Employing the WERC International Environmental Design Contest as a Part of a Capstone Course

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Since its beginning in 1990, WERC: A Consortium for Environmental Education and Technology Development (WERC), has been uniquely successful in addressing issues related to the management of all types of environmental waste through education, technology development, technology transfer and public outreach. A main focus of the program is the WERC International Environmental Design Contest. The Contest seeks innovative solutions and approaches to water, waste management and energy problems. Now in its 26th year, it provides university and college teams with the opportunity to research, design, develop and deploy practical solutions to real-world environmental and human health challenges facing this nation. The student teams design and develop fully operational bench-scale solutions that are presented to panels of judges comprised of environmental professionals. The judging criteria includes: process feasibility and practicality, cost analysis, community relations and outreach, adherence to various applicable regulations and permitting, safety considerations, and a discussions of potential waste streams. Held at New Mexico State University in Las Cruces New Mexico, the Contest creates a venue for the synthesis and application of a student's knowledge and skills acquired over the course of his or her college career. Many universities use the Contest as part of their capstone classes.

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Background

WERC: A Consortium for Environmental Education and Technology Development (WERC) was created in 1990 by the U.S. Department of Energy as a partnership between several New Mexico universities, and Los Alamos and Sandia National Laboratories. The International Environmental Design Contest hosted by New Mexico State University serves as the flagship for the WERC environmental education and research activities. The WERC program has continued to be funded through grants from various industrial partners, U.S. agencies, and a Foundation that was created in 2006 from a donation to the program.

The Contest is structured to give university student teams an opportunity to compete in an international contest for design and development (technical, economic, public communication, and regulatory aspects) of an environmental control process. Each team designs a full-scale process and tests their design on a bench-scale model. Teams also prepare publishable papers and poster presentations. Their work is presented to a group of judges from government and industry. The student teams compete for trophies and cash awards.

When learning a new game one can read and understand the rules; but the capability to develop a strategy only comes with experience. The Contest is an educational experience that has been designed to simulate actual career challenges. Similar to the problems that students will eventually face in their careers, the Contest requires a strategy, recognition of the boundaries associated with the task, identification of a path forward and a personal commitment to follow through to achieve success.

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. The creators of the tasks provide participants with a professional learning experience.

The competition is structured around three distinct focus areas: Water, Energy, and Waste Management. The problem statements are developed with the assistance of government and industry personnel who also provide funding to the Contest Foundation and serve as judges at the competition.

By blending the fresh ideas and energy of students with the knowledge and experience of faculty, industry, and government, the Contest creates new resources and stimulated novel research. Environmental issues are formatted into problem statements that are suitable for

universities to use as part of their capstone design classes. The students are allowed to take risks by thinking outside of the box, unencumbered by a "business-as-usual" attitude; however, their solutions must work within regulations, codes, laws, public attitudes, and economic constraints.

Many past contestants have commented that the Contest, although a frustrating undertaking that requires working with a variety of personalities, is among the best experiences of their university careers. Riley[1] notes that, "…this competition incorporates a significant written report, oral and poster presentations, prototype bench-scale demonstration where as many as five different teams of industry judges evaluate individual bench-scale presentations. The organization, supportive environment for students, and professionalism of the many staff members and industry participants running the contest each year over the course of the four-day competition is a model for success."

A Career-Enhancing Experience

Upon entering the business world, college graduates will undoubtedly have opportunities to make presentations to senior managers or clients. They will need to demonstrate their knowledge, skills, common sense, creativity and clarity in preparing and presenting ideas. The Contest is designed to help students develop those skills that will remain relevant throughout their careers.

The Contest prepares students for the professional world in several ways. First, it gives students an opportunity to develop skills required in business in a competitive environment. Second, it gives students the opportunity to make presentations to and interact with judges who are experienced professionals. Third, the Contest gives students experience in being subjected to both objective (quantitative) and subjective (qualitative) criteria, something they will be exposed to many times during his or her career.

Who is Involved?

The Contest is open to student teams from any two-year, four-year or higher education institution. Figure 1 shows the location of many of the schools that have participated from 1990 through 2016 during which over 5,000 students from 94 U.S. universities and 8 international schools have attended the Contest. Many institutions have returned multiple times over the years.

The Contestants

Each team is composed of several students and a faculty advisor. Similar to the work environment, successful approaches to the Contest require a multidisciplinary team bringing a variety of skills to the task. The number of students who participate on a team is not nearly as critical as the composition of students involved in the task. The Detailed Information description for each task (including any attachments) should be carefully read to determine what skills are needed to establish a team. A common error is composing a team with people who have only technical expertise. While the task itself may be technical, presentations must also include economic, social and regulatory analysis. Students who have completed classes in cost estimating, accounting, public administration, communication, journalism, business, safety or environmental law are often assets to a team. Another consideration in a team's composition is age and experience. Teams composed of students ranging from freshman through graduate have at least one advantage; one or more members will be available the next year to mentor a new team.

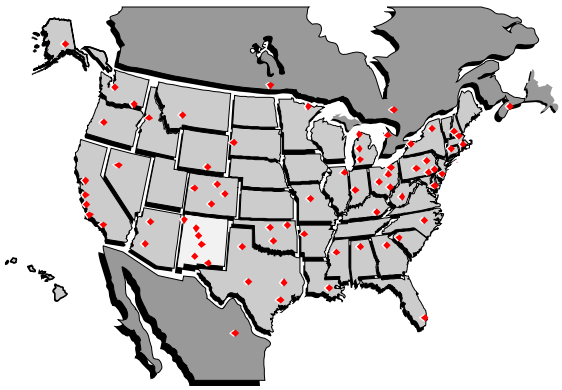

Figure 1. 1990-2016 Participating Teams. (Some international teams not shown).

The Judges

The average judge has 15 to 20 years' experience and is a professional leader. The judges come from all walks of life and different backgrounds. A broad base of judges is needed to bring expertise in physical and biological sciences, engineering, business, economics, health and safety regulations, environmental regulations, public policy and communications to the Contest.

The Faculty Advisors

The faculty advisor is an integral part of a Contest team and provides an invaluable liaison between the university and WERC staff. The advisor helps students identify and acquire appropriate funding, equipment, services and interdisciplinary cooperation. Advisors can also counsel students on technical merits of a design and ways to advance through each stage of a project. The advisor should provide guidance in setting goals and keeping a project moving at an appropriate pace to assure its completion within the Contest time frame.

The advisor can provide continuity to competing teams from year to year on the logistics, rules, and procedures of the Contest. The advisor is also familiar with the policies or practices of their own university.

Past judges have noted that a close relationship between a team and its faculty advisor contributes to the success of that team. Judges have noted that teams accompanied by their advisors throughout the Contest generally perform significantly better than teams whose advisors do not attend.

The Four Parts of the Contest

The Contest has four parts: a paper that describes a full-scale process analysis and design; an oral presentation; a bench-scale process demonstration (with samples taken of the product for analysis); and a poster board presentation.

All four of the Contest elements are intended to communicate and advance ideas and projects toward implementation in a business environment. Previous teams have successfully submitted their papers and posters from the Contest to various conferences and journals for publication such as the Elsevier's Desalination journal[2]. Detailed requirements, including judging criteria, for each element can be found at http://www.ieenmsu.com/outreach/events/international-environmental-design-contest/guidelines/.

Schedule

Each year, the problem statements are developed with industry assistance during the summer and are posted in the early fall semester. Each university builds their team, based on the disciplines required to effectively address the environmental challenge presented by the Contest. The schools address one or more of the various tasks and often spend up to six months developing their solutions before the final competition in April.

Some universities, including the University of Arkansas, have shared that their students begin their capstone course in the spring semester, while others, such as Idaho State University, have indicated that their students have two semesters of capstone classes to work on their entries.

Riley[3] presents a detailed list of activities for the teams that works well for those students participating in the Contest with two semesters of capstone classes: **Fall semester** - Define the problem, Develop design specifications, Plan and manage the project, Research possible solutions or supporting information, Generate concepts, Evaluate each concept using engineering tools/analysis, Evaluate the competition, Design using engineering tools/analysis, Develop proof of concept(s), Present/defend the design through critical design reviews, and Document all steps and preliminary design details in a comprehensive technical document; and **Spring semester** - Build/implement the final design**,** Develop a test engineering plan and test the design**,** Redesign or make improvements based on the test results, Implement the improvements, Test again, improving the test scope if appropriate, Improve the design and implement the improvements, Present/ defend the design through design reviews, Document all steps and final design details in a comprehensive technical document, and Present final design in a design showcase to industry representatives, faculty, fellow students, and the community at large. Students in a one semester capstone class would need to significantly increase their time commitment to complete the activities.

Post-Contest Feedback

For participating universities, Contest feedback has become a useful tool when addressing the outcome assessment requirements for ABET (Accreditation Board of Engineering and Technology) innovative criteria – EC 2000[4,5]. The Contest correlates to ABET requirements a-k. To address the Contest tasks, the students have to: apply knowledge of mathematics, science, and engineering; have an ability to design and conduct experiments, as well as to analyze and interpret data; design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; function on a multidisciplinary team; identify, formulate, and solve an engineering problem; understand professional and ethical responsibility; communicate effectively; understand the impact of engineering solutions in a global, economic, environmental, and societal context; recognize the need for, and an ability to engage in life-long learning; acknowledge contemporary issues; and use the techniques, skills, and modern engineering tools necessary for engineering practice[6].

Specifically, the Contest provides outcomes such as critical thinking, quantitative reasoning, interpersonal skills, problem solving, integrating and transferring learning, communication skills, ethical understanding, and current event challenges related to engineering, as well as global issues and challenges. The students must be able to design and demonstrate functionality of a complex engineering system in an interdisciplinary manner. The team work required by the Contest and the creation of a working bench-scale model fulfills these requirements. The Contest also addresses ABET item i as it serves as a technique to energize the students and inspire life-long learning.

The Contest provides professional evaluation of the strengths and areas for improvement. After the Contest, WERC sends the student teams their scores, laboratory

analytical results, and a professional evaluation of the strengths and areas for improvement which provides, the feedback and assessment that addresses the ABET feedback requirement. The scores sent include their own score for each of the four areas and the high and low scores for each of the areas from the other teams. Table 1 is an abbreviated example of the judging results that is sent to the teams. The scores can be aligned to specific ABET student outcomes (i.e. oral presentation scores align with ABET item g, and bench-scale scores align with ABET items a, b, e, etc.). The scores are based on the following criteria:

- **Paper (30%)**

Executive summary, basis for design, equipment and process selection, depth of research, laboratory evaluation, testing, waste generation, discussion of legal and health implications, economic analysis and/or cost benefit discussion, professional audits/public involvement, overall quality/succinctness, clarity of communication.

- **Oral Presentation (25%)**

Completeness of presentation, inclusion of key sections, effectiveness, team participation, audio-visual materials, and ability to answer questions.

- **Bench-Scale Demonstration (30%)**

Effectiveness and overall performance, originality, craftsmanship, completeness, safety, environmental and public health considerations, waste generation, cost effectiveness, scalability, processing time, ease of use, and reliability.

- **Poster Presentation (15%)**

Effectiveness, graphic impact, presentation, completeness, and ability to answer questions.

Table 1. Abbreviated Example of Judging Feedback.

	Paper	Oral	Bench	Poster
High	414	398	454	236
Team Score	414	398	454	236
Low	188	204	260	146
	600 max	500 max	600 max	300 max
STRENGTHS: •Excellent oral presentation, very professional •Excellent paper •Very thorough in process evaluation and economic assessment •Using COD for oil detection is an innovative idea •Permeating oil rather than water is also an innovative concept •Process is very simple and easy to implement				
AREAS FOR IMPROVEMENT: • Consider the importance of regulation and permitting, particularly related to waste disposal • Should improve bench design to process specified quantity of water • Adjust volume to ensure voice projection is suited for the room during presentation • Should improve on safety, and community involvement • Should put on appropriate protection gear at bench scale • Improve process equipment design to avoid leaking of the filtration unit				

Conclusions

Since 1991, the WERC International Environmental Design Contest has combined an unparalleled educational experience with the site specific environmental issues faced by industrial sponsors. The result – preparation of today's students for their graduation and entry into the job market. Design competition can contribute substantially to the educational experience of engineers. The WERC Contest gives students a source for real projects where their results are put into practice, simulates the workplace, and students that participate gain an understanding how competition can work when bidding on future engineering projects. For additional information, visit the WERC website at http://www.ieenmsu.com/.

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