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The Role of Environmental Design Competitions in Engineering Education*

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Engineering design is an essential and integral part of engineering education. It must always be carried out within certain constraints that may include technical, economic, environmental and societal concerns. Environmental design competitions represent an effective tool in enhancing the role of design in dealing with real engineering challenges. This paper presents a case study of the Environmental Design Competition (EDC) at the UAE University. The organizational procedure, the structure as well as the students' perspectives are presented. The education outcomes of the competition are also presented and compared with ABET (Accreditation Board of Engineering and Technology) criteria.

Keywords: capstone courses; design competitions; environmental design; engineering education; group work; ABET

1. Introduction

In the last few decades, there has been an increasing emphasis placed on design in engineering curricula [1]. The Accreditation Board of Engineering and Technology (ABET) requirement for programme accreditation is the inclusion of engineering design content in the programme. The ABET criteria require engineering design education to include considerations such as the environmental, health, safety, ethical, social and political impact of engineering design. The main part of this requirement is usually accomplished by senior 'capstone' design courses that require student teams to tackle open-ended 'real' engineering problems. It is an advantage if the student teams gain hands-on experience during the design process by developing working prototypes. The industry need is that the engineers are able to solve open-ended problems and produce quality design work [2]. The hope is that the engineering students gain enough experience in working on a real problem in a team environment to prepare them better for their future career.

As reported by Delson [3], team motivation is an important factor in quality of the design outcome. Students' competitions may be considered to be one of the incentives that can create team motivation. It is reported that student competitions are useful in teaching the creative and practical aspects of engineering design [4] and have provided a valuable experience for the participating students who are better prepared for the team environment found in industry [5]. Abdul-Wahab [6] reported that competition exposed the students to a variety of engineering principles and suggested that there was a need to integrate competitions into the engineering curricula. It is also reported that the students claimed that the competition increased their understanding of engineering design, improved their communication skills, and provided them with the knowledge and capabilities to design a novel and marketable process.

Although the competition can be general for any project, the projects that are directed towards specific areas could be much easier in terms of implementation, logistic and evaluation. These projects can be in the areas of manufacturing, building materials, carbon capture or environmental management. Competitions in the design of environmentally relevant engineering projects are essential to make engineers aware of the environmental concerns [6]. Gaining experience and knowledge in the area of environment, acquiring awareness and sensitivity to the environment, and obtaining skills for solving environmental problems are some of the benefits for students in these types of competitions, as reported by Nguyen and Pudlowski [7].

Although there are few universities and education institutions that organize design competitions, these contests are usually limited to the local community or region and limited to a certain discipline or field of study. The Waste-management Education & Research Consortium (WERC), which is now known as the Energy and Environment Institute, organized an environmental design competition within the USA. To the best of the authors' knowledge, there have been no reports in the open literature on environmental design competitions that involve teams from different disciplines and from different countries, where the design projects are integrated within the capstone courses of the programme curriculum. The international design competition at the UAE University was geared towards environmental design to reflect the Faculty of Engineering and the university's commitments to the environment. Therefore, the aim of this paper is

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to describe the UAE University experience in international student design competitions in an attempt to better prepare the graduates for the multidisciplinary, multinational, team oriented industry.

2. Rationale of Environmental Design Contest (EDC)

The main objective of the competition is to provide a forum for student teams from local, regional and international universities to tackle real world environmental challenges that are specific to UAE industries, addressing all relevant issues, including technical and legal aspects, health and community relations issues, and economics. The problems (challenges) are developed in cooperation with major local industries, government agencies and academic institutions.

Several benefits are gained through this industry–government–university activity, including:

- the development of innovative designs for meeting real environmental challenges facing industry and the country at large;
- providing hands-on education and practical problems for students to conduct their capstone senior designs under the supervision of faculty members;
- enhancing education and research interaction between participating institutions as some innovative designs will prove worthy of field application;
- sharing and exchanging technology and experience from academic institutions, industry, and government agencies throughout the world.

In addition, the industry sponsors receive a number of well documented, bench-scale tested and thoroughly researched solutions for their sponsored tasks, which could be used as basis for the development of novel processes. This approach benefits the specific industry as well as the students who will be future leaders in environmental issues.

3. Structure of EDC

The Faculty of Engineering starts the preparation process by assembling an organizing committee that includes faculty members from different engineering departments and may include faculty members from other disciplines such as Science, Medicine and Information Technology. The organizing committee formulates subcommittees, with specific assigned duties, who then begin to carry out their duties through the following steps:

1. Discussion with the industry to (a) propose real environmental challenges and formulate the tasks and (b) secure the required funding for the event.
2. Finalizing and publishing the tasks in the EDC website.
3. Call for submission of abstracts 'summary reports' of the proposed approach or solution by the possible participating teams.
4. Screening the 'summary reports' by a subcommittee and announcing the selected teams who are eligible for participation.
5. Working with the students to provide them with any additional information needed for the completion of their tasks.
6. Selection of the judges for each task.
7. Receiving the final reports and sending them to the judges for review.
8. Preparing for the final stage of the event, which include: oral presentations, bench-scale demonstrations, and poster presentations.
9. Hosting the participating teams and judges during the event.
10. Finalizing the event by the closing ceremony and announcing the winners.

One of the subcommittees is responsible for technical support and follow-up of all pre-contest activities. These include problem development and refinement, interaction with sponsors, and assistance in problem distribution to universities. This will also include visits to the companies to identify 'tasks', and plan for activities during the contest. The subcommittee will also assist in post-contest activities such as interaction with sponsors, solution distribution and ultimate application of selected technologies.

3.1 Problem formulation

The most important aspect of the capstone design project is the selection of the tasks. The developed tasks must be real industry-oriented problems. The industry is heavily involved in problem formulations, funding and evaluation of the projects. The required information for each task is provided by interested industries that are generally the sponsors of these projects. With the cooperation of the industry, the tasks are formulated to be 'open-ended' problems with insufficient information to be solved. Table 1 lists some of the tasks developed in collaboration with local industry.

3.2 Evaluation and judging

Students are required to form a multidisciplinary team to design and construct a bench-scale working model and demonstrate their process. Their demonstration is to include the following.

1. A written report to include description of the process and a detailed plant design. It should

also include cost estimation, a discussion of legal and health implications, and a plan for presentation to the community for public acceptance so that problems are minimized after construction.
2. A practical bench-scale model of the process to demonstrate functionality of the process.
3. A brief oral presentation of the design, including economics, health, business development, regulatory and other related issues.
4. A poster presentation containing highlights of the design, economics and other issues.

A group of five experts from industry, government agencies and universities are selected for the evaluation of the projects for each task. The judging is based on technical as well as other important criteria such as economics, risk analysis, health regulations, public policy and communication. The judges evaluate the written reports and bench-scale demonstrations; they also cross-examine the students during the oral and poster presentations. The work of each team will be evaluated based on established criteria for each category, which will be provided to the judges. The judging starts from the first day and continues until the end of the event. Tables 2–6 list the judging criteria along with the weighting factor of each category.

Table 1. Examples of selected tasks for EDC

1	Nitrate removal/control from sandy soil in Arid Farms
2	In-situ technique for detection of oil pollution in seawater
3	Removal of ammonia and phenol from refinery wastewater
4	Production of brackish water from sea water for agricultural and landscape irrigation
5	Nitrate removal from drinking water
6	Sour gas treatment
7	Ballast water treatment
8	Hydrocarbon polluted soils
9	In-situ monitoring of water quality
10	Brine management
11	Re-use of spent lubricating oils
12	Utilization of elemental sulphur
13	Oil spill clean-up absorbent technologies

4. UAE University experience

The Faculty of Engineering at the UAE University has hosted four International Student Environmental Design Contests so far. Abu Dhabi National Oil Company (ADNOC) and Shell Abu Dhabi have been the major sponsors of the four events. In addition to teams from UAE Universities (UAEU, Sharjah University and the American University of Sharjah), student teams from different countries have participated in the four EDC events. These include Oman, Qatar, Jordan, Palestine, Algeria, Iran, India, Malaysia, Singapore, Taiwan, China, Canada, England and the USA. Table 7 shows a

Table 2. Judging criteria for the written report (Max. Marks = 600)

No.	Criterion	Score (0–5)	Weight	Total score
1	Executive summary		10	
2	Engineering basis for design		30	
3	Basis for option/process selection		20	
4	Technical content and organization		20	
5	Economic analysis		20	
6	Overall quality		20	
			Total	/600

Table 3. Judging criteria for oral presentation (Max. Marks = 400)

No.	Criterion	Score (0–5)	Weight	Total score
1	Justification and advantages of the proposed solution		15	
2	Overall scientific and engineering basis		15	
3	Ability to answer judges' questions		15	
4	Presentation delivery and effectiveness		15	
5	Overall quality		20	
Deduction: Failure to observe 20 minutes time limit: −**10** per each extra minute				
			Total	/400

Table 4. Judging criteria for poster presentation (Max. Marks = 300)

No.	Criterion	Score (0–5)	Weight	Total score
1	Clarity of the process description		15	
2	Completeness and conciseness		15	
3	Quality of the poster presentation and team's ability to answer questions		15	
4	Overall impression		15	
			Total	/300

Table 5. Judging criteria for bench-scale demonstration (Max. Marks = 700)

No.	Criterion	Score (0–5)	Weight	Total score
1	Unit stability		25	
2	Safety and environmental friendliness		30	
3	Design and craftsmanship		25	
4	Functionality and effectiveness		50	
5	Cost of construction of bench scale		10	
			Total	/700

Table 6. Judging criteria for innovation and practicality (Max. Marks = 500)

No.	Criterion	Score (0–5)	Weight	Total score
1	Innovation of the idea		60	
2	Practicality/Applicability of the design		40	
			Total	/500

Table 7. Growth of EDC at UAEU

EDC	Number of participating teams	Number of international teams	Industrial sponsors
1st	10	4	ADMA-OPCO, ADCO
2nd	17	11	ADNOC, SHELL
3rd	19	12	ADNOC, SHELL, Schlumberger
4th	28	23	ADNOC, SHELL, Etihad Airways, EnPro and Corodex Industries

summary growth of student-participation in the four EDC events.

Awards are given for first and second places for each task. In addition, there are general awards for the most innovative solution, best oral and poster presentations, best written report, and most practical bench-scale model.

5. Students' experience

All students were given the opportunity at the final award ceremony to talk about their experience and describe their participation from the day they selected the task to the day that they presented their innovative design. One of the students described his team participations as:

> a challenging experience that could not be taught in classrooms and could not be gained by reading textbooks or browsing the Internet. Definitely, there was a lot of time and effort involved. Many sleepless nights, many tight schedules, many mental and physical stresses, but in spite of all that, we were very enthusiastic, and worked hard. Because what really mattered to us, was designing something extra-ordinary and unique that would represent a practical solution to a real engineering problem. Sitting together as a team—discussing our plans, sharing our joys when we succeeded, and concerns when we faced difficulties—taught us the meaning of group work and problem solving. It is engineering at its best: group work, innovation, solving problems and caring for our environment. This contest made us reach and break the barrier between Engineering Education and real engineering life. It is an experience we will never forget and will treasure for the rest of our lives.

6. Educational outcomes

There is no doubt that the UAEU environmental design competitions contributed to the engineering education of the participating students in many ways. These include: improving their communication skills; the ability for process design and economical assessment; awareness of environmental challenges; and the ability to work in multidisciplinary teams. A comparison of the main requirements of EDC and the engineering education criteria set by ABET 2000 is presented in Table 8. It is clear that EDC requirements ensure that the event is more than just an extra-curricular activity; it is a hands-on learning experience that satisfies the ABET criteria. Furthermore, many of the winning design projects have been either published or lead to successful and publishable research work.

At the UAEU, most of the participating teams have presented their projects as final graduation projects in their departments and achieved high grades. One of the UAEU successful projects that won first prize in the second competition '*Oil spill clean-up absorbent technologies*' has been published in the proceedings of an international conference [8]. The successful outcome of another winning project in the fourth competition '*Production of brackish water from sea water for agricultural and landscape irrigation*', lead the advising faculty members to carry out successful research in the area, which was published in a reputable international journal [9].

Table 8. A comparison of EDC requirements with ABET Criteria

ABET criteria	EDC requirements
(a) Ability to apply knowledge of mathematics, science, and engineering principles.	The students must have understanding of maths, science, and engineering principles to use in solving real life problems.
(b) Ability to design and conduct experiments that comply with safety and environmental regulations, as well as analyse and interpret data.	The students must demonstrate their proposed solution through the design of an experimental plan, design a bench-scale model, conduct experiments and interpret data.
(c) Ability to design economical, safe and environmental friendly systems, components, or processes to meet desired needs.	The students must design an economical, safe and environmental friendly process for their proposed solution.
(d) Ability to work in multidisciplinary teams.	The competing teams consist of 3–8 students. The students plan, organize, distribute tasks and work in a teamwork environment.
(e) Ability to identify, formulate and solve engineering problems.	An innovative solution is required for the real life problems given to the students.
(f) Understanding of professional and ethical responsibility.	The students need to understand ethical issues and comply with their ethical responsibility.
(g) Ability to communicate effectively.	The students are required to present their work in the form of a written report, oral and poster presentations. They also have to make a bench-scale demonstration of the selected process.
(h) Ability to understand the impact of engineering solutions in a global and societal context.	The tasks are developed in collaboration with the local industry and the solutions are forwarded to the funding agency for possible use.
(i) Recognition of the need for, and an ability to engage in life-long learning.	The students are encouraged to seek some of the required information/knowledge from the funding agencies or other experts in the area.
(j) Knowledge of contemporary issues.	The students are encouraged to adopt advances in technologies and disciplines related to Engineering.
(k) Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.	The students are required to apply modern techniques and tools such as the use of software and the Internet for obtaining innovative solutions to the real life environmental problems.

7. Examples of other winning projects

This section presents a brief description of two examples of winning projects dealing with major environmental problems.

7.1 Problem definition

The desulphurization of petroleum products and natural gas generates huge amounts of sulphur. It is estimated that more than 2.1 million metric tons of sulphur are generated annually by refineries in the UAE. The accumulation of these amounts represents major environmental and economical problems to the UAE petrochemical industries and society as a whole. The prime objective of the project was to design a spouted bed process for sulphur coating fertilizers such as urea. The successful process will convert the generated sulphur into a useful and a valuable product.

7.2 Process description and approach

The proposed process consists of eight major units: two hoppers to feed urea and granular sulphur; a sulphur liquefier (melter); two spouted beds for coating the urea and cooling the product; and a cyclone to remove any sulphur particles entrained with the air leaving the spouted beds; a filter to remove the traces leaving the cyclones; and a heater to heat the air needed for spouting. Granular sulphur particles will be fed through the first hopper to the sulphur melter, where sulphur is liquefied at 150°C. Compressed air is used to transport the liquid sulphur to the spouted bed through an atomizer, which is positioned either at the top or at the bottom of the bed. The urea particles, which are fed to the first spouted bed through the second hopper, are kept in continuous motion through air spouting. Liquefied sulphur is sprayed over the urea particles, creating a thin layer of sulphur; the thickness of which can be controlled through the spouting velocity and spraying rate. The coated urea is then sent to the second spouted bed, which acts as a dryer to cool the particles and prevent agglomeration. The final units, the cyclone and the filter, are needed to clean the exhaust air from any sulphur contamination. The process is designed to handle 600 000 metric tons of urea per year, which use almost 450 000 metric tons of sulphur per year. In order to handle these huge amounts of urea and sulphur, an array of the major units was repeated in order to reach the desired values.

The students tested their proposed process using a semi-batch bench scale (Fig. 1). The bench-scale was designed and built to coat about 8.9 kg of urea using about 5.8 kg of sulphur. The students won the first prize in their task and their proposed solution

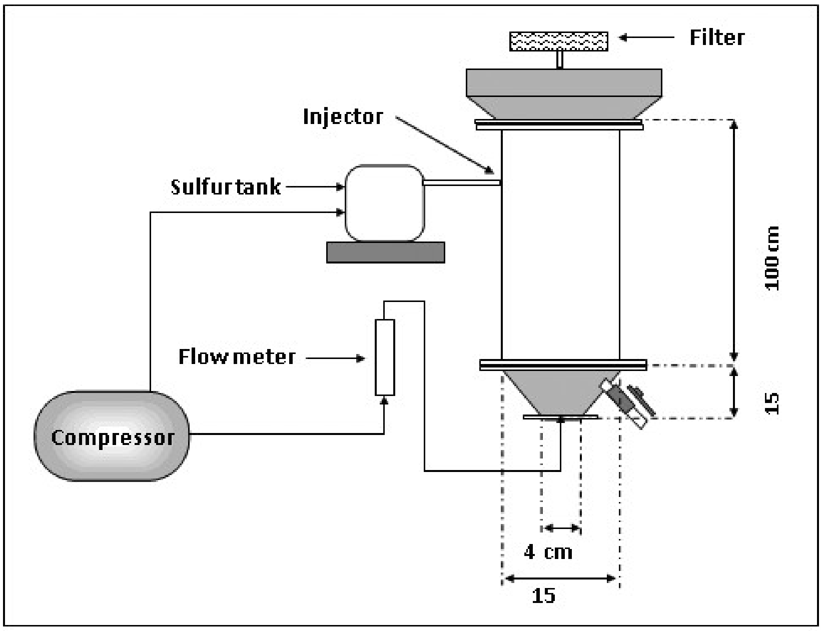

Fig. 1. A bench-scale set-up for the sulphur coating of urea [10].

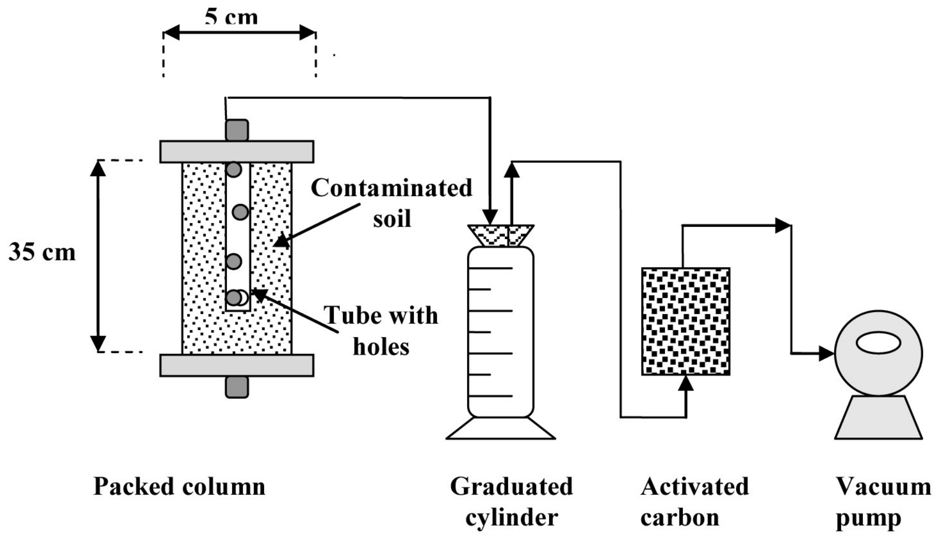

Fig. 2. A bench-scale set-up for the bioremediation of contaminated soil [11].

attracted the attention of the judges as well as spectators who attended the bench-scale presentation.

7.3 Problem definition

Soil contamination with hydrocarbons near storage tanks at refineries or at service stations is an environmental concern and may lead to the more serious problem of ground water contamination. It is a major problem in the world and many countries suffer from these contaminants because of their bad impact on the environment. Most of oil spills involve crude oil, which poses a more significant environmental risk than other hydrocarbons due to its complexity and low viscosity, allowing for rapid spreading and penetration into porous soils, generating subsurface oil pockets. The ultimate goal of this project is to develop a remediation method for the treatment of UAE soil contaminated with Arabian crude oil.

7.4 Process description and approach

The main objective of this project was to clean the hydrocarbon contaminated soil using extraction and bioventing methods. A number of experiments were conducted on a bench-scale set-up (Fig. 2), which consisted of a packed column (5 cm diameter and 35 cm high) containing 1000 g of soil saturated with 175 ml of Arabian crude oil. The packed column includes a pipe with small holes covered by a filter paper or stainless steel mesh. A vacuum pump was used to extract the free oil, which will flow through the holes of the filter paper (or mesh), which prevents small sand particles from entering the pipe. A graduated cylinder was used to determine the volume of extracted oil. An activated carbon unit was used to treat gases and volatile components that were produced during the extraction process. The bench scale was used to evaluate the applicability of the selected process and to optimize some of the parameters needed for the pilot-scale.

8. Conclusions

Environmental design competitions can contribute to raising the standards of the design components in any engineering curricula and can enhance the students' awareness of the major challenges that they may face in their engineering practice. A case study of the EDC at the UAE University has been presented and discussed in terms of organizational and students perspectives. Students who participated in these events felt that the experience had improved their understanding of and coping with real engineering challenges and gave them a better feel of their role as future engineers in dealing with the environment. The involvement of multidisciplinary teams from different countries and different cultures made the participants feel the magnitude of the global environmental challenges. In addition, a comparison of the main requirements of EDC with the engineering education criteria set by ABET 2000 clearly showed that EDC is more than just an extra-curricular activity; it is a hands-on learning experience that satisfies the ABET criteria and contribute to engineering education.

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References

1. C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey and L. L. Leifer, Engineering design thinking, teaching, and learning, *Journal of Engineering Education*, **94**(1), 2005, pp. 103–120.
2. L. M. Nicolai, Viewpoint: An industry view of engineering design education, *International Journal of Engineering Education*, **14**(1), 1998, pp. 7–13.
3. N. J. Delson, Increasing team motivation in engineering design courses, *International Journal of Engineering Education*, **17**(4), 2001, pp. 359–366.
4. M. L. Davis and S. J. Masten, Design competitions: does multidisciplinary contribute to the team building experience?, *Proc. Frontiers in Education (FIE 1996) 26th Annual Conference*, Part 1, Salt Lake City, UT, USA.
5. J. F. Marchman III, Multinational, multidisciplinary, vertically integrated team experience in aircraft design, *International Journal of Engineering Education*, **14**(5), 1998, pp. 328–334.
6. S. A. Abdul-Wahab, Contribution of international environmental design competition in raising the profile of environmental education in engineering students, *International Journal of Engineering Education*, **21**(5), 2005, pp. 973–980.
7. D. Q. Nguyen and Z. J. Pudlowski, Educating engineers for the environment: a pilot study on how students assess the concept in engineering curricula, *Global Journal of Engineering Education*, **3**(2), 1999, pp. 105–114.
8. A. Al-Marzouqi, A. Busamra, F. Mohammed, S. Al-Shehhi and W. Abdul-wahab, A novel absorbent-skimmer technology for cleaning oil spills, *Coastal Engineering VI: Computer Modeling and Experimental Measurements of Seas and Coastal Regions*, WIT Press, 2003, Southampton, Boston.
9. M. H., El-Naas, A. H. Al-Marzouqi and O. Chaalal, A combined approach for the management of desalination reject brine and capture of CO_2, *Desalination,* 251, 2010, pp. 70–74.
10. A. Hussain, A. Naser, M. Al-Jaberi and S. Mohammed, Design of a spouted bed process for sulphur coating of urea, *EDC Final Report, UAE University*, March 2002.
11. A. Zaidi, A. Jassim, F. Mohsen, M. Hussain and S. Hussain, Design of an effective remediation method for hydrocarbon contaminated soil, *EDC Final Report, UAE University*, April 2004.

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