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Contribution of International Environmental Design Competitions in Raising the Profile of Environmental Education in Engineering Students*

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Every two years since 2000, the College of Engineering at the United Arab Emirates University (UAEU), has held a Student Environmental Design Competition, where engineering students from all over the world converge to put their best designs to the test. It is a cooperative effort between industry, government agencies, and academia to tackle real environmental problems facing industry in the region. The teams must prepare four different assignments: written, oral, poster and bench scale design. The concept of the competition is interesting because the engineering students are to approach the task as though a company has asked them to solve an environmental problem. Each team design is compared and judged with other competing designs to decide the winners. And more importantly, the competition is a unique event that brings together industry, government, and academia in the search for improved environmental solutions. It also provides the engineering design content required by the Accreditation Board for Engineering and Technology (ABET). Hence, it is one solution to the missing bridge between fundamentals of engineering and appropriate design training that is a basic issue in engineering education. In the Third International Design Competition (EDC 2004) which was held on May 2–5, 2004, at the UAEU, 20 competing teams comprising 60 students participated. The competition gathered students from regional and international universities to tackle real environmental challenges while addressing issues including technical, legal, health, community relations and economics. The goal of the competition was to design, develop, and test actual environmental processes for real-world problems. Typically, the environmental tasks presented had no known solution, or the available solutions did not meet the desired performance criteria. In this competition, 6 students from Sultan Qaboos University (SQU), College of Engineering (Mechanical & Industrial Engineering Department) participated. The SQU team received first place in two tasks. This paper presents the experience and highlights the need for such competitions to raise environmental awareness of engineering students. All competing teams agreed that this competition was the best part of their engineering education.

INTRODUCTION

DESIGN-AND-BUILD competitions are useful in teaching the creative and practical aspects of engineering design [1]. At the end of the day, the engineering students will gain great experience in working on a real problem in a team environment, just like what awaits them in the real engineering world after graduation.

The environmental education of engineers is a critical part of their curriculum because of the wide-ranging effect their work has on the environment. Their work in industrial developments, water and wastewater management, transportation networks, etc., has an impact on day-to-day living, on human health and on the environment [2]. Nguyen and Pudlowski [3] reported that it has become clear in recent times that engineering students were educated for a particular engineering discipline with emphasis on technical aspects of the discipline and with no relevance and reference to the environment. It is recognized that an urgent transformation of engineering education is necessary in order to cope with the changes of modern times. Therefore, environmental education has become an increasingly important issue in schools of engineering in the area over the last few years. Universities have realized that changes to engineering curricula were needed in order to inject environmental and sustainability concepts, topics and ideas into engineering theory and practice [3].

One of the aims of environmental education within engineering curricula must be to show students how to analyze problems, find causes and their effects, and make clear the conditions under which certain processes take place and what effects these have on the quality of the environment. Thus, subjects dealing with issues of the environment and sustainable development needed to be introduced to engineering curricula in order to provide engineers with the knowledge, skills, awareness and attitudes to take steps to protect the

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environment from damage, to fight those who pollute for profit and to correct existing problems [2, 3]. The concept behind the integration environmental education in engineering curriculum is that every student needs to have understanding of environmental issues and problems that affect our lives.

From a literature review on the same lines of research, many studies have addressed the sustainability and the need for its inclusion in the context of education [3–8]. In particular, competition in the design of an environmentally relevant engineering project is necessary for engineers to be environmentally aware. It is an important way to raise the profile of environmental education in engineering students. Such competitions enable engineering students to research, develop and design sustainable solutions to environmental challenges. It provides the engineering design content required by the Accreditation Board for Engineering and Technology (ABET). Many additional benefits results from participation in the design of an environmentally relevant engineering project. These include the design and construction of equipments that can be used for teaching and research and participation by students in international design competitions.

Environmental design projects provide a great chance to work as a team and compete against other universities. Students encounter real-world technical and logistical challenges while at the same time gaining exposure to today's global/ethical considerations [9]. According to Nguyen and Pudlowski [3], the main benefits of such competitions are to help students:

- gain a variety of experience and knowledge in the environment and associated problems;
- acquire skills to identify and solve environmental problems;
- acquire an awareness and sensitivity to the total environment;
- acquire a set of values and attitudes for the environment and the motivation to actively participate in environmental improvement and protection;
- participate with an opportunity to be actively involved at all levels in working towards the resolution of environmental problems.

The objective of this paper is to present the experience of SQU students at the Third International Design Competition (EDC 2004) which was held on May 2–5, 2004, at the United Arab Emirates University (UAEU). The event gave the engineering students from around the world an opportunity to exchange information and participate in an international competition. The paper also addresses the environmental problems that SQU team tackled in this competition. An overview of the bench scale designs that presented by the SQU team is also presented. Finally, the paper attempts to show how such competitions can be incorporated into the engineering curriculum.

THIRD INTERNATIONAL DESIGN COMPETITION (EDC 2004)

The purpose of this competition was to encourage students to participate in the design of an environmentally relevant engineering project. The contest was structured to give engineering students from around the world an opportunity to exchange information. The general goal of the competition was to encourage and motivate the university students to tackle and solve real-life environmental problems prevailing in the region. The specific objectives of the contest were to challenge university students to solve, demonstrate and present innovative solutions for real environmental problems. It was open to various industries to sponsor and universities to participate in its activities:

- providing sponsoring industries innovative non-traditional solutions at a small cost;
- providing a forum for information exchange between industry, government, and universities.

Tasks are used as the capstone design course for senior students as a preparation to their future careers. The tasks were classified by the UAEU into specific and general categories. The topics of the specific tasks were assigned by UAEU, whereas the topics of the general tasks were left to be selected by the participating teams. However, in general tasks the participating teams had to present an innovative solution or technique addressing some contemporary environmental problem. The following general topics were strongly recommended by UAEU: effective treatment of offshore platform sewage effluents, cooling water discharges to the sea, and remote monitoring of flue gases. The teams (3–8 students per team) were expected to work on the tasks for about 6 months with the supervision of the faculty advisor(s) and present their work in the form of a written report, oral and poster presentations and bench-scale demonstration of the selected process. More than 12 international experts from academia and industry who analyzed the solutions from multiple angles judged the work of participating teams. The evaluation was based on technical, health, legal, community and economic considerations. Written, oral and poster presentations, as well as fully operational bench-scale models of the submitted designs, were presented by the participating teams in front of the panel of judges. The awards were presented to the winning teams during the closing ceremony. There were awards for first and second places for each specific task. In addition, there were general awards for the most innovative solution, best oral and poster presentations, best written report and most practical bench scale model.

In this competition SQU team Mechanical & Industrial Engineering Department had competed with other teams in solving two real problems that came basically from industry and so they have a

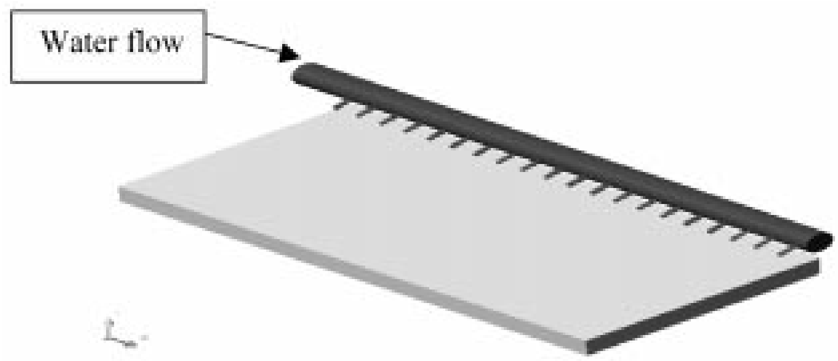

Fig. 1. Cooling water using a wide plate.

customer. The students worked on their tasks for about 6 months (starting from October 2003) under the author's supervision. The SQU team took first place honour in their specific task 'Brine Management'. They worked to shed light on the economic opportunities associated with the utilization of brine wastes for on-site generation of sodium hypochlorite. The team also won the 'Best oral presentation' in their general task of 'Cooling water discharges to the sea'. The study aimed at the determination of the best bench-scale solution of the thermal pollution problem.

In the next two sections, more details are given on the two missions of SQU team in this competition to show how SQU team applied basic science, fundamental engineering principles and design to practical real problems that came from industry. The results indicated that learning to apply engineering fundamentals in design methodology occurs best in the context of an industrially posed problem. Moreover, the practice of engineering requires learning to communicate effectively and learning to apply fundamental engineering principles to solve realistic problems.

GENERAL TASK: COOLING WATER DISCHARGES TO THE SEA

The main impact of the desalination processes is due to the discharges of the concentrated brine and the cooling water to the sea. The return of the concentrated brine and cooling water to the sea may harm the marine ecosystem in the area of the discharge. Thermal pollution that results from cooling water discharges to the sea can be defined as a major change in the temperature of seawater resulting from discharge of heated effluents from the desalination/power plants into the sea. A reduction in water quality caused by increasing temperature is expected. The chemistry of water changes considerably and most significantly by affecting the solubility of oxygen in seawater.

The SQU team presented field and design investigations that address the problem of cooling water discharges into the sea. The team had the opportunity to take this real problem, extract its essence, apply an analysis, and then make design decisions based on this analysis. The field part was conducted to check the effects of the thermal discharges from power and desalination plants. These effects were examined in terms of measuring simultaneously the temperature and the amount of the dissolved oxygen parameters at different distances from the discharge zones of the desalination plant. The measurements were taken in varying directions from the discharge zones. In addition, the measurements were taken in the intakes of the plant. There is evidence of a gradient in values of temperatures with the highest values at the points of discharge. An opposite trend was seen with the dissolved oxygen. The results of these observations were analyzed, compared and presented.

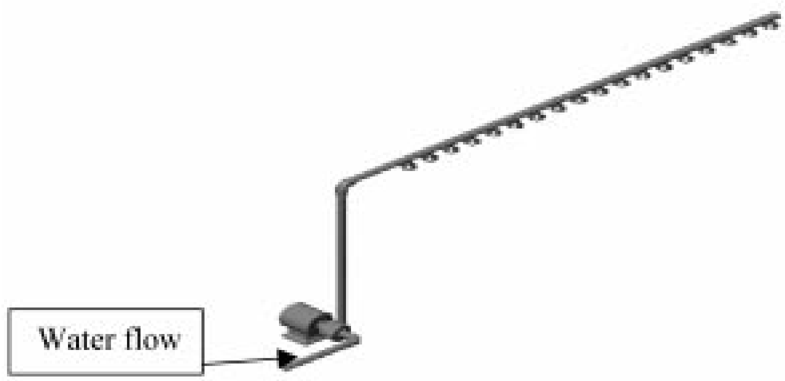

Fig. 2. Cooling water while it is falling down.

Fig. 3. Cooling tower design.

The design part aimed at the determination of the best bench-scale solution of the thermal pollution problem. The objective was to come with a new design, which can be applied to any desalination and power plant in the world. The team presented many ideas and various designs (Figs 1–5). An innovative technique was finally developed as a solution to the problem of cooling water discharges to the sea (Fig. 6). During testing the final design it was found that it reduces the temperature by around 5ºC, which is basically a significant reduction. In addition, this design did not only solve the problem of the thermal pollution problem but also it can be used as a source of electricity. The mechanical energy produced by its waterwheels can be recovered (employing energy recovery) by converting this energy to electricity or by transforming this energy to the feed water (e.g., to preheat the feed water).

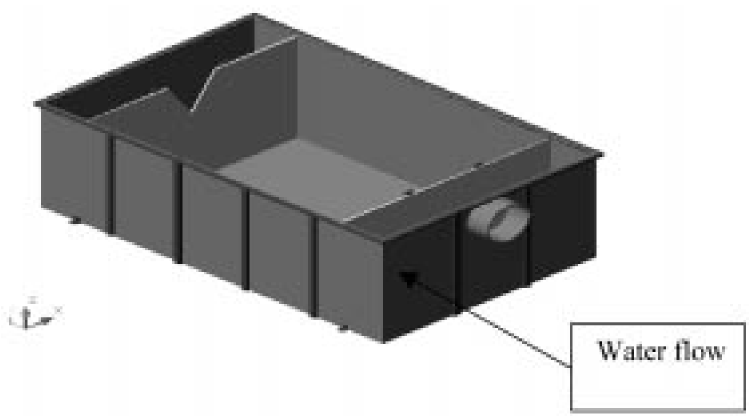

Fig. 4. Weir box structure.

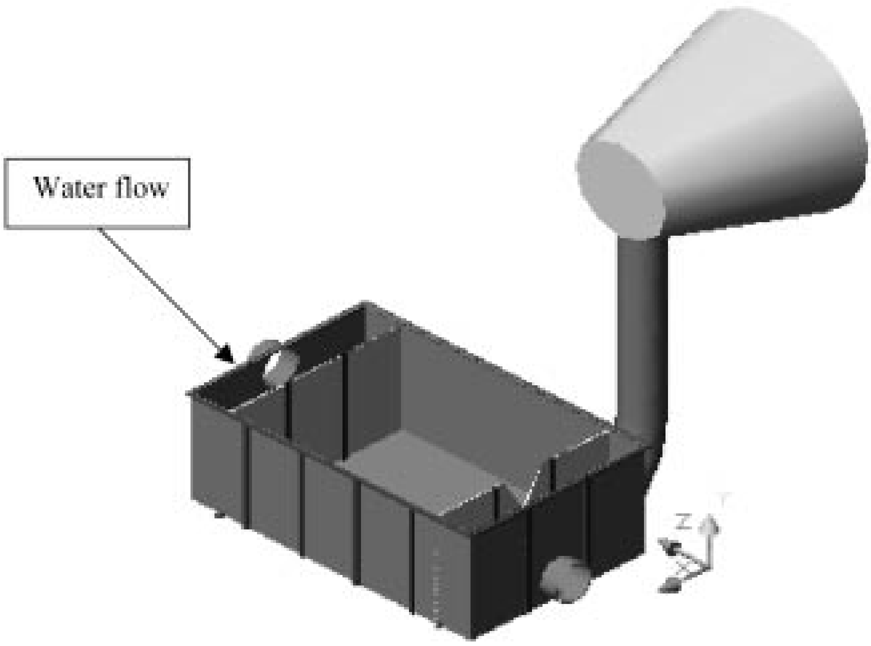

Fig. 5. Weir box structure with a compressor.

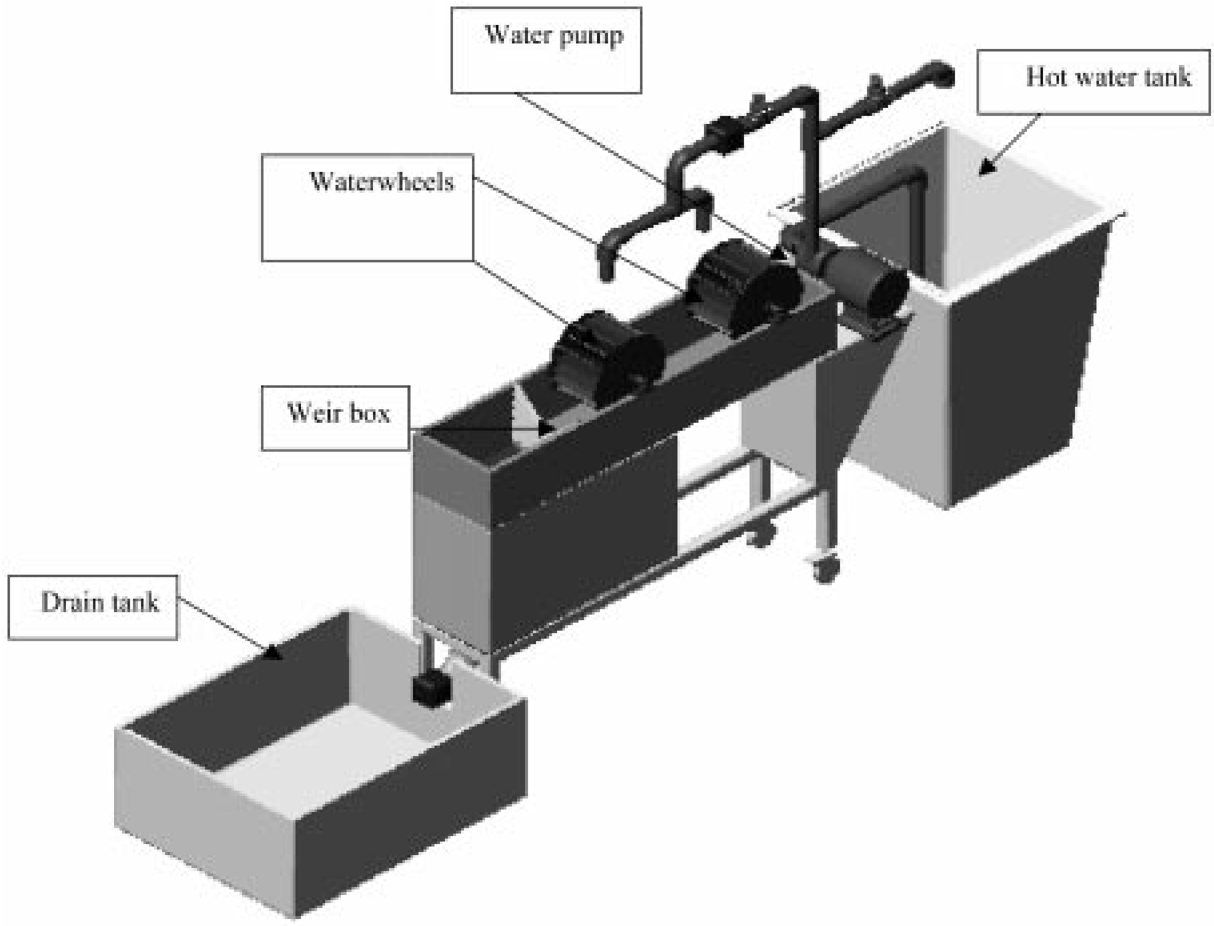

Fig. 6. Final bench scale design (best design).

Bench scale design (final design)

The bench scale information sheet of this experiment is described as shown below:

- *Name:* Best design solution for thermal discharge problem.
- *Objective:* To cool the hot brine discharged from the plant.
- *Components:* the bench scale consists of five main parts (Fig. 6) as shown below:
  - Hot water tank (i.e., to be used as a source of the hot water).
  - Drain tank (i.e., to be used as a sea beach).
  - Water pump (i.e., to pump the hot water from hot water tank to the waterwheels).
  - Waterwheels (i.e., to mix the hot water with the ambient air).
  - Weir box with a V-notch weir (i.e., for the purpose of cooling).
- *Procedure:* An electric heater is used to heat the water inside the source tank (Fig. 6). Then, the water pump was used to pump the hot water from the source tank to the waterwheels. This fallen water makes the waterwheels rotate in reverse direction to each other. After that, the water flows downward over the V-notch weir. The water falls from a high level to a lower level through this V-notch. This results in creating some bubbles, which takes up some heat from the water. Finally, the water is directed to the drain tank at a lower temperature. This system has two advantages: (1) the problem of the cooling water discharges to the sea is solved; (2) the mechanical energy produced by the waterwheels can be recovered by converting this energy to electricity or by transforming this energy to heat the feed water which is required for the steam generation.

THE SPECIFIC TASK: BRINE MANAGEMENT

The desalination process has been developed as an alternative source of drinking water in arid climate regions such as Oman and the rest of the Arabian Gulf countries. The growing concern in desalination in Arabian Gulf countries as the source of water supply is the result of major improvements in desalination technology and lack of other alternatives to meet the water difficulty. The main environmental problem related to the desalination of seawater is the brine discharge coming from the processes of desalination of seawater. For coastal desalination plants, the most practical and least expensive brine disposal method is to discharge it into the sea at the plant's outfall. However, there are several harmful environmental effects caused by this direct discharge. This discharged brine (concentrate wastewater) has many properties badly affects the environment. This discharged brine consists of highly concentrated salts and any un-reacted pre-treatment chemicals. It also brings with it heavy metals resulting from the corrosion of tube and flash chamber wall material. Therefore, the largest impact of desalination on the environment occurs at the outfall of the desalination plant.

In their specific task, the students addressed the problem of brine or effluents generated from the desalination production process. The mission was basically conducted with the objective of discussing the current 'state of the art' brine management strategies associated with desalination facilities. These strategies included: deep injection wells, irrigation systems, evaporation ponds, freeze, salt recovery/harvesting systems (or salt harvesting), direct discharge of the brine at the coastline, discharging the brines by a long pipe far into the sea, discharging the brines via the outlet of the power station's cooling water, direct discharge to waste water treatment plant, power generation (methods of energy recovery), aquaculture, and on-site hypochlorite generation.

The specific objective of their mission was to shed light on the economic opportunities associated with utilizing brine wastes for on-site generation of sodium hypochlorite, otherwise it will be discharged into the sea. In general, the process was aimed at the dual benefit of on-site generation of sodium hypochlorite and reducing the concentration of the brine. Therefore, the process not only generated sodium hypochlorite, but also helped to protect the environment.

Sodium hypochlorite is a useful and valuable chemical product. It is the most widely used active chlorine compound in disinfection. There are many overall advantages resulting from the on-site generation of sodium hypochlorite such as:

- The process requires only salt, water and electricity.
- The process provides the power of chlorine without the danger of storing or handling hazardous materials.
- Sodium hypochlorite generated on-site does not degrade like commercial sodium hypochlorite.
- The total operation cost is less than conventional chlorination methods.
- On-site generation of sodium hypochlorite allows the operator to produce only what is needed when it is needed.

The design part was aimed at the determination of the bench-scale for the production of sodium hypochlorite from the discharged brine. The SQU team presented a process for converting the concentrated brine into a useful product (sodium hypochlorite). This process of dealing with the concentrated brine will protect the environment and it will return something to an investor as well.

Bench scale design

- Objective: To demonstrate the electrolysis of brine solution that results in the production of sodium hypochlorite, hydrogen and other deposit.
- Components:
  - Two 0.5 m copper wire.
  - 24 DC supply system.
  - Two gravitas electrode.
  - Brine solution.
  - HACH spectrophotometer.
  - DPD total chlorine indicator.
  - Resistance of 10Ω.
- Connection: the two electrodes are immersed in the brine solution and then connected to the DC variable source. Indeed, a resistance is connected to the circuit to avoid any short circuit occurrence since there is no load.
- Procedure: insuring that the electrical circuit is complete and there is no contact between the two electrodes (i.e., to avoid the short circuit):
  - Switching on the DC supply and start working first at low voltage level (e.g., 10 V).
  - Starting gradually to increase the voltage until the level reach to 24 V.
  - At this stage the reactions occurring at both the cathode and the anode electrodes are noticed
  - Checking the bubbles that are generated at the anode.
  - Taking the solution and measure the total chlorine by spectrophotometer using HACH tablet.
  - Examining the color of the solution, this will be changed after adding the HACH tablet.
- Results: the results of the experiment may be summarized as follows:
  - Sodium hypochlorite ($NaClO$) is generated and examined by HACH tablets (the colour of the brine solution changes to pink colour).
  - Hydrogen is generated at the anode and was examined by the spark.
  - Sodium chloride is accumulated at the cathode electrode.
  - Brine salts (carbonates and hydroxides) are deposited at the bottom.
  - Amount of hypochlorite generated depends on the time of the reaction and the DC voltage supplied.

DISCUSSION

In an attempt to evaluate the experience gained from this exercise, the students were engaged in a discussion session. The objective of this discussion was to provide valuable information on this experience and its importance to appear in engineering curricula. The discussion showed that the competition exposed the engineering students to a variety of engineering principles such as thermodynamics, materials engineering, fluid mechanics, thermal, and heat transfer. The results suggested that there was a need to integrate competitions into the engineering curricula. The students expressed appreciation that SQU took the initiative to participate in the competition. They pointed out that the competition increased their basic understanding of the environmental aspects of engineering design. It developed their oral communication skills. Also, it provided them with knowledge on how to design a project that may be marketed and acquire skills to identify and solve environmental problems. They expressed the view that these issues should be covered in great detail in the engineering curricula. The college should offer such projects that deal directly with the overall environment and skills to provide engineering solutions to environmental problems. The impression that one may get from students' discussions was that there is insufficient coverage of topics and issues on the environment in the curricula. From the information provided by the students, an awareness of the impact on the environment due to engineering projects should be promoted in the engineering curriculum.

Designs as the ones developed by SQU students can be used for teaching and research. They may be integrated into the thermodynamics, fluid mechanics, thermal and heat transfer. This will enable the students to demonstrate the concepts learned in these disciplines in a practical way. Also, such competitions can be integrated to appear in environmental engineering courses to reflect the total environment. The competition demanded consideration of economics, business, regulatory, health, safety, engineering, basic science, and community relations aspects of design alternatives. This multidisciplinary contributed to the team building experience.

CONCLUDING REMARKS

In the Third International Design Competition (EDC 2004) held on May 2–5, 2004, in the College of Engineering at the UAE University, six students from College of Engineering at Sultan Qaboos University (SQU team) had competed with other teams from other universities. The goal of the competition is to design, develop and test actual environmental processes for real-world problems. Typically, the environmental tasks presented have no known solution, or the available solutions do not meet the desired performance criteria.

Through this competition, the students learned valuable engineering skills without the ever-present academic question 'Where will I apply this?' The students were introduced to engineering design and were involved in incrementally progressive design experiences. The competition showed the students the relationship between fundamentals and practical engineering. The students recognized that while everything might fit together and work on paper, it's often a totally different story when the parts are actually made. Through such competitions and faculty-guided analysis, a great link can be created between fundamentals and design that is particularly critical to a smooth transition from engineering study at the university to engineering practice in the real engineering world after graduation. Hence, it is one solution to the missing bridge between fundamentals of engineering and appropriate design training that is a basic issue in engineering education.

The increase in magnitude of environmental problems suggests that changes to engineering curricula are needed in order to inject environmental topics into engineering theory and practice. The issues concerning the environment should form an important part of engineering curricula if future engineers are to play a significant role in the protection and management of the environment.

The students were asked to summarize their feelings about this experience. All competing teams agreed that this competition was the best part of their engineering education. They mentioned that this experience built their confidence and developed their oral communication skills. In addition, it generated interest in other students who came and watched the team worked in the lab and applied theoretical concepts through running the experiments. They all felt that this form of education should be strengthened by the college.

It should be noted that the objective of the exposing the students into international competitions was to initiate interest among the students, create an appreciation of this kind of experience and enhance interactions with students from other universities. Therefore, we did not include the evaluation of their performance into the overall grading of the students. However, they were encouraged by the Dean who congratulated them upon their return. We hope that this will become a practice in which students can gain credit for participating in such competition.

Engineering faculties may take the experience of SQU students as a model to evaluate, emulate or build upon in encouraging their students to participate in competitions of this kind. This will be useful especially for students studying thermodynamics, fluid mechanics, environmental engineering or thermal and heat transfer. A panel of experts in university education may be formed at the regional level to agree on how to generalize this experience and integrate competitions into the formal education system.

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