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An International Design Project for First Year Engineering Students at Multiple U.S. Institutions

Dr. Thomas J. Siller, Colorado State University

Tom Siller is an Associate Professor in Civil and Environmental Engineering at Colorado State University. He has been a faculty member at CSU since 1988.

Ms. Erica J Marti, University of Nevada - Las Vegas

Erica Marti completed her PhD in Civil and Environmental Engineering at the University of Nevada, Las Vegas (UNLV). She holds a Master of Science in Engineering and Master of Education from UNLV and a Bachelor of Science in chemistry from the University of Illinois at Urbana-Champaign. Prior to graduate studies, Erica joined Teach for America and taught high school chemistry in Las Vegas. While her primary research involves water and wastewater, she has strong interests in engineering education research, teacher professional development, and secondary STEM education. In 2021, Erica received the ASEE Pacific Southwest Early Career Teaching Award and two awards at UNLV for mentoring undergraduate and graduate students. She also received the Peter J. Bosscher Outstanding Faculty Advisor Award in 2019 from Engineers Without Borders and was recognized as a Nevada Woman in STEM by Senator Jackie Rosen.

Cory Budischak, Temple University

Cory is a teacher and researcher who strives to reduce the harmful effects of energy production and use. Teaching has always been his central passion. He started as a group tutor in college, which led him to his full time career as an Assistant Professor of Instruction at Temple University in the Department of Electrical and Computer Engineering. He employs innovative instructional methods such as problem based learning, flipping the classroom, and teaching through interactive games. His research focuses on the transition to 100% renewable energy and effective engineering instruction using problem based learning, flipped classroom approaches, and design thinking. He spent 8 years at Delaware Technical and Community College in the Energy Management Department as an Instructor and Department Chair before transitioning to his current role at Temple University. When Cory is not educating or researching, he enjoys backpacking, yoga, volleyball, and hiking with his family. More information about Cory can be found at www.bit.ly/corybud.

Dr. Matt Gordon P.E., University of Denver

Dr. Matt Gordon is Professor in the Department of Mechanical and Materials Engineering. His research areas include numerical and experimental plasma physics, chemical and physical vapor deposition, electronic packaging, and bio-medical engineering. He has supervised to completion 26 MSME students and 5 PhD students. Publications include 1 book chapter, 32 journal publications, 47 refereed conference proceedings, 29 non-refereed publications, and 27 non-refereed presentations. He is responsible for funds as PI or Co-PI from 52 separate proposals totaling almost $6,500,000. Courses taught include undergraduate finite elements, thermodynamics, fluid dynamics, heat transfer, and engineering economics and ethics, and graduate finite elements, numerical methods, thermodynamics, statistical mechanics, plasma fundamentals and gas dynamics.

Dr. Carlo Salvinelli, University of Colorado Boulder

Dr. Salvinelli is a Teaching Assistant Professor at the Mortenson Center in Global Engineering at the University of Colorado Boulder where he teaches courses on humanitarian response and disaster management, international development project management, and field methods for development engineers. He has a BS in Industrial Engineering and a MS in Engineering Management from the University of Brescia, Italy, and a PhD in Geological Engineering from the Missouri University of Science and Technology where he conducted research focused on household water treatment systems for underserved communities. Dr. Salvinelli spent six years working as a practitioner for international NGOs, especially in Central

America, where he designed and implemented international development projects, coordinated emergency response efforts, and facilitated international policy dialogues. The projects he managed addressed key development challenges including rural livelihood, water and sanitation access, rural electrification, disaster risk reduction, and natural resources management. His research interests include monitoring and impact evaluation of water service delivery solutions, the development of tools for disaster risk reduction and disaster management, and the coherence between humanitarian and development efforts in response to forced displacement related crises.

Full Paper: An International Design Project for First Year Engineering Students at Multiple U.S. Institutions

Introduction

Multiple U.S. institutions of higher education are participating in an international design challenge aimed at first- and second-year engineering students. The Engineering for People Design Challenge has been operating since 2007 and 2011 through Engineers Without Borders (EWB) organizations in Australia and the United Kingdom (UK), respectively. Beginning in 2019, EWB organizations in South Africa, the UK and USA partnered to develop a design challenge and run the associated competition in each of the nations. In the 2020-2021 academic year, four U.S. universities participated in the program and EWB-USA competition. During the 2021-2022 academic year, a total of five schools were involved. In this paper, the course instructors provide an overview of the program and describe how the schools implemented this design challenge. Several different approaches for the design challenge are described as each school integrated the program into their existing curriculum. In addition, each school describes the motivation for participating in the program and how it fits into their curriculum.

The program, Engineering for People Design Challenge, comprises a collaboration between a community, a local non-governmental organization (NGO), and EWB national offices. Collaboratively, a team develops an extensive design brief that includes a project description—identifying eight design areas focused on local community needs—along with cultural background on the community. Additional resources provide guidance for instructors and students on how to proceed with the design process and how marking criteria are used to assess the projects. Each participating school is then allowed to submit five top projects to the international competition. An international panel of judges then chooses the top submissions to participate in each nation's Grand Finals based on the project submissions, which can take the form of a design report or video and poster. The top ten teams are selected for the Grand Finals and showcase their project through an idea pitch in front of judges.

The Engineering for People Design Challenge was devised to provide beginning engineering students with an opportunity to practice their skills and address global issues as a means to develop globally responsible engineers. The benefits of this program to our first-year engineering programs are described in this paper. These include applying the engineering design process to a real world context, meeting accreditation requirements, motivating engineering students—especially women—who seek help- or social-oriented careers, and increasing engineering self-identity. The primary goal of the paper is to inform more faculty about this program, and encourage widespread participation in the U.S.

Project description and process

The EWB-sponsored Engineering for People Design Challenge is designed to benefit students in the following manners [1]:

- *Gain an understanding of their role in the engineering community.*
- *Learn to consider the consequences of design decisions at both local and global levels.*

- *Learn how engineering underpins everyday life.*
- *Learn how to place people at the heart of their designs.*
- *Develop their engineering skills.*
- *Develop skills in communication, planning and project management, effective distribution of work and collaboration.*

This program is specifically designed for first- and second-year engineering students. Notice that the focus is on social aspects of engineering design rather than technical skill development. This is one of the reasons why this program is a good fit for beginning engineering students. It facilitates the introduction of engineering design through social aspects before students have developed the technical skills to engage in highly technical detailed design. A goal is to encourage students to develop an understanding of the social aspects that they can carry forward in their future studies as engineering students. Additionally, for U.S.-based schools these goals and the team-based aspect of the project address outcomes 2-5 of the ABET Student Outcomes for accreditation [2].

Each year the design challenge engages with a community and a non-government organization (NGO) to develop the design challenge brief, a guidance document of 50+ pages with information on local problems and case studies pertaining to the community. This year's community is the Cape York Peninsula in North Queensland, Australia [1]. The NGO is the Centre for Appropriate Technology, which is controlled by the Aboriginal and Torres Strait Islanders peoples. In conjunction with EWB, a joint design brief is developed that reflects the needs of these communities, along with extensive resources regarding the culture of the people and region as a context for the design. The design brief can be accessed as an all-encompassing PDF, but the website for the design brief includes many other multimedia and interactive elements, including interviews with many residents, and a discussion board to engage other students and faculty from other colleges participating in the challenge. The challenge comprises eight different technical areas: Food & Land management, Transport, Energy, Digital, Built Environment, Waste, Water, and Sanitation.

Students are tasked with following these four steps of the design process [1]:

1. Analyze the context
2. Define the problem
3. Explore lots of options
4. Justify your recommendation

Figure 1 shows the marking criteria that the students are scored on for the competition. These marking criteria has been specifically designed for students to think about the 3E framework [3] of sustainability by including the social/community (equity), environmental, and economic context of any design. As mentioned previously, the marking criteria are not focused on technical skills but the social aspects of the design process. It also introduces students early on in their engineering career to the engineering design process. As shown in Figure 1, students need to demonstrate a methodical process for comparing design options against criteria and consider potential problems associated with implementation. Greater points are awarded for detailed responses and justifying approaches or assumptions. In addition, the

marking criteria call upon students to reflect and evaluate their process, adding another layer to the activity and pushing students to grow through the team-based learning.

Marking Criteria		**Mark Allocation**				
		1	**2**	**3**	**4**	**5**
1.	**Appreciation of the context**					
a.	Demonstrate inclusion of the **social/ community** context	No consideration	Some reference but little/no connection to the design	Description of context and some connections made to design	Good description of context and relevant connections made to design throughout the design process	Detailed description of context. Excellent connections made to design throughout the design process
b.	Demonstrate inclusion of the **environmental** context	No consideration	Some reference but little/no connection to the design	Description of context and some connections made to design	Good description of context and relevant connections made to design throughout the design process	Detailed description of context. Excellent connections made to design throughout the design process
c.	Demonstrate inclusion of the **economic** context	No consideration	Some reference but little/no connection to the design	Description of context and some connections made to design	Good description of context and relevant connections made to design throughout the design process	Detailed description of context. Excellent connections made to design throughout the design process
2.	**Reasoned solution**					
a.	Demonstrate **methodical assessment process** to select preferred option by comparing design options against criteria	Little/no methodical assessment process used	Some attempt to use a methodical assessment process. Poorly documented	Some methodical assessment process used. Well documented	Good methodical assessment process. Well documented, logically presented with clear communication of relevant design iterations.	Detailed, well-reasoned and methodical assessment process used. Well documented, logic excellently presented, design iterations clearly considered.
b.	Demonstrate consideration of **implementation** of design and **predicted difficulties**	No consideration	Little consideration given to aspects of implementation	Some thought given to aspects of implementation. Basic implementation plan provided.	Good appreciation of aspects of implementation. Clear implementation plan provided.	Detailed appreciation of aspects of implementation. Well designed and appropriate implementation plan provided.
c.	Evidence of **reflection** and **critical thinking**	Little/no reflection	Reflection provided but lacks any analysis or depth of evaluation	Reflection provided and some analysis and depth of evaluation	Good reflection provided with analysis and depth of evaluation with examples given of how the process and/ or teamworking can be improved.	Deep reflection provided with analysis and depth of evaluation with detailed examples given of how the process and/ or teamworking can be improved

Figure 1: Engineering for People Design Challenge Marking Criteria [1]

While each school has developed its own implementation, as discussed herein, there is a common competition for the schools. The process requires each participating school to choose its top five student project reports for submission to the U.S. design competition. A parallel process is implemented for non-U.S. schools for a separate competition. During the 2021-2022 competition, EWB-UK provided the website for collecting the project reports. At this stage, EWB-UK had a group of professionals judge the submissions and pick the top two reports from each school. The student teams chosen were then invited to a Grand Finals competition where, over the course of two days, the teams made an online ten-minute pitch to a group of judges put together by the U.S. participating schools. The winners of this competition were then announced at a final event in the beginning of June 2022.

Discussion

During the 2021-2022 academic year a total of five schools in the U.S. participated in the program (Table 1). Each school developed its own implementation approach, as indicated in the table. For some schools, the project was a required component of a course. In another instance, the design challenge was an optional component of an extracurricular program. The number of students participating varied, with some schools offering the program for a single discipline and other schools offering the program across all engineering disciplines.

Table 1. School Implementations

School	Required/Optional	Number of Participants	Semester/Quarter	Course/Extracurricular
Colorado State University (CSU)	Required	166	Spring 2022	First-year Course
Temple	Required	690	Fall 2020 through Spring 2022	First-year Course
University of Denver (DU)	Required	78	Fall-Winter quarter	Partial, first-year course
University of Nevada, Las Vegas (UNLV)	Course-based program: Required Non-course program: Optional	34 7	Fall 2021 Spring 2022	Second-year Course Extracurricular
University of Colorado, Boulder (CU)	Required	123	Fall 2021	First-year Course

Reasons for Implementation

This project serves several purposes at CSU. First, this project provides an actual project for students to work on as they learn about engineering design. Second, it also facilitates developing students' understanding of the professions of civil and environmental engineering. Another value of this project is the cultural and social aspects of the design constraints. It is easy to present purely technical content and to mention social aspects, but this project involves real communities of indigenous peoples struggling with community development. This moves the discussion of these topics from the abstract to the real, incorporating tangible details.

At Temple, the Engineering for People Design Challenge is introduced in a first-year course titled "Introduction to Engineering and Engineering Technology." Students must complete the challenge as part of their course work, and it is one of the major assessments in the course. To make the project more manageable, it is broken into 3 milestones, a rough draft, and a final draft. In the first semester it was delivered, a teaching assistant gave feedback on all stages of the project. Unfortunately, this feedback was not detailed enough and led to weak final products. In the following semesters, the professor gave feedback to the students, and this led to much better design projects overall. Many students listed this project when asked on their course evaluations, "What aspects of this course contributed most to your learning?" This project has been an obvious fit for our curriculum as college faculty have been tasked with incorporating engineering design in more courses before the students take their capstone senior design experience.

At DU, we believe the Engineering for People Design Challenge is a great way to accomplish many of our engineering goals. First, it allows us to introduce the design process to freshmen. We expect these freshmen to thus be better prepared for our more advanced junior and senior design project courses. Second, this project really helps to motivate many of our students to stick with engineering. Often, courses in the first two years of engineering are not very applied and some students lose interest. Seeing how engineering can help solve such problems that are relevant to actual people can be the difference for some students deciding to stick with engineering. In end-of-course reviews, we have in fact heard from some students that the project was the best part of the class and why they plan to continue with engineering. Thirdly, the project is great for introducing team work, a very important part of our engineering curriculum. Finally, and related to the teaming aspect, this project enables our first-

quarter freshmen to meet their fellow engineering peers. Such a connection early in the engineering curriculum can also be the deciding factor for some students to stick with engineering.

A second-year engineering experience course was added at UNLV in Fall 2021 in order to build on the success of the first-year engineering experience. A few of the goals of the one-credit course included increasing exposure to engineering activities within the specific engineering discipline, increasing engineering identity, and increasing the sense of community. The Engineering for People Design Challenge was an excellent match for these goals, as well as extending students' experience with the engineering design process. Several of the design challenge technical areas fit within civil and environmental engineering, giving students the opportunity to dig deeper into interests in transportation, sanitation, waste, water and infrastructure (built environment). Through the design challenge, students were able to further their identity as engineers by working on a real-life problem to recommend solutions. All students surveyed (n=31) indicated that taking part in the design challenge helped them to feel like an engineer. Regarding sense of community, 71% of the surveyed students felt that the course contributed positively to their sense of belonging in the engineering department at School 4, and the team-based aspect of the design challenge was intended to be a driving force in building this feeling of community. Going forward, School 4 plans to use this course and the design challenge for ABET accreditation in order to show student growth in achieving student outcomes 2-5.

UNLV also implemented the design challenge through an extracurricular program for first- and second-year civil engineering students. The Engineering for People Design Challenge has been a part of the program for three years, and it was chosen because it provides students with engineering design experience in a real context, as opposed to a theoretical and abstract problem. Students in the program each year have commented that the project requires quite a bit of time, but they feel a great sense of accomplishment and find it to be a very rewarding experience.

At CU, the Engineering for People Design Challenge is integrated in "Introduction to Global Engineering," a three-credit course targeted at students who live in a first-year residential academic program focused on Global Engineering, and a core requirement of the Global Engineering Minor. The course focuses on social issues (including geopolitical and historical contexts of health and socioeconomic disparities within and between countries) and technical interventions that address water, sanitation, hygiene, energy, infrastructure, shelter, and agricultural needs (linked to the United Nations Sustainable Development Goals (UN SDGs)). The design challenge provides a great opportunity for students to further analyze and apply the content shared in class and to explore the different phases in the iterative process of engineering design while creating innovative solutions for underserved communities. The students were asked to navigate the different stages of the engineering design process and to deliver multiple presentations (project selection, preliminary design review, critical design review) during which they received feedback from the instructors and their classmates. At the end of the semester, the students presented their solutions at an Expo organized for the course. An additional requirement was added specifically for this course: the proposed solution, besides responding to one or more of the challenges described in the design brief, needed to be related to at least one of the 50 Breakthroughs published by the Institute for Transformative Technologies. These breakthroughs were defined as the most important science and technology innovations needed to achieve the SDGs, and they have been adopted by the UN Commission on Science and Technology for Development as a technology roadmap [4]. The combination of the design brief and the 50 Breakthroughs, with extensive

information about the context, the problems the population faces, and ideas for possible solutions, provided the right amount of constraints without restraining the student's creativity when defining and developing their project.

Program Challenges

Whenever faculty implement new programs, we can expect to face challenges. Here, we describe challenges encountered at the upper level with program management. During the first two years that the Engineering for People Design Challenge was held in the U.S., EWB-USA facilitated the program, which included helping to prepare the design brief, organizing informative "Launch Lectures" for students at each participating school, and coordinating the Grand Finals event. In 2021-22, EWB-USA was not able to be involved and EWB-UK served as the lead. There were logistical challenges created by differences in time zones, school semester calendars, and availability of EWB-UK staff to take on the additional workload. In addition, the funding EWB-USA had secured to support student prizes at the Grand Finals was no longer available. Going forward, both EWB-UK and participating schools hope to find a U.S. partner willing to facilitate the program.

Conclusions

The Engineering for People Design Challenge is a rich, contextualized engineering design experience for first- and second-year engineering students. Because the focus is not on a technical design, it is appropriate for beginning engineering students. In addition, removing the emphasis on technical concepts and engineering analysis allows students to concentrate on stages of the engineering design process (i.e., analyzing the context, defining the problem, developing and evaluating solutions) that prepare them for upper level design courses and capstone experiences. The Engineering for People Design Challenge pushes students to consider, social, cultural, environmental and economic aspects of design solutions. Through interacting with the design brief and website, students are engaged in a genuine problem that emphasizes sustainability and global awareness. The design challenge connects to several ABET criteria, which is a strong selling point for institutions to integrate the program into their curriculum. Another compelling factor is that student response to the design challenge has been very positive at the participating schools. We hope to see more U.S. schools participate in this design challenge in the future.

References

[1] EWB-UK. "Engineering for People Design Challenge." EWB-UK. https://www.ewb-uk.org/upskill/design-challenges/engineering-for-people-design-challenge/ (accessed 18 May 2022, 2022).

[2] ABET. "ABET Accreditation Student Outcomes." https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/#GC3 (accessed.

[3] Ávila-Gutiérrez, M. J., Martín-Gómez, A., Aguayo-González, F., & Córdoba-Roldán, A. (2019). Standardization framework for sustainability from circular economy 4.0. *Sustainability*, *11*(22), 6490.

[4] *Institute for Transformative Technologies*, "50 Breakthroughs", 2019. [Online] Available: https://50breakthroughs.org/, Accessed May 30, 2022