AC 2009-1197: PRACTICAL ENGINEERING DESIGN COURSES: A BAROMETER FOR THE FUTURE SUCCESS OF FEMALE EMIRATI ENGINEERING UNDEGRADUATES?

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Practical Engineering Design Projects: A Barometer for Future Success of Emirati Female Engineering Undergraduates?

The Petroleum Institute is a fledgling engineering university located in Abu Dhabi in the United Arab Emirates. Set up in 2001 by ADNOC (one of the richest oil companies in the world), and managed by Colorado School of Mines (one of the most celebrated engineering colleges in America), its mission is to prepare local male and female students for work in the oil and gas industry in the UAE. Given its links both with a national oil company and a prestigious engineering university in the USA, it is a unique venture. ADNOC, together with their international partners, TOTAL FINA ELF and JODCO, provide fantastic financial and administrative support. Colorado School of Mines (CSM) for their part, were responsible for the initial design of the academic courses and the recruitment of faculty.

Clearly, with so much experience and prestige, there is much to be gained from such an amalgamation. Yet, despite the obvious benefits, there are also challenges. Is it possible to implement a system of education and management, so effective in the United States, in a country with a culture so completely different? Is it possible over a 4 year engineering degree to compensate for an aging and out-of-date schooling system? And perhaps most intriguingly for this study, is it possible to shake the foundations of a hitherto male-dominated engineering profession by preparing young Emirati ladies for work in the oil and gas industry?

Now in its 8th year of operation, it is becoming clearer to what extent these challenges are being met. The paper will focus primarily on the last challenge mentioned. Research will centre on the following key areas:

- What is the current state of education and employment for females in the UAE?
- What is STEPS and what are its origins?
- Can the Petroleum Institute (PI) successfully challenge long-held stereotypes by treating Emirati females in the same way as they treat the males?
- Are there any clear differences in how male and female students perform on practical engineering courses?
- What implications do the results of our investigation have for the PI, its sponsor the National oil company and potentially for the country as a whole?

The conclusions drawn will then be used to suggest how the STEPS team can move forward, ensuring that the young Emirati females are given parity with their male counterparts and are also given the skills necessary to continue to change the face of local employment.

Third-level education in the UAE

The pace of change in the UAE over the last 10 years has been incredible. Its property market is one of the most vibrant in the world. Tourism, as a result of tremendous vision of its leaders, is booming. Plans for a ‘cultural village’ housing its own Louvre and
Guggenheim museums are at an advanced stage. Coupled with this, oil reserves that are guaranteed for the next 100 years, ensure that the country will continue to go from strength to strength. However, against this background of prosperity is an educational system that compares unfavourably with its counterparts in the West. Although the UAE’s literacy rates compare well with other countries in the Middle East, (and uniquely, show women with a slightly higher literacy rate than men) the education system is still far short of where it ought to be. However, in a move to combat this, the UAE’s government has, over the past 10 years or so, made available an incredible amount of money for education. This money has generally been earmarked for tertiary education which means that students are still arriving at university from an outdated secondary school system. However, as with many aspects of the UAE, results are expected ‘now’; rather than completely restructure the entire schooling system, it appears that the consensus is that if enough money is made available for third-level education, all the problems will be fixed. Clearly, this is not the case. However, the sheer volume of money has certainly resulted in a plethora of choices for UAE undergraduates. The country now has one of the highest application participation rates in the world. Ninety-five per cent of all females and 80 per cent of all males who are enrolled in the final year of secondary school apply for admission to a higher education institution. And as many young Emiratis are encouraged to stay at home, it is important that the choices are there. The UAE’s flagship third-level institute is the Higher Colleges of Technology (HCT) Opening its doors in1988 to 239 students, today, 12 men’s and women’s colleges right across the UAE provide a diversity of programs to over 15,000 students in modern, technologically equipped campuses. New colleges and facilities are being added to the list on a regular basis. Built on a total area of 43,000 square metres and costing around Dh200 million, the new campus of the Dubai Men’s College, provides a truly world-class environment. Clearly, when it comes to third-level education, money is no object. And alongside the flagship university, Zayed University, (named after the country’s founding President, Sheikh Zayed) and the UAE University provide alternative options. There is also an Abu Dhabi chapter of the prestigious Sorbonne University, indicating again how much the UAE’s stock has risen as a provider of respected third-level education.

In addition, Dubai Knowledge Universities (DKU) is currently being established as a multi-university complex on 2.33 million square metres in the heart of Academic City in Dubai. On completion it will be able to accommodate 20 to 30 universities and house between 30,000 and 40,000 students and will be designed to provide a quality of student life and services that is international, culturally diverse and dynamic. The campus will have two wings, a west campus for undergraduates and an east campus for graduates.

So, clearly much is happening at this level. Students leaving the school system are being offered excellent choices as they seek to further their education. But in a part of the world where the first school for women was only opened in the early 1960s, how do women fare in third-level education? Are they active participants? And if yes, are they then well represented in the UAE’s workforce?
UAE Women in Education and Employment

“Nothing could delight me more than to see a woman taking up her distinctive position in society... nothing should hinder her progress. Like men, women deserve the right to occupy high positions according to their capabilities and qualification.”

The words of the late president of the UAE, Sheikh Zayed have been the inspiration for the recent sea-change in the face of women in education in the UAE. Despite their late start, women have made extraordinary progress at all levels of the education system. The UAE has a female registration rate of an incredible 77% in higher education.

However, this success of women in the educational arena is not replicated in the workplace. Only 14.7 percent of Emirati women were in full-time employment in 2003, an increase of 5.1 percent from 9.6 percent in 1985, with the majority of women employed in the public sector as teachers or clerical workers. Engineering is still a sector that while not closed to females, is very much a male-dominated arena.

This is of course not restricted only to the UAE; it is a major issue in the Middle East as a whole, which, together with North Africa has the lowest female labor participation rates in the world. According to a report by World Bank in February 2004, *Gender and Development in the Middle East and North Africa: Women in the Public Sphere*, states the region's governments have spent an average of 5.3 percent of the GDP on education, the highest allocation in the world. This huge investment in education has closed the gender gap, with women outnumbering men in higher education institutions in several countries and has resulted in the largest increase in rate of employment over the last decade. Yet despite this increase, the female labor force participation in the region for the year 2000 stood at 32%, the lowest in the world.

The lack of Emirati women in the workplace can be traced to two main factors. In the UAE, the family plays a pivotal role in the life of both men and women. Family concerns are often seen as more important than individual concerns, and often decisions about employment are taken out of the women’s’ hands. Family attitudes about female employment and a woman's ability to combine both work and family responsibilities are often identified as key to accessing work and remaining within the labor force.

Second, and this is particularly relevant for our study, social conditions often dictate that women need to abide by what is known here as a "code of modesty". This recommends segregation of men and women in the quest to guard family honor. This code is adhered to in varying degrees by different groups within the society and often confines women to seeking work in predominantly female work environments, such as schools. Engineering undergraduates who wish to pursue their chosen career will have no choice but to work with male counterparts.

As we have discussed, the UAE has achieved a great deal its short 37-year history. Although education is only now beginning to receive the attention it deserves, the advancement of women, even within a flawed education system, is nothing short of remarkable. However, there is still much to be done when it comes to balancing the percentages of males and females in the workplace. Men still have much greater access to high-status and high-paying executive positions while only small number of women
occupy key decision-making positions. Barriers to the employment of women are being addressed, but only slowly. If women are to fully contribute to the nation-building process, it needs to begin with a change in attitude.

**The Petroleum Institute**

Watching the blossoming third-level education system and spotting a possible niche in the market, ADNOC, the national oil company decided that if they were to attract local men to the workforce, they may well be better served doing it themselves. As a result, the Petroleum Institute was established in 2001. Hitherto, the majority of engineering jobs in ADNOC were taken by expatriate workers, often contracted from other major oil companies. In an attempt to nationalize the workforce, ADNOC set itself an ambitious ‘Emiratisation’ program whereby 75% of the workforce would be local by 2010. Part of this nationalization program involved providing young Emirati students with the opportunity to study engineering closer to home. With a goal of ‘providing a world-class education in engineering in order to support and advance the petroleum and energy industries, the Institute ‘is committed to academic excellence, and to fostering an intellectual environment that leads to the development of our graduates as whole persons and as the future leaders in their respective fields of expertise in the United Arab Emirates and beyond’

The Petroleum Institute offers degrees in four engineering disciplines: Chemical, Electrical, Mechanical, Petroleum with Petroleum Geo-sciences making up the fifth major. Students who complete their studies at the PI, are contracted to work for the oil company for a minimum of five years. Graduates will immediately be expected to become active contributors to the workforce, being inducted through ADNOC’s Competency Assurance System (CAMS), a system that allows graduates only to progress when they have shown competency at various levels.

Significantly, however, the initial plans of the Petroleum Institute did not involve prospective female engineers. Only in its 5th year of operation, was a decision taken to open the female campus, with a stated goal of preparing young Emirati females for work in the oil and gas industry; an industry traditionally an almost exclusively male domain. Showing vision and a belief that wasn’t backed by the statistics of UAE women in the workplace, the oil company was taking a risk. Clearly, there was a tremendous need to open up its doors to women; its aim of emiratizing the workforce was only possible with the addition of women. And yet they knew as they did so, that much work needed to be done to ensure that young Emirati females not only performed well at university, but were prepared (and excited) for a job working alongside their male counterparts in the oil company and its operating companies. In order to do this, it was imperative that the females were treated insofar as possible in exactly the same way as their male counterparts.

Now in its third year of operation, we are beginning to get a better picture of who our female students are. The female campus is home to over 200 young women with retention rates of over 80%, compared with only 60% on the male campus. We are also, for the first time, able to see how girls are performing on courses that fall outside
traditional ‘core courses’. How well they do as more ‘practical’ courses are introduced will be of tremendous interest. This study will look at how the females are performing in engineering design courses that for the first time thrust them into real-world engineering problem solving.

**Strategies for Team-based Engineering Problem Solving**

The partnership with a prestigious American engineering university not only helped raise the Petroleum Institute’s profile, it also provided the Institute with many of its faculty and courses. One course that was implemented in 2003-4 academic year was STEPS (Strategies for Team-based Engineering Problem Solving). Although initial hurdles involved in introducing a Western model of an engineering design program to a foreign culture, including overcoming the broad barriers of language, religion, values, manners, and ethnocentrism, it was a course that was quickly seen as an ideal vehicle for preparing students for life as future engineers in ADNOC. Although many of the aspects of the CSM model were transferred, the Institute’s curriculum needed to be carefully planned. The curriculum needed to be planned in the context of preparing our students to be successful participants first in their senior design courses, and then as they took up their positions in ADNOC. The course also needed to develop a range of behavioural skills and competencies identified by ADNOC’s Competency Assurance System, including teamwork, critical thinking, communication and time management.

It was decided that given we knew exactly who our stakeholders and end users were, a learning outcomes approach was the sensible way to frame our curriculum. As Fitzpatrick (1995:13) states:

*Outcomes for student learning are based on a shared vision of a well-educated graduate and are defined in terms of interdisciplinary learning such as problem solving and communication skills, and essential discipline-based learning in specific content areas*

Learning outcomes are the abilities, skills and attitudes that make up the integrated learning needed by a graduate of a course or program. Using this approach, the STEPS team was able to ensure that curriculum design, content, delivery, and assessment was based on an explicit identification of the integrated knowledge, skills and values needed by both students and society.

The learning outcomes for the STEPS courses (STEPS I taken in Sophomore I and STEPS II, taken in Junior year) require that students:

- Demonstrate competency in applying the steps of the engineering design process to solve open-ended problems.
- Demonstrate ability to present design solutions in oral presentation and written reports.
- Practice understanding principles of project management.
- Demonstrate skills in effective teamwork.
- Demonstrate ability to gather, analyze, and interpret data.
- Demonstrate ability to self learn, research and use information
- Gain awareness of ethical, social, global and economical influence of engineering design.

Another key component of the STEPS program is its requirement that projects utilize ‘real-life’ problems from industry. By teaming up with industry and by introducing students to real clients, students are given the opportunity to have real world experience before graduation. While this is interesting for both male and female students, it has more significance for the prospective Emirati female engineers. This will be an early indication if how well they cope in a male-dominated world, where by necessity, many of our ‘real-world’ clients are men.

**Approach: STEPS II, Fall 2008**

Determining a project for STEPS courses is not easy. Careful thought must be given to what we are asking them to do, who we are asking them to work with and also how it will benefit our students long-term. The project that forms the basis of this study (which is only part one in a much larger study) saw the STEPS department team up with local industry. MASDAR, a UAE government-led initiative, is an entity that is seeking to create the world’s first carbon-free city. The city will cover 6 square kilometres and will accommodate 50,000 people. Cars will be banned within the city; travel will be only be via public mass transit and personal rapid transit systems, with existing road and railways connecting to other locations outside the city. The city will be walled, to keep out the hot desert wind. Key to the STEPS department’s involvement with Masdar is their decision to employ a variety of renewable power sources. Among the first construction projects will be a 40 to 60 megawatt solar power plant, which will supply power for all other construction activity. This will later be followed by a larger facility, and additional photovoltaic modules will be placed on rooftops to provide supplemental solar energy totalling 130 megawatts. Given its reliance on solar energy and given the well-documented problem in the UAE of ‘soiling’ (where sand and dust accumulate), an opportunity arose for our female students to get involved. After negotiations with MASDAR the following client statement was presented to the students:

**Develop and build practical designs for a cleaning device to be used for removing the dust and sand accumulated on the photovoltaic panels to be used in MASDAR city. The designs must be technically sound, intrinsically safe and economically feasible. The design must be capable of cleaning a 50 W PV Panel without the use of any power sources except for the sun. The cleaning prototype must be constructed from materials that can be found locally, and can utilize no exotic components. The cleaning mechanism design should be scalable to clean larger PV areas used in solar power generation site.**
The students were encouraged to use the Engineering Design process, to respond to the client request. This process is introduced in STEPS I, and is developed further in STEPS II.

The 5 stage engineering design process was tackled over the course of a 16 week semester. In early discussions, it had been suggested that due to the difficulty that young women in the UAE face in getting the materials and tools required for a successful build, that the project only take the students through to the conceptual design. However, it was felt that if the project was to be a useful lesson in engineering design and if it were to help prepare students for work in ADNOC, then it would be self-defeating to end the project anywhere other than with final Design and demonstration.

The first stage (Problem Definition) involved negotiation with the client in order to ensure that the students understood the client needs. The negotiation took place face to face with MASDAR representatives and was a useful exercise not only in clarifying the project, but establishing an important relationship between the client and the designers. Students responded with a letter of understanding and a Project Plan Presentation where their understanding of the project was presented.

The next step involved the generation of three conceptual designs which the girls felt would best accomplish the project objectives (Figure 2). The girls used decision matrices
to determine which of the three designs was best and then presented their initial design to the client both orally and in a written report.

![Conceptual Design for one female team](image)

**Figure 2 Conceptual Design for one female team**

With the client’s approval to proceed, the girls then moved on to the preliminary design stage, which involved evaluating and testing of the design. At this stage, a prototype is built and demonstrated (Figure 3); from here, the students look how they can improve the design. The changes that arise from this are documented and the students present their detailed design report.

![Prototype demonstration](image)

**Figure 3 Prototype demonstration**

Again, with client approval, they began the final stage of the process, which involved complete documentation of the entire project, and final build and delivery of the product.

**Results**
As this was the first semester where both males and females completed the STPS course at the same time, the results of both courses would have to be analyzed closely to determine if there had been any significant difference in how the courses had been received. Would the females perform as well as the males? Would they find the practical side of the design too difficult?

An analysis of the three men’s courses and the one female course in Fall 2009 indicates that the female students actually outperformed their male counterparts. The percentage of students achieving As and Bs was significantly higher, and no female achieved less than B, whereas several males did. As this final mark is a culmination of all aspects of the course (report writing, presentations, group work, design and build) it is only useful insofar as it shows that the course itself presented no real problems to the female students. As the study continues, and as the sample increases, we will be able to analyze each area of the course in more detail.

Of more significance was the response to the questionnaire that all female STEPS students completed. The girls were asked to respond to a series of questions on the course. The purpose was to see if the girls saw benefit in the course other than completing a required three-credit course. The most significant questions and their responses are presented below.

Perhaps the issue of most concern was how the girls viewed the course in the overall scheme of preparing to become engineers. Of particular relevance were the questions that required the girls to indicate to what extent they believed the course had prepared them for the workplace, and specifically for work in ADNOC. (Figures 4 and 5)
The responses to these two questions certainly give cause for optimism. While this is their first exposure to practical courses and they have little to compare the STEPS course to, the responses indicate that the girls have seen value in the course, with only one respondent indicating that the course had no practical value beyond the classroom. It appears that they see the course as a ‘first step’ to becoming ‘real’ engineers.

Students were also asked whether the relationship with a ‘real’ client had been of benefit. (Figure 6) This was of interest as until now, the females had had no interaction with male engineers. Again, the responses indicated that setting the course up as a ‘real-world’ project increases motivation.

**Limitations**

Even though the author has repeatedly stressed that this study is at its very early stage, it is important to recognize that although the initial results both in the course and in the
student questionnaire are impressive, there are limitations to the current findings. Decoupling the actual design project from the teaching styles of the respective instructors on the men’s and women’s campuses would be necessary. Secondly, the project chosen this semester, given its links to an exciting and pioneering environmental project, may also have helped raise motivation and performance among the girls. It is important to state again that the study is only a surface case study. At this stage it is not a piece of action research; rather, it is part one of a study which it is hoped will be part of a much larger and definitive study as our student body grows and as the first batch of girls graduate.

Conclusions and recommendations for further study

The early indications are that the oil company’s bold decision to open its doors to both women as well as men will pay off. Our initial results certainly suggest that the girls are performing just as well as their male counterparts in the courses which simulate real engineering design. Their responses to the questionnaire are also positive. It augors well. However, as we discussed earlier, the UAE struggles to entice its female graduates into the workforce, especially in the fields of science, technology and engineering. This study cannot be complete until we see how many of this first year female STEPS students actually take up positions in ADNOC. Once there, the study will continue to evaluate their performance in the oil company’s CAMS system. Only then will we be able to determine whether the ‘hands on’ education that they have received at the Petroleum Institute has made any difference to their intrinsic motivation. It appears that at this stage, motivation and ability compares very favourably with the men. ADNOC’s brave and visionary (and costly) decision to open its doors to female Emiratis looks as if it may well pay dividends.
Bibliography


