INTEGRAL APPROACH TO ENHANCE ENGINEERING EDUCATION IN AN OFFSHORE UNIVERSITY CAMPUS

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Abstract: The relevance of engineering education to the needs of rapidly developing industries in the Gulf region of the Middle East is of paramount importance. Heriot-Watt University has taken a lead in setting up a campus in Dubai to offer British education to students from the Gulf region and beyond. Conducted surveys have highlighted that one of the centrepieces of the skills most valued by employers in this part of the world are the engineering reasoning skills of graduates. This paper describes the development of real life integrative applications complementing normal delivery aligned to produce graduates that can meet the need of local industry and provide at the same time the required skills set that enables them to adapt to rapidly changing industrial and job market environments.

Keywords: engineering education, engineering reasoning skills, international education

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1. INTRODUCTION

Heriot-Watt University is the first UK University to set up in Dubai International Academic City, offering British education to students and executives from around the Gulf and further afield. The School of Engineering and Physical Sciences started offering its four-year BEng (Hons) mechanical engineering degree courses in Dubai during the academic year 2006/2007. The school's intention from the beginning was to produce competitive and well-rounded engineers capable of contributing immediately upon their graduation to the local/regional economies. To achieve this aim and to make the degree offered by the school "the degree of choice" the strategy was to diffuse problem solving skills into the delivery. To accomplish this we needed to contextualize concepts of the engineering reasoning skills into the delivery of individual modules whenever possible. Since the emphasis was to deliver high quality and competitive education, staff had to address the following key points:

- Capture the basic engineering principles
- Develop and enhance engineering reasoning skills
- Employ best practices to diffuse critical thinking and critical appraisals.

To develop an understanding of the skills set highly valued by industry it was decided to complement previously conducted surveys (by the author) with an up to date survey that led to the construction of a survey of surveys covering a time period from 1983-2009 (individual surveys were conducted from 1983–1993, 2004-2005 and 2006-2009). The survey of surveys summary is shown in Figure 1. It is interesting to note that companies that have remained

successful to this day ensured that their recruits possessed the top four sets of skills in the figure below.

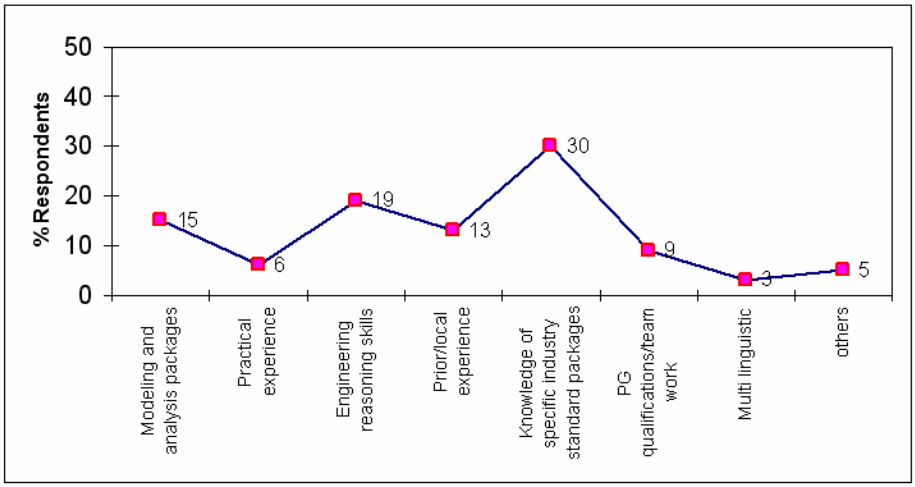

Figure 1: Percentage of companies which stated a particular skill is highly valued

The school capitalized on the remarkable development of Dubai in setting typical life problems/exercises and arranging interactive site visits. All were facilitated due to the close proximity of most landmarks to the campus. This paper presents examples and approaches used in the mechanical engineering course delivery.

2. TEACHING METHODOLOGY

2.1 Engineering Science 2

During semester two, the first year students were required to develop further the core skills of a mechanical engineer. This module provides three components for their engineering toolbox namely dynamics, strengths, and materials analysis tools. Analysis tools must be validated through experimentation in real life situations. Hence the validation of their analysis knowledge is vital to their skills as an engineer. To demonstrate this to the students a project has been developed to test their analysis knowledge gained through attendance at the lectures and modules, which will be validated through experimentation. As we are located in Dubai it was prudent to apply the theme of infrastructure and transportation, both key components of this rapidly expanding emirate.

The project is entitled “Sink or Swim”. The students’ task was to transport a scaled car across a void of water, using only straws, balloons, and tape. The car and tank of water are fixed, the students must use their knowledge and skills to design and build a prototype. This will be tested in the form of a class presentation, thus validating their predictions. The learning outcomes are: a sound understanding of key engineering principles: validation of theoretical predictions; working as a group of engineers; crucially they will experience the consequence of errors in calculations, they will sink or swim-their device will succeed or fail. The overriding purpose is to demonstrate that engineering ingenuity is encouraged but must be backed by sound engineering principles in order to succeed.

2.2 Fluid Mechanics

The approach used in the delivery of the Fluid Mechanics was directed towards promoting the underlying physical concepts rather than focusing on memorizing or merely programming and solving formulae sets. This was complemented by continuously sparking third year students' interest through introducing local and visible problems. As students needed to make logical assumptions and approximations to arrive at reasonable solutions this had led students to appreciate the validity and limits of their assumptions and approximations (in case they broke down). The case below is an example used to present the unsteady isolation of vortices.

When considering a long cylindrical object shedding vortices, the correlation for frequency of shedding is given by:

$$\frac{fd}{v} = 0.198\left(1 - \frac{19.7}{\mathrm{Re}}\right) \quad \text{where:}$$

f=vortex shedding frequency (Hz), d=diameter (m), v=free stream velocity (m/s) and, Re=Reynolds number.

The above formula will generally hold true for a range of Reynolds numbers. Having previously encountered laminar and steady flows which occur at low Reynolds number, students can appreciate the effect of increasing Reynolds number and the onset of flow separation. This occurs at the trailing edge of the cylinder in this type of flow and such behaviour pattern will lead to the formation of stationary vortices in the wake. For Reynolds number between 100 and 200, unsteady oscillating vortices start shedding from the trailing edge of the cylinder, Figure 2. If the frequency of the oscillation reaches the resonance frequency of the cylinder, the amplitude of the oscillation will increase until structural failure. It was decided to arrange a visit to Burj Khalifa, Figure 3, and to form small groups to work on analyzing the forces on the structure based on the theory given above. Students were also given simple portable wind meters to measure local wind speed. Theoretical analysis of flow around cylinders similar to the flow at 100 Re was related to the aerodynamics on complex building design.

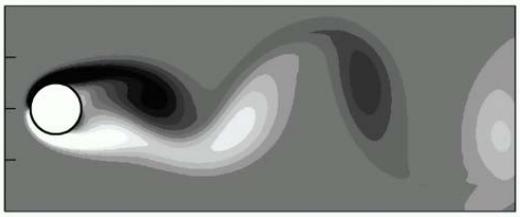

Figure 2: Vortex shedding behind a cylinder when Re=100, Barkley (2006)

All the groups were able to use their acquired knowledge to estimate flow distribution along various cross sections of the burj and arrived at a generally reasonable answer that: considerable reduction in forces due to wind loading could be achieved by encouraging disorganized vortex shedding for the burj structure. An unexpected bonus was creation of interest in Computational Fluid Dynamics, which could be defined as software that combines complex fluid theory with Computer Aided Design through a simple user interface. Thus, the traditionally laborious task of complex iterative mathematical solutions is condensed into a simple methodology. Moreover, the visual output display of the solution engages the students with practical applications of fluid dynamics. The data obtained from the site visit was used as boundary conditions to the flow simulation exercise.

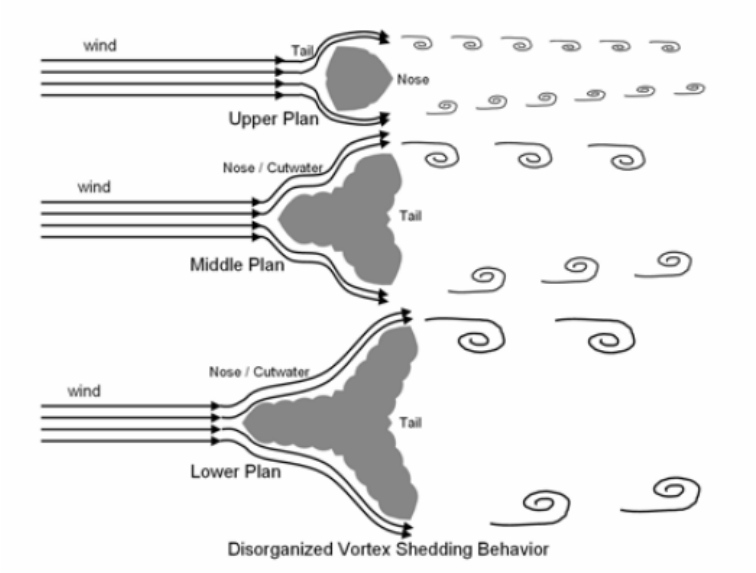

Figure 3: Vortex shedding behavior, Baker et al (2008), and the Burj Khalifa structure

2.3 Thermodynamics

It is widely accepted that the standard of living of different people living on earth depends on their per capita consumption of energy. A fact which is not so well known is that quality of life first rises with rising standard of living and then starts to decrease with further increase in standard of living as a consequence of environmental worsening conditions, e.g. Lagarias (1960) and WED (2007). Since energy consumption per capita is the most important indicator of standard of living, the natural consequence of sharp increase of energy consumption is the deterioration of our climate. Our primary source of energy is fossil fuels or hydrocarbon fuels. Increasing use of these fuels is responsible for obnoxious emissions of greenhouse gases including CO_2 , Figure 4, EIA (2009), below highlights power consumption and CO_2 emissions past and projected. A proper understanding of thermodynamics is necessary in order to improve thermal efficiency and reduce emissions from external as well as internal heat engines including reciprocating, rotary and rotodynamic types.

2.3.1 Thermal Power Plants

In spite of the importance of thermodynamics for energy conservation and protection of the environment many engineering students develop a dislike for thermodynamics. Consequently they do not find the applications of the laws of thermodynamics to real life problems. At the same time they do not find it easy to get a feel of the size, dimensions and overall cost of power systems and find it difficult to predict the operational efficiency as opposed to the theoretical efficiency of real power plants.

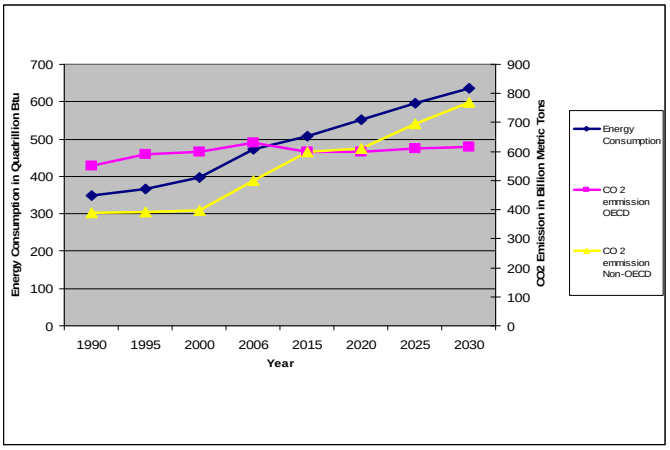

Figure 4: Energy consumption and CO_2 generation over time

A new approach was needed to introduce thermodynamics to our engineering students. It was decided to ask power plant operation and maintenance engineers to interact directly with students and at the same time arrange for site visits for real life data gathering and analysis. The students' first task was to draw a schematic diagram of the power station to get a feel of what is what, how the pieces were arranged and how the entire plant was put together. This was accomplished and a block diagram similar to Figure 5 was produced by students.

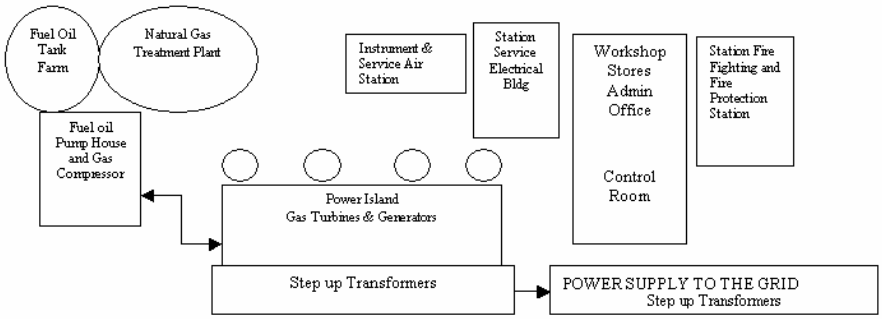

Figure 5: Simple schematic showing an open cycle power plant

Groups of third year students were then asked to carry out performance calculations based on the data that they obtained from plant engineers.

2.3.2 Thermal efficiency calculation

Calculation and subsequent analysis of data enabled students to conclude that the gas turbine thermal efficiency varies with the ambient temperature and that the inlet temperature of the gas turbine is a limiting factor which is limited by the turbine blade metallurgy. Hence they observed turbine thermal efficiency would be de-rating upon rise in ambient temperature and humidity. It was also concluded that achievement of maximum thermal efficiency and maximum specific work in power producing plants (gas turbine) was dependent on:

- Operating conditions such as the ambient temperature and ambient humidity among others.
- Advancing the basic thermodynamic parameters (such as turbo-machinery poly-tropic efficiency, turbine inlet temperature and compressor pressure ratio).
- Use of better materials able to withstand higher turbine inlet temperatures.

- Introducing additional features such as recuperation, inter-cooling, re-heating, water injection, among others.

Students were then able to produce a graphical analysis of the actual power plant at various loads as shown in Figure 6.

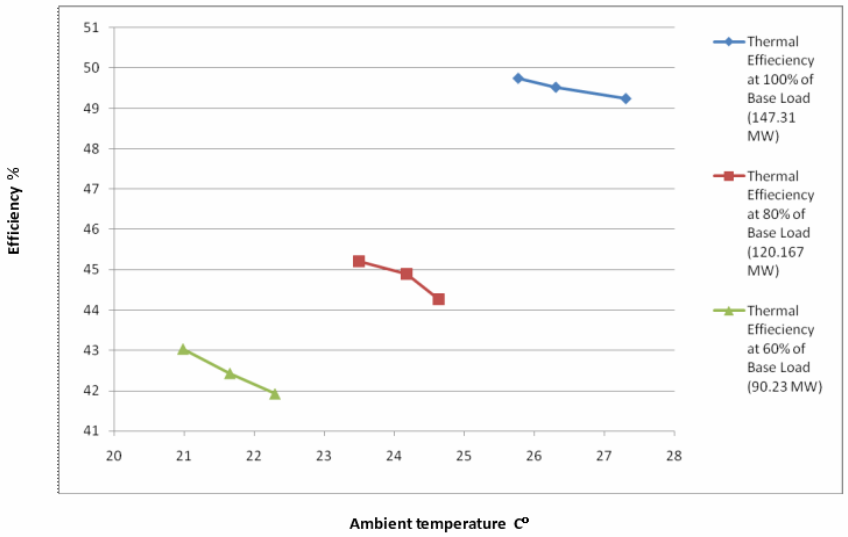

Figure 6: Graphical representation of the behaviour of gas turbine thermal efficiency at various loads and varying ambient temperatures

3. STUDENTS' EDUCATIONAL EXPERIENCE

While it is difficult to pin point the effect and influence of the above-mentioned delivery initiative and delivery strategy on every aspect of students' educational experience, the outcome could be qualitatively assessed by observing a number of indicators including:

- The academic prizes won by our students year on year. Figure 7 shows the percentage increase in outstanding merits awards and awards for taking the highest place in the year across the school and across the campuses. In the 2008/09 academic year there were three times more prizes won than in the first year of operation (this is high even after factoring the effect of increased students' numbers). No change to the course or entry qualifications was made during the period in question.

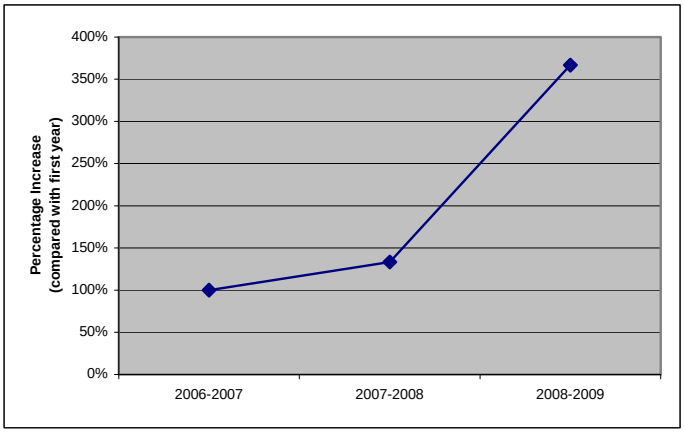

Figure 7: Academic awards by academic year

- Pass rate. Figure 8 compares the pass rates between the university's campuses in the Mechanical Engineering modules delivered during the academic year 2008/09. It is noteworthy to mention here that all Dubai exam scripts were moderated and passed through the same modules and progression board. The results show a consistently higher pass rate at Dubai in most modules from those surveyed. It could be argued that this was a consequence of using local examples and open-ended problems (e.g. Mourtos 2004) as everything else was identical.

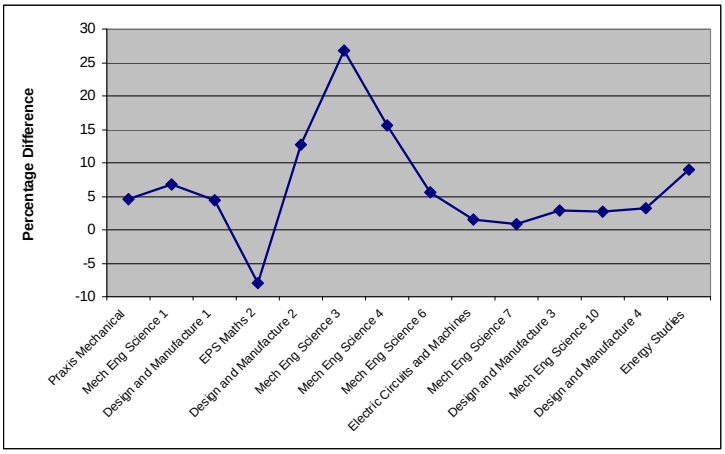

Figure 8: Pass rate compassion Riccarton vs. Dubai for academic year 2008-09

Students' satisfaction and enrolment numbers. Figure 9 shows students satisfaction survey results from recent years and the percentage year on year enrolment in the courses at Dubai. It can be seen that satisfaction rate is on the increase every year and around 86% of students' population are satisfied at 2008/09. Enrolment has also increased year on year. The steady increase in the enrolment is accounted for by three key factors: active participatation by the school's staff in the programme of secondary school visits, widespread positive word of mouth communication from current and graduate students and very successful response rates from the on-campus university open days.

4. CONCLUDING REMARKS

- Demonstrations of the relevance of engineering education are necessary to show the applicability of theoretical concepts to real life engineering problems.
- Examples of the use of some core mechanical engineering subjects to solve practical problems have been given to emphasize the relationship between theory and practice.
- Hands-on exercises and carefully supervised discussion groups were found to be effective tools to arouse interest and stimulate the sense of enquiry. The students' overall performance indicated that the approach used was and is working as quantified by the academic awards received since the 2006/07 academic years.
- High percentage of last year's graduates secured jobs soon after graduation.
- Engineering reasoning skills development through frequent use of open-ended problems at ill-defined situations in which students had to make major assumptions is believed to offer the best way forward to producing capable engineers able to work even outside the immediate discipline area.

The efforts spent are believed to have made our engineering delivery stimulating for students, as our survey has shown. It was also possible to address and improve vital skill sets that are

demanded by industry and necessary for today's job market place. These endeavours have enhanced our academic reputation, which translated into improved enrolment.

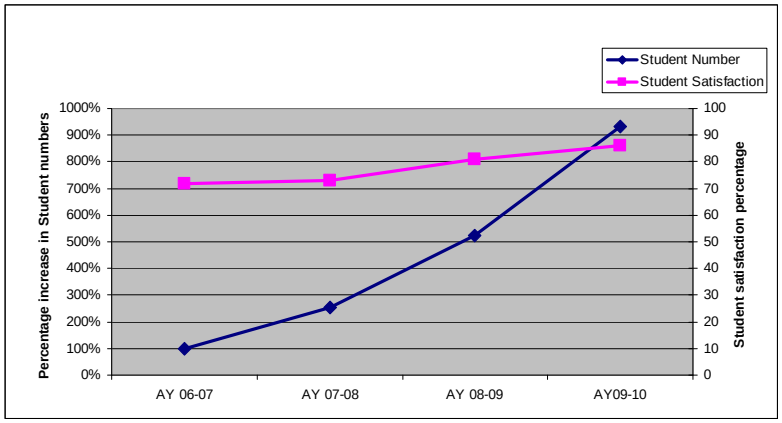

Figure 9: Percentage enrolment year on year and students' satisfaction

5. ACKNOWLEDGMENT

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