122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #14085

Building Human Capacity to Meet Demand for Engineers and Scientists in the Middle East and North Africa (other)

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Abstract

Several countries in the Middle East and North Africa (MENA) have been investing significantly in the past two decades to promote and attract young and upcoming talent to pursue professions in science, technology, engineering, and mathematics (STEM).

This paper summarizes some of the recent projects implemented by Texas A&M University at its Qatar campus to promote STEM disciplines among the next generation to realize the Qatar's national development strategy for transforming from a hydrocarbon-based economy to a knowledge-based economy. The paper further documents some of the primary findings about messaging and marketing strategies designed to stimulate interest in STEM disciplines among young generations in the MENA region.

Introduction

Strategic investment in STEM disciplines has significantly been growing in the Middle East and North Africa, particularly among the oil-rich countries, since the 1990s. The State of Qatar is one of the countries in the region that has made one of the greatest investments in building human capacity to meet its development strategy, which is described in the Qatar National Vision 2030 (QNV). The QNV, which is the touchstone for all governmental spending priorities, highlights goals for Qatar's economy, in human and social development, and for environmental stewardship (1).

Qatar is a small peninsula located on the northeastern coast of Arabian Peninsula. The south of Qatar shares a land border with the Kingdom of Saudi Arabia; otherwise the country is surrounded by the Arabian Gulf (Persian Gulf), which also separates this country from island of Bahrain. The current population of the country is estimated to be about 2.2 million, of which an estimated 10-15 percent are Qatari nationals (2). Qatar's relatively small population creates greater demand and importance for a qualified technical workforce of Qatari nationals to capitalize on Qatar's natural resources.

Qatar is the among the richest country in the world in terms of per capita gross domestic product (3) and is considered as one of the most developed countries in the Middle East region. Qatar holds about 13 percent of the world's natural gas reserves (4). In 2010, Qatar was selected to host the World Cup soccer championship in 2022.

To build the necessary and sustainable human capacity for Qatar's economic transformation, Qatar Foundation for Education, Science, and Community Development was established in 1995. Qatar Foundation's vision is to lead human, social and economic development of Qatar,

making Qatar a nation that can be vanguard for productive change in the region and a role model for the broader international community (Qatar Foundation Vision, 1995).

To jumpstart Qatar's knowledge-based economy and to better facilitate the delivery of technical education, Qatar Foundation developed Education City, a state-of-the-art educational and technical complex with several world-class amenities, around 1999. At present, six well regarded American universities offer on-site degrees in Education City.

Texas A&M University at Qatar is a branch campus of Texas A&M University in College Station, Texas, that offers ABET-accredited undergraduate engineering degrees in chemical, electrical, mechanical and petroleum engineering. Since its inception in 2003, Texas A&M University at Qatar has been recognized as one of the leading institutions offering engineering degrees in the region. The campus has attracted over 85 full-time faculty members representing some of the best minds in engineering education and scholarship.

STEM Education

The State of Qatar has long acknowledged the intrinsic value of science, technology, engineering and mathematics (STEM) for empowering upcoming Qatari talent and to transform this fast-growing country into a world-class research and discovery icon in the region. Further, Qatar's efforts to nationalize its energy workforce and reduce dependence on foreign workers creates an educational exigency for motivating young Qataris to choose STEM educational pathways amid myriad options for high-paying government jobs that require little, if any, post-secondary education. To contribute to this vision, Texas A&M University at Qatar, in partnership with local industry, developed and introduced STEM enrichment programs for K–12 students and teachers through its Initiative in Engineering Leadership, Innovation, and Teaching Excellence (ELITE). ELITE has become an organizational fulcrum for marshaling campus-wide collaboration in support of STEM enrichment, and for developing the external partnerships necessary to fund such efforts.

Development and Implementation

The Office of Academic Outreach, in close coordination with the Office of Strategic Partnership and Alumni Relation (SPAR) at Texas A&M University at Qatar, developed several distinctive STEM programs in 2013. The programs include:

- ***Young Engineers and Scientists***. This program has been developed for primary school students in grades 5 and 6. This one-day engineering and science awareness program is intended to allow elementary school students to develop an appreciation for engineering and science through hands-on group experiments. Several commercially available kits were introduced to students to allow them to build structures of experiments to better understand scientific principles of force, friction and engineering mechanics.

- ***Engineering Explorers***. This three-day program has been developed for students in grades 7, 8 and 9 to partake in hands-on engineering design exercises and to learn principles of chemistry and physics. Students learn fundamental science knowledge and apply that toward engineering problem solving and design exercises. Students also learn about teamwork and leadership through group activities.
- ***Future Engineers***. This eight-day program has been structured exclusively for high performing students in grades 10 and 11 and is intended to promote engineering as discipline of choice as those students begin thinking about plans for university studies. In addition to hands-on engineering design activities and team projects, including computer aided design and 3D printing, participants are introduced to engineering disciplines along with advanced math and sciences, and they learn about career opportunities they will would enjoy after graduating with engineering degree.

Observations

Texas A&M University at Qatar in 2013 and 2014 has delivered the above stated program under sponsorship of a local petrochemical company. The programs were well received among students and their teachers, in addition to leaders in Qatar's industrial and government sectors. They have proven to be effective in gaining the attention of the Qatar's brightest young students as Qatari society places a high value on education in engineering and sciences.

For the **Future Engineers** program, 44 students representing grades 10 and 11 from 11 high schools were participated in the program. Of this group, 50 percent (22 students) were female and 50 percent (22 students) were male. In addition, 32 students (86.5 percent) were Qatari nationals and the remaining 13.5 percent were expatriates (Appendix A: Future Engineers Program).

At the **Engineering Explorers** three-day workshop, Texas A&M University at Qatar hosted 47 students representing seven middle schools. A short questionnaire was distributed at the conclusion of the workshop to gauge and assess students' interests regarding materials covered during the course of this workshop (Appendix B: Sample questionnaire distributed). About 98 percent of the students found the chemistry activities conducted during the course of workshop very enjoyable and learned from the exercises conducted. The same percentage of students also concluded that they fully understood the materials and lessons thought. Almost 100 percent of respondents in this group liked the engineering projects (mouse trap racer and circuit light kits) and learned new concepts.

The ***Young Engineers and Scientists*** workshops drew over 40 students representing four elementary schools. These one-day programs captured the attention of participants and helped them better understand the scientific concepts and engineering work behind things around them.

The outreach strategy for these STEM enrichment programs is described in Figure 1.

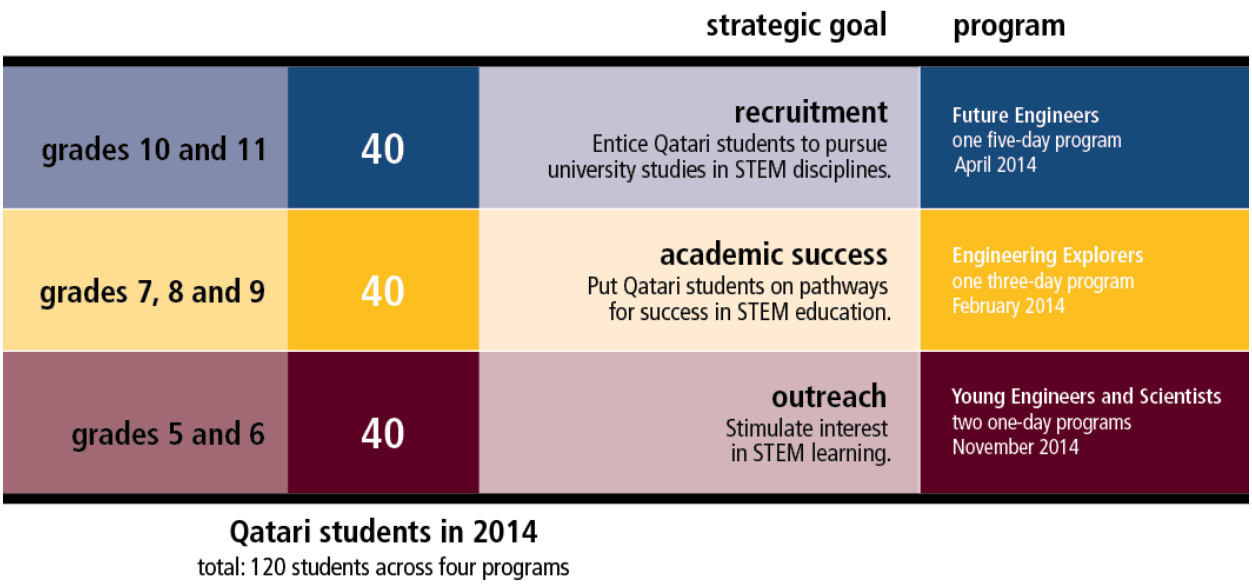


Figure 1: Texas A&M University at Qatar STEM Outreach Strategy, 2014

Anecdotal evidence suggests that the *n* (Qatari students) is small for creating relatively substantial impact on the development of a technical workforce comprising Qataris. Industry partners have indicated that the success metric is "tens of students" being inspired to chose STEM disciplines in lieu of non-STEM disciplines as a result of STEM enrichment programs developed and deployed for K–12 students. This microcosmic scale creates unique opportunities for universities while also posing unique challenges for engaging students and influencing their selection of educational and career pathways. These challenges are magnified by linguistic and cultural constraints that are a major factor in those decision making processes.

Training STEM Teachers

Offering workshops to introduce and further promote science, technology, engineering and mathematics (STEM) for elementary, middle school and high school students in Qatar have been further enhanced through developing and implementing workshops for STEM teachers. Since its inception in 2003, one of Texas A&M University at Qatar's primary objectives has been to contribute in building human capacity through community engagement. It is strongly believed that training teachers through professional development and providing them with opportunities to further increase their skills and expertise in delivering lectures in the classroom will enhance students' desires in pursuing engineering and science careers. Working closely with schools in Qatar has proven to be beneficial, and Texas A&M University at Qatar has been asked by government agencies to continue offering training workshops for STEM teachers.

Conclusions

This paper underscores the importance of STEM education in the Middle East and North Africa and highlights efforts taken under the leadership of Texas A&M University at Qatar with sponsorship of local industry to engage young and upcoming talent in science and engineering. The paper further documents some of the preliminary observations and feedback received from different age groups about their experience. Texas A&M University at Qatar's plan is to expand its offering of programs developed by faculty and staff for students and teachers to further enrich their education and give them the opportunity to clearly realize the advancement opportunities might be achieved individually and collectively for the country and the region.

References

1. Ministry of Development Planning and Statistics, State of Qatar: http://www.gsdp.gov.qa/portal/page/portal/gsdp_en/qatar_national_vision

2. Statistics Sector, Ministry of Development Planning and Statistics, State of Qatar: http://www.qsa.gov.qa/eng/PopulationStructure.htm

3. International Monetary Fund: http://bit.ly/1tERmbP

4. https://www.cia.gov/library/publications/the-world-factbook/geos/qa.html

Appendix A: Future Aggie Engineers STEM Development Program: High Schools

The program was designed to familiarize young students with the different engineering disciplines offered at Texas A&M at Qatar. The program entailed science activities, hands-on engineering projects and a computer-assisted design (CAD) contest to challenge students' design and creative skills. The five-day program entailed activities to familiarize students about the University's student life and opportunities. Students were divided into teams to work on engineering hands on projects, and CAD contest to challenge their math, science and design skills. They learned about engineering concepts, design, teamwork and creativity through different activities conducted in labs. The students also visited the Maersk Oil Research and Technology Centre at Qatar Science and Technology Park (QSTP).

During the morning sessions, students listened to all 4 engineering majors' introduction, they were also introduced to the following interactive demos:

Mechanical Engineering Demos:
During the 50 minutes demo session, MEEN lab coordinators showed case and demonstrated different areas in mechanical engineering like:

- Design in mechanical engineering: motorized wheel chair example.
- Controls: inverted pendulum (Segway) and magnetic levitation (fast trains).
- Thermo fluids: Stirling engine (energy conversion) and non-Newtonian fluid.
- Manufacturing: 3D Printing and 3D scanning.
- Material Science: high speed cam and thermal cam were used to explain different aspects of material science with real-life examples.

Electrical Engineering Demos:

During the 50 minutes demo session, ECEN lab coordinators introduced the students to the following demos:

- A Laser beam circuit. A simple electronic circuit produce sound when an object cuts the generated laser beam.
- An FPGA board work as embedded system and connected to a PC monitor. The system ran a game of memory skill.
- Play "ROBO Artist" video. A short video shows a robot drawing the A&M logo. The robot was built by freshman students as their course project.

Chemical Engineering Demos:

During the 50 minutes demo session, CHEN lab coordinators introduced the students to the following demos:

- Oxidation/apple:
- Exposure to oxygen makes sliced apple turn brown. The browning is caused by the enzyme, tyrosinase which is activated when the apple cell is damaged (cut) and thereby exposed to oxygen. By coating the sliced apple in another substance you can keep inhibit the reaction of tyrosinase with oxygen in the air, and keep it whiter longer! Demonstration of effect of water lemon juice (and the control apple slice with no treatment)

- Shape Memory Alloys:
- Explaining the properties and the application of SMA. Demonstration of Nitinol wire and Flexinol wire.
- Laminar flow:
- Visual demonstration of how laminar flow works, showing properties/reversibility of laminar flow. Glucose syrup is added to the demonstrator vessel. Three drops of color is added at different locations in the syrup. The vessel is turned slowly 5 times and the color seems all mixed in the syrup. Turning the vessel back slowly will show that the colors were in fact only sheered and they are reversed into the original drops.
- Iodine clock:
- Demonstrate the Iodine clock reaction.
- Gas Density demonstration:
- Properties of gas: SF_6 gas heavier than air, He lighter than air. Demonstration of floating an item (balloon or alufoil boat) "on air" in an aquarium filled with SF_6. Demonstration of the different weights by seeing the behavior of 4 balloons filled with: air

Petroleum Engineering Demos:

Students visited Maersk Oil facilities in QSTP, during the tour the students learned about the three key research areas undertaken at the facility including horizontal well technology, enhanced oil recovery methods and environmental research. They also experienced the new digital core lab, visualization room where they learned about the marine biodiversity and whale shark projects and received an overview of the Al Shaheen field and operations through the center's interactive LEGO model. This visit replaced the Demo session of the Petroleum Engineering program.

Electrical Engineering Project:

Introduction: Wind solar hybrid street lighting is an intelligent and complete stand-alone LED street lighting system. It composed of solar modules and small wind turbine, deep cycle batteries, controller and one or few street lights. This hybrid system harvest energy from both wind and solar and store it in deep cycle batteries to power street lights during night. Using a combination of wind & solar resources the system will provides a stable and constant flow of power to power the street lighting. The major advantage of wind solar hybrid street lighting system is that when solar and wind power productions are used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced slightly as there is less reliance on one method of power production. Often, when there is no sun, there is plenty of wind. Wind speeds are often low in periods (noon time & summer) when the sun resources are at their best. On the other hand, the wind is often stronger in periods (evening time & spring, winter) when there are less sun resources. Even during the same day, in many regions worldwide or in some periods of the year, there are different and opposite patterns in terms of wind and solar resources. And those different patterns can make the wind solar hybrid systems the best option for street lighting.

Evaluation criteria, teams' evaluation was based on the following rubrics:

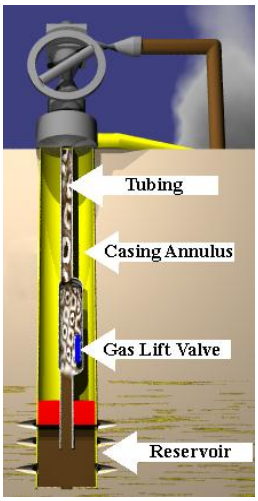
a. Determine how many solar cells are required to be connected in series, and how many batteries are needed.
b. Find appropriate values for the voltage divider to provide a reference voltage to turn on the LED.
c. Build the project circuit on a breadboard correctly.

d. Successfully run the setup and measure the generated voltages.
e. Determine an approximate amount of generated power using experimental measurements.
f. Prepare a presentation of the project, explain the function of each part of your circuit, and show calculations and experimental results.

Project outcomes:

a. Introduce the students to renewable energy, like solar and wind.
b. Introduce the students to different electronic components and devices.
c. Understand basic electrical quantities: current, voltage, and power.
d. Apply basic knowledge on circuit analysis and science to the solution of practical problem.
e.

Petroleum Engineering Project:



Gas lift experiment:

There are some oil wells that have insufficient reservoir pressure to produce the well. In the petroleum industry, the process involves injecting gas through the tubing-casing annulus. Injected gas aerates the fluid to reduce its density; the formation pressure is then able to lift the oil column and forces the fluid out of the wellbore. Gas may be injected continuously or intermittently, depending on the producing characteristics of the well and the arrangement of the gas-lift equipment.

The amount of gas to be injected to maximize oil production varies based on well conditions and geometries. Too much or too little injected gas will result in less than maximum production. Generally, the optimal amount of injected gas is determined by well tests, where the rate of injection is varied and liquid production (oil and perhaps water) is measured.

Chemical Engineering Project:

The students were asked to produce a bottle of lemonade, utilizing various unit operations. The learning target is for the students to gain some elementary knowledge of industrial processes and to have a basic understanding of the build-up of a factory.
Steps followed:

- imitate factory production of lemonade
- produce a flow diagram of the process using Visio software
- become environmentally and economically conscious by determining the best use of their waste product
- present knowledge gained on a poster
- design attractive packaging

Expected outcome:
One bottle of lemonade with attractively designed label.
Poster containing three main parts:

1. Lab work, showing how their product was made

2. Visio, flow chart of process as it may look in the industry
3. Environment and economy, trading the waste products (lemon peel) to use in a different product vs discarding the waste

Furthermore the poster should include: introduction, conclusion and citations.

Evaluation criteria:

- Do they have a product? Attractive label?
- Poster containing
  - Clear explanation of the process and lab work
  - Visio flow diagram showing an industrial process
  - Plan for waste product (lemon peel)

Mechanical Engineering Project:

Air Stream Kit:

Students were divided into teams of 3. Each team received an experiment kit. The kit is intended to build hovercraft and air driven models. Each kit included plastic frames, blowers and fans. In the first two days, students were given small tasks to build certain configurations. These initial tasks helped the students understand the capability of their kits, and learned how to follow instructions. Simple physics laws and principle projectile motion were explained. In the following days, teams started to compete using their designs to transport a mass from point A to point B.

CAD competition:

All students were given access to use computers available in our computer labs.
Day 1: brief introduction on CAD and its benefits and uses. And showing some interesting videos to attract their attention.
Day 2: 123 design software introduction, going through all of its tools and ending the day by announcing the competition.
Days 3 and 4: we asked students to work on designing their own models, and we left it for their imagination to model whatever they like.
Then by the end of day 4, faculty judges announced the winners.
The winning projects selection for the CAD competition was based on:

1. Degree of innovation, creativity, and novelty
2. Functionality and Usefulness

3. 3D printability
4. Marketability and Feasibility
5. Quality and clarity of presentation materials.

Appendix B: Sample Questionnaire

Texas A&M University at Qatar **Engineering Explorers Program**

Student Name:

School Name:

Thank you for attending Engineering Explorers STEM Development Program.

Your feedback is highly appreciated
Please answer the below questions on a scale of 1 to 10: 1 Very Bad and 10 Excellent

Chemistry activities conducted in the lecture hall:

Did you enjoy the sessions?
Di you understand the material or lessons taught?
Did you learn anything new?

Physics activities conducted in the lecture hall:

Did you enjoy the sessions?
Di you understand the material or lessons taught?
Did you learn anything new?

Engineering projects conducted in the labs (Spaghetti tower and bridge):

Did you enjoy the sessions?
Di you understand the material or lessons taught?
Did you learn anything new?

Engineering projects conducted in the labs (Mouse trap racer kit & Circuit lights kits):

Did you enjoy the sessions?
Di you understand the material or lessons taught?
Did you learn anything new?