practice that enhanced student learning. In most cases robotics kits and their use were enthusiastically adopted by students. Even while teachers faced challenges in understanding the best ways to use robotics for STEAM instruction, those schools with qualified engineering teachers and teachers trained in how to use robotics kits found them to be highly impactful for students.

Robotics act as a tool that enhanced students' learning experience by offering hand-on learning that also engages students' knowledge and understanding of systems and circuits.

Teachers reported that excitement around robots increased student motivation toward STEM and provided avenues for students who do not demonstrate high ability in mathematics or science subjects to engage with STEAM productively.

Robotics kits also offered students access to the identity of maker or innovator.

Teachers reported that students' interactions with robotics kits allowed them to imagine new and ambitious projects in which they were the driving force or the maker that was able to take something from an idea to a material reality.

Collaboration between Schools

Our interviews indicated that there was a sincere effort by schools to share experiences and best practices. Schools with resource limitations were looking to inter-school collaborations and partnerships in order to offer their students access to resources that they may not be able to offer. One such school that we visited reported meeting with a school next door to talk about sharing resources and experiences. As a result of these meetings, the schools decided to share their outdoor student spaces and students were able to interact with one another school by way of a shared wall now made more porous.

Schools which belong to the same corporate umbrella such as Taaleem or GEMS can rely on their networks of schools for resource and experience sharing. Those networks organized workshops and seminars that included multiple schools under the umbrella. These workshops encouraged the sharing of best practices in which heads of department or particularly successful teachers ran workshops with colleagues.

Large conferences such as GESS offer another example of ways in which schools share their experiences as well as learn from external experts that come to the UAE primarily to talk about new trends in teaching and learning. This kind of conference brings together teachers from multiple schools around the UAE.

These existing experiences offer an opportunity for expansion in a way that enables schools and teachers to learn from one another but also to develop a joint and on-going definition of STEAM education and define a set of good practices around it.

Extracurricular STEAM

While STEAM education cannot be said to be implemented in an integrated way within curricula in Dubai schools, the implementation of STEAM in extracurriculars offers an important opportunity to pilot and test STEAM integration. This opportunity gives teachers an avenue to respond to the trade- off challenge that they currently face. While teachers may not have much latitude to integrate or experiment with STEAM in the curriculum, teachers and students are able to explore and experiment with STEAM concepts, methods and tools outside the curriculum.

Extracurricular STEAM practices already exist, but with great variability. Some schools have a very strong hand in guiding student extracurriculars and others allow students to shape these activities. Extra-curriculars and designed in a way that centers the student and offers experiential learning opportunities.

Extracurriculars can be used more deliberately however. Curriculum development projects can be piloted within these activities including curricular integration but also the use of new technologies. These activities also allow students to become actively involved as one of the main stakeholders in STEAM education development. Teachers might be more comfortable eliciting suggestions and feedback from students in these environments rather than in the classroom.

This form of experimentation creates a space where successful teaching methods can be slowly integrated into the classroom.

POLICY RECOMMENDATIONS – TOWARDS ADVANCING STEAM EDUCATION IN THE UAE

The findings of this extensive research project suggest several policy recommendations for overcoming the highlighted challenges and advancing STEAM education in the country.

Encouraging Curricular Integration

1. Developing a nation-wide interdisciplinary STEAM framework and guide. The MOE in collaboration with local entities such as the KHDA and ADEC can develop an expert and national STEAM framework that:
    - Defines STEAM clearly and consistently for all parties
    - Defines curricular integration as a spectrum so that teachers and principals can identify the degree of curricular integration in their school.
    - Defines indicators for measuring curricular integration and the corresponding cognitive skills that students should achieve.
    - Provides strategies and tools for curricular integration for teachers and principals that are flexible, adaptable and can be employed even within a rigid curriculum.

Addressing Issues of Equity/Resources

1. Encouraging resource sharing between schools through regulatory incentives. Regulatory bodies in the Emirates can develop a parallel rating framework that determines the degree of contribution that a school has to the community in which it operates. This can be a kind of social responsibility framework and rating system. This kind of system can have elements that determine the degree to which a school shares its resources and best practices with others, whether public or private schools.
2. Encouraging schools to offer scholarships and other financial aid through

regulatory incentives. The same social responsibility framework could encourage schools to offer financial assistance and scholarships to outstanding students who demonstrate financial need. These kinds of financial aid schemes, which are nationality and ethnicity blind, and which are merit and need based can encourage expensive profit driven schools to designate seats to scholarship students.

3. Developing more robust policies to disincentive excessively high school fees. The existing policies that limit school fee hikes and determine school fees based on market dynamics can be made more robust and directed. A cap can be placed on school fees such that no school can enter the market above a certain fee rate based on its facilities, curricula, teacher student ratio, etc.

Funding for and provision of professional development for teachers

1. STEAM and interdisciplinary teaching can be included as a part of the teacher licensing programs being rolled out across the UAE. These programs must be purposive and designed to help teachers explore integrated interdisciplinary teaching frameworks, practice developing integrated lesson plans, and understand the principles of STEAM education and become exposed to best practices in STEAM education delivery.

Encouraging more holistic integration of technology

1. Encouraging more holistic integration of technology requires access to advanced technologies such as gaming, virtual reality and simulations that are aimed at students and young learners. This kind of access requires a market that incentivizes the entry of educational technology companies and local innovation in these technologies. This can be achieved through local accelerators aimed at education technology. As a part of the conditions of their subsidization and funding, these start-up companies can be encouraged to pilot their technologies in local schools and to offer solutions that are tailored toward STEAM education.

CONCLUSION

The UAE, like many other countries in the world, will be impacted by the fourth industrial revolution and the rise of artificial intelligence. As discussed in the earlier sections of this report, the UAE is one of the leaders in the MENA region with respect to providing high-skilled jobs. However, the percentage of jobs that will be lost to automation in the UAE is estimated to be 47% by 2030 (WEF, 2017). A decline in jobs is not the only outcome of automation, there will be serious changes to the skills profile, where the market will witness emergent roles in a variety of sectors.

This imminent condition requires a strong policy direction and effective policy interventions that will prepare future generations for the rapidly changing world that they will encounter. Adoption of integrated STEAM education is an important response to the needs of the future. Such curricular reforms and interventions at the school and district level need to be guided, supported and improved by effective policies.

This study uncovered a number of challenges and opportunities for the implementation of STEAM education in Dubai private schools. By and large, we found that there was awareness of the importance of STEAM and an appetite for STEAM related initiatives. While, on a strategic level, schools and teachers intended to implement STEAM education, we found that efforts at implementation presented multiple practical challenges that are related to resources, teacher capacity, and overlapping objectives.

Current efforts also presented a number of opportunities. STEAM education was enthusiastically adopted and encouraged in schools. Teachers were eager to learn from one another and to integrate project based learning and robotics into their teaching practices. Extracurricular STEAM initiatives present an opportunity for experimenting with STEAM education teaching methods.

To respond to these challenges and opportunities. We have suggested a number of policy responses that aim to (1) provide further guidance to teachers about what STEAM means and how to measure success of STEAM initiatives, (2) increasing access to high quality STEAM resources for all students irrespective of income, (3) developing teacher capacity in STEAM and (4) encouraging technological adoption and integration in STEAM teaching.

This report and the corresponding recommendations aim to increase awareness of some of the practical challenges of STEAM implementation and the ways in which policy, and not just school administration, can assist in advancing these efforts and improving their outcomes.

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