Abstract – This paper presents the research efforts taking place at Qatar University, the only national university in Qatar. Being a teaching institute, conducting research faces many challenges. The paper focuses on the experience of the electrical engineering department in incorporating research through the senior design project course. The work of the students was on a research project sponsored by the local communication provider. Many ABET learning outcomes are shown to be fulfilled through this activity, which shows that incorporating research in the undergraduate curriculum is becoming essential. Several factors contributed to the success of the activity, and are described in the paper. The paper concludes by anticipating the future of research in Qatar at large, and by recommending some specific points for similar activities to attain similar if not better success.

Index Terms - Undergraduate Research, ABET, Qatar University

INTRODUCTION
In recent years, many universities around the globe have started to structure special research programs for undergraduate students. The well known REU, Research Experience for Undergraduates, of the NSF, the National Science Foundation, has attracted many submissions, and is becoming one of the most successful programs of the NSF [1]. The reason behind this movement is that the focus of new trends in engineering education is to increase students' abilities and skills, especially in self learning, rather than to increase their knowledge through the dominant lecture-based teaching1. Consequently, research started to emerge into undergraduate curricula in various universities across the globe, with little efforts in the Middle East area. This is due to the fact that the emphasis of many universities in this area is on undergraduate teaching, with no focus on research in general. In addition, incorporating research is not as easy as introducing a new course to the curriculum, i.e., special arrangements should be considered to prepare undergraduate students for conducting research.

Research targeting undergraduate students has many benefits [2]. Students are better prepared for future careers by improving their self learning capabilities and exposing them to real life problems through applied research. Moreover, students who conducted research in their undergraduate years have a better chance to pursue and succeed in graduate studies. In addition, as will be shown later on, many of the program learning outcomes can be fulfilled through this activity.

Qatar University (QU) was founded in 1976 with only two colleges. The college of engineering was established in 1980 with four programs, namely: electrical, mechanical, chemical, and civil engineering. Originally, the college accepted male students only. In 2002, female students were accepted to the newly established programs, computer engineering and industrial and system engineering. Currently, the college has about 900 students, 60 of which are in the EE department which offers its program to male students only. The paper focuses on the experience of the EE department at Qatar University (QU). Research was incorporated into the senior design project course followed by an independent study course. This paper explains in details the project conducted, challenges faced, key factors contributed to the success of this new experience, and the targeted way ahead.

RESEARCH AT QU
Qatar University is the only national university in the state of Qatar. Currently, QU is a teaching institute with a primary goal to improve the quality of its undergraduate students. QU has gone through a major reform recently to achieve this goal. Nevertheless, due to the importance of research, a new position, associate vice president for research, was created to support various research activities.

His highness the Emir of Qatar has announced recently that 2.8% of the state's national GDP should go towards supporting research. This huge amount of money is being used to build a wide scale infrastructure that includes the education city, and the Qatar Science and Technology Park (QSTP). The former managed to attract highly ranked Western universities that are famous for research. These include Texas A&M, Weill Cornell, George Town, Carnegie Mellon, and Northwestern. In addition, QSTP is going to host parts of the R & D sectors of many well known international companies.
such as GE, Air Products, Shell, and others. With all these research related activities going on, incorporating research in the undergraduate curriculum at QU seems very challenging, yet a natural step in establishing a research culture at QU.

QU announced in 2005 the starting of an internal fund to support research. Priorities will be given to undergraduate research implemented through the senior design project course. In a recent letter to QU members, the vice president and chief academic officer stated: "As has been declared in the mission of QU, equipping our students with a quality education that ensures life-long and independent learning is a major goal for all programs offered at QU. This mission can be attained through research-oriented teaching and supported by the injection of research thinking and methodology in the daily-class setting."

However, research at QU faces mainly the following two challenges:

1. Lack of graduate studies (Human-resources issue): The majority of programs at QU offer BSc degrees only. The reason for this is that the market demand on people with post graduate degrees is low. This is due to the nature of the industry in Qatar which doesn't have research and development sectors in general. The emphasis is on the operation and maintenance of state of the art equipments brought from abroad.

2. Relatively high teaching loads for faculty members: The current teaching load for regular faculty members at QU is 21 credit hours per annum. This leaves little time for faculty members to conduct research. In addition, faculty members are usually involved in many committees such as accreditation which consumes good portions of their time.

However, those two issues were taken care off partially by the recently adopted policies that enable load reduction with granted research funds [4], and the ability to utilize such funds to invite graduate students from other schools to spend specific periods of time at QU.

One more variable to the process is the way to assess students involved in such activity, especially if this is a different activity from the senior project. The solution was to create an independent study course, and to add it to the registrar database of courses. This way, commitments from students' side as well as systematic grading can be assured.

**QU-EED EXPERIENCE**

*I. The 3G Project*

The EE department at QU enjoys excellent relations with the local industry, especially with the telecom sector. On January of 2005, a contract was signed with Qatar Telecom (Qtel) to conduct an electromagnetic radiation measurements' campaign in the State of Qatar, the first of its kind in the region. In addition, on December 20th of 2005 a memorandum of understanding was signed between Qtel, Texas A&M Qatar (TAMU-Q), QU, and College of the North Atlantic Qatar (CAN-Q) to establish a mutually beneficial collaborative research into third generation (3G) networks, technologies and services [3].

One of the main objectives of the two projects is to involve students in research activities through their graduation projects. The focus of this paper will be on the second project as more research activities are taking place.

As all the students involved in the project have only preliminary knowledge on communication systems through the signal and systems course, the project started by preparing them through a series of short courses on the 3G subject. The period included lectures as well as self learning part where students were put in groups of four representing different schools involved as well as engineers from Qtel. These groups were given topics to research and present within a certain period of time. Then, a measurement campaign took place to collect the required data. The first round of measurements was done with minimal students' involvement in structuring the setup of data collection. The data was analyzed and presentations were given by the groups. A smaller group of students (QU students) was chosen to do the second round of measurements. In this round, students decided on the type of data to be collected, and the scenario of collection, i.e. it was a bit more systematic. Students went to the field knowing in advance what they were looking for and why.

The students worked on the collected data to design a path loss model for the propagation of signals in different parts of the state capital, Doha. The work involved of course literature survey on propagation models, and comparison of the designed model with those available in literature. The second part of the project involves the development of a simulation tool of Qtel wireless network based on the vendors' specifications. This tool helps in predicting the extra needed network components for any predicted capacity increase.

The first two parts laid the research platform for the students, and made them ready to tackle research problems related to 3G networks that go beyond the undergraduate level. In their last semester at QU, the two students involved in this activity are registered in a two-hour independent study course. One student is working on the problem of combining power loading optimization with transmit diversity systems, and the other is working on studying the performance of RAKE receivers due to self and other interference. This activity is expected to produce novel results on these topics, and may lead to journal publications in reputable transactions.

**II. Linkage to ABET Program Learning Outcomes**

The EE department at QU has achieved ABET substantial equivalency in 2004. The continuous improvement process in assessing the learning outcomes made it necessary to diversify assessment methods in various courses. In what follows we show how some of ABET criterion 3 program outcomes were satisfied through the project. However, we will not get into the details of assessment (i.e. performance criteria developed/rubrics used,...).
Outcome (b): An ability to design and conduct experiments, analyze and interpret data.

As mentioned above, students were involved in two rounds of measurements. The second round (experiment) was designed solely by students including routes to be taken, test procedure, data to be collected, etc. In addition, students analyzed the data to draw conclusions about the performance of the operating network. They have also used the data to design a propagation model for different environments.

Outcome (d): An ability to function on multidisciplinary teams.

Teaming skills of the students were sharpened through the interaction with:
- Students from other institutes (TAMU-Q, CAN-Q).
- Qtel's engineers.
- Vendors' personnel (engineers, technicians, etc.).
- Faculty members from different institutes.

In all phases of the projects, specific tasks were given to different team members, and the team leader had the duty of the follow up.

Outcome (g): An ability to communicate effectively: graphical, oral, written and electronic.

In different phases of the project, students had to submit written reports, conduct oral presentations, and to brief the supervising faculty members on their progress through regular meetings.

Outcome (i): A recognition of the need for and an ability to engage in life-long learning.

The self learning ability was enhanced when students were given topics to read and investigate using the library, vendors' printouts, and supplied multimedia tutorials.

Outcome (j): A knowledge of contemporary issues.

The project involved the students with the 3G network of Qatar and its deployment.

Outcome (k): An ability to use techniques, skills and modern engineering tools necessary for engineering practice.

Students worked on several modern tools and software provided by Qtel/ its vendors. They also used Matlab to process the collected data, and to build the simulation model.

III. Success Factors

In order for the process of implementing research in undergraduate education to succeed, several factors should be considered. These factors were extracted from the local experience with EE students at QU, but probably apply to similar cases in other institutions.

1. Selection of students: Students participating in this activity should be carefully selected. Students with high GPA's (such as those on honor programs) are the best to be engaged in this activity. This process cannot be applied on a wide scale where all students are involved.

2. Good preparation of students: Even excellent students need very good preparation to participate in research activities. This can be done through short courses or special topic courses to precede the engagement in research.

3. Applied research: It is easier to involve undergraduate student in applied research than in fundamental research. The latter needs extensive preparation with smaller chance of success or useful findings in a short period of time.

4. Industrial mentor: As mentioned in the previous point, applied research has a better chance of success in this program. Hence, one of the key success factors is to have an industrial mentor for the students, preferably a PhD holder working for the industry. The mentor can contribute to the research itself as well as in guiding students to acquire technical and non-technical skills necessary for their future profession.

THE WAY AHEAD

Even though QU is currently geared towards teaching, the future of research looks very promising. Internal support comes from the special annual fund dedicated for research, which can be used to buy equipments, and to bring graduate students/post docs for certain periods of time, enough to carry out specific research projects.

Externally, Qatar Foundation, a private non-profit organization in Qatar fostering the advancement of education [5], has recently established a special fund, Qatar National Research Fund (QNRF), with a mission "to advance knowledge and education by supporting original, competitively selected research in: the physical, life, and social sciences; engineering and technology; the arts; and the humanities"[5]. An important component of that fund is a program to support undergraduate research, namely: the Undergraduate Research Experience Program (UREP). UREP aims to engage undergraduates under the mentorship of faculty members in all universities in Qatar on research projects related to Qatar’s national needs. UREP has many advantages for undergraduates, supervising faculty members, and eventually the State of Qatar. It also has the advantage of complementing internal funds from Qatar University for the same projects by funding different related activities. In addition, QNRF is deploying a new program for funds related to applied research that is aligned with the national needs of the state of Qatar.

Having all these opportunities in place, the burden is on the shoulders of faculty members to prove eligibility of load reduction, and to attract graduate students from abroad. The only challenge that appears in the horizon, especially if graduate programs do not materialize, is the loss of undergraduate students upon graduation. That is to say, from a teaching point of view, students are getting the benefit and
research skills. However, they graduate when they are ready to produce from a research point of view.

Finally, other schools in Qatar, TAMU-Q in specific, are planning to initiate graduate studies in the near future. Ways for interaction to secure joint supervision of graduate students and access to research facilities should be explored.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, research should be done in a structured fashion, and should not be left to individual efforts. In addition, applied research is easier to implement in undergraduate curriculum in contrast to fundamental research. For similar activities to attain better results, the following is recommended:

- Students are better enrolled in "independent study" courses rather than the "senior design project" course; especially if the latter is the capstone course. Major design experiences may not be fulfilled through research activities.
- Students’ selection is essential. Wide scale implementation of the activity is not recommended.
- Having this activity with stipends can have a highly positive effect on motivating the students.
- Other points mentioned under the success factors.

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