

Conducting Electrical and Computer Engineering Capstone Design Projects Abroad: The Limerick Experience

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This paper describes the process involved in setting up and advising off-campus electrical and computer engineering senior capstone design projects being conducted by U.S.-based undergraduate students in Limerick, Ireland. Insights into the educational objectives and outcomes, project program logistics, financial support, faculty involvement, and future developments of this specific project site will be presented. These capstone projects conducted in Limerick can serve as a model for providing more US-based electrical and computer engineering students with opportunities for meaningful experiences when studying abroad such that they can obtain a better understanding of the impact of engineering within a global context.

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Introduction

The senior design experience is an increasingly popular approach for the integration of the broader ABET outcomes, such as communication skills and teamwork, within the engineering curriculum^{2,4}. In particular, senior design projects can address many, if not most, of the ABET Program Outcomes depending on their implementation¹. For instance, design activities that involve going beyond the classroom environment and facilitating team-based open-ended problem solving in real-world contexts can effectively demonstrate a wide range of learning outcomes.

One particularly challenging learning outcome is for students to demonstrate an understanding of how engineering relates to the broader contexts of society and the world. For instance, the ABET Program Outcomes indicate the need for a "broad education necessary to understand the impact of engineering solutions in a global and societal context"¹, rather than demonstration of that understanding itself. Nevertheless, the careers of our students as technologists in an increasingly interconnected world will require them to possess a solid understanding of the contexts and consequences of their engineering efforts in order to make decisions that are both responsive and responsible.

This paper describes how Worcester Polytechnic Institute (WPI) provides students majoring in electrical and computer engineering with senior design experiences located within international settings. Specifically, we focus on the Limerick, Ireland project program by providing insights into the educational objectives and outcomes, project program logistics, financial support, faculty involvement, as well as future developments of this specific site. The authors hope

that this program can serve as a model for providing more US electrical and computer engineering students with opportunities for meaningful experiences when studying abroad such that they can obtain a better understand of the impact of engineering within a global context.

Project-based Education at WPI

In 1970, the faculty of Worcester Polytechnic Institute adopted a new project-based curricular structure for its undergraduate programs of study in engineering, science, and management. The resulting *WPI Plan* specifies degree requirements that feature three project experiences, namely: the *Humanities and Arts Requirement*; the *Interactive Qualifying Project (IQP)*, and the *Major Qualifying Project (MQP)*.

The Humanities and Arts Requirement takes form as the integrative experience for a thematic course of study in some specific area of the humanities and arts. Conducted as an independent study under the guidance of a faculty member, this project requirement possesses similar characteristics to a minor. The IQP serves to connect the technical studies of the students to their work in the humanities and social sciences by enabling them to examine how science and technology interacts with societal structures and values via a project-based experience. Due to the techno-societal aspects that IQPs provide students, it has become the foundation of the WPI Global Perspective Program⁵.

The MQP serves as the capstone design experience for most engineering students, which is designed to provide students with an opportunity to conduct a professional-level application of their engineering skill set and knowledge to a problem defined within their major field. Equivalent in credit to three courses and

completed in small teams under the guidance of one or more faculty members, the MQP typically involves the design, synthesis, and realization of a solution to a real-world technical problem. Usually conducted in the final year of undergraduate studies, the MQP challenges a student to bring disciplinary and general knowledge to bear upon an open-ended problem within a team setting, culminating at the end with a formal written technical report and a formal oral presentation describing the engineering design process and the resulting outcomes and solutions.

Consequently, these degree requirements form the basis for degree programs that emphasize critical and contextual thinking, written and oral communication, integration and synthesis, and interdisciplinary collaboration. In particular, the IQP and MQP have enabled students to learn how to apply their skills and knowledge to unscripted, real-world problems. Therefore, these projects are not limited to academic investigations on campus, but naturally lend themselves to projects supported by external organizations at local, national, and international sites.

Limerick, Ireland Project Center

To facilitate students conducting either off-campus IQPs or MQPs, WPI has established a network of "Project Centers" located around the globe and operated under the aegis of the WPI Global Perspective Program. For electrical and computer engineering (ECE) undergraduate students, the Limerick, Ireland Project Center has enabled many to complete their MQP requirements within a single term of their senior year of studies since the establishment of this project center in 1996.

The creation and ongoing support of the Limerick, Ireland Project Center has centered on the strength of previously existing professional contacts. Based on these pre-existing relationships, project sponsorship has been obtained over the past 14 years, with the first team of WPI students going to Limerick to complete their MQP requirement at Analog Devices. Since then, 77 students have completed 26 projects for 7 different corporate and academic sponsors in the Limerick area. The students live in rented apartments or townhouses in the city and spend 10 weeks on site.

Student Recruitment

The process of selecting WPI students to participate in the Limerick, Ireland Project Center begins in November of the previous year. During this time period, applicants are interviewed by one of the center directors during a 30 minute one-on-one meeting. The purpose of this meeting is to ascertain whether the applicant possesses an adequate technical background and personality traits, e.g., team player, mature,

responsible, that would be conducive towards a rewarding capstone design experience in Limerick. Students also submit an application package with grades, references, a resume, and an essay.

Once all the interviews have been completed, the center directors decide on which applicants to accept for the project center. Acceptance notifications are usually sent out at the beginning of January. The accepted students are provided with detailed information about living abroad in Limerick since many of them have never traveled to Ireland prior to their MQP, or even outside the United States. A group meeting between all the accepted students and the center directors is usually held in March in order to ensure that all the students have studied the informational material, as well as to answer any questions.

The number of WPI student teams that have been sent to Limerick has varied over the years, ranging from just one team to as many as four teams in 2001. However, in order to maintain a reasonable level of logistical complexity, on average two WPI student teams are sent per year to participate at this project center. Teams nominally consist of three students.

Project Definition and Preparation

The capstone design projects are usually defined via an iterative process between the center director and the project sponsor. The sponsor will initially propose a project that is based on an activity that is currently being pursued at the sponsor's location. Since the educational goals of these team projects are substantially different than the objectives of a typical internship, the center directors work with the sponsor to ensure that each of the proposed projects will provide the students with a rewarding educational experience and satisfy the MQP requirement in the projects' 10 week timeframe. This process usually starts during the spring and continues until the start of the projects in August.

During the summer months, the students are organized into teams of approximately three students. The teams are formed by the center directors, who base their decisions on the student interest levels of the proposed projects. Once the teams have been formed, each team is provided with background reading material in preparation for their projects that start at the end of the summer. Since there is no formal preparation prior to arrival in Limerick, the students arrive three weeks prior to the start of the academic term in order to get acclimatized to the new environment as well as the project.

Logistics

The Limerick, Ireland Project Center is sustained by the ongoing commitment of one or more faculty members who serve as its *center director*. The center

director negotiates with project sponsors, locates suitable student and faculty housing, recruits and selects student participants, and either serves as faculty advisor to the projects or recruits colleagues to do so. Since WPI has a network of Project Centers around the globe, there is a considerable infrastructure on campus to support the student application process, to ensure that health and safety issues are addressed, and to provide basic information regarding travel issues. On-site support is also crucial, especially since in most years the number of students participating in the Limerick, Ireland Project Center is insufficient to warrant the residency of a center director throughout the duration of the project. Consequently, a *local coordinator* works part-time for WPI to assist with housing, travel/transportation, and sponsor logistics, while a center director will reside in Limerick for the first two weeks in order to ensure a smooth start of the projects.

Project Advising

With guidance from the center directors in residence and the professionals at their sponsoring agencies, the students spend the first two weeks conducting background research, defining goals and objectives, developing specifications, and writing a formal proposal including design methodology. During the subsequent eight weeks, they are responsible for bringing their projects to a successful conclusion, delivered a working system to their sponsors, submitting an extensive formal project report to their center directors, and publicly presenting the results of their work.

Since the center directors will often return to the WPI campus for most of the project duration, it is necessary to conduct remote project advising and coordination with the student project teams, as well as with the project sponsors. Although weekly teleconferences with the students and sponsors have often been used, as well as email communications, we have recently employed videoconferencing conference technology in order to coordinate with the students and sponsors on a weekly basis. With a time zone difference of five hours, it is feasible to conduct these videoconferences during normal business hours at both sites.

Furthermore, to ensure progress towards the completion of the final project report due at the end of the 10 week project, the student teams are responsible for producing weekly reports describing their achievements, problems and issues, proposed solutions, and future work. Not only do these reports serve to keep the center directors informed of the progress achieved by the students, they can also be used to form the final report at the end of the term.

Finally, it is vitally important that the sponsor provides a liaison to the student teams for the duration of the project. This liaison is usually an engineer or

engineering manager who works closely with the student team on their project. We have found that project liaisons provide a key component of mentoring and guidance to most projects.

Funding

Since the students are receiving academic credit for their project work, they cannot be paid. However, we have found that project sponsors are often willing to provide fees to support such project programs. Depending on the nature of the sponsor, the source of funding in support of these fees will differ as well as how these projects fit into the larger context of ongoing activities of the sponsor. For instance, corporate sponsors will usually focus on a non-critical path topics related to current product lines, and the funding to support the project fees will come from these related activities. On the other hand, academic sponsors will usually support projects that are a component of a much larger government-funded endeavor.

Learning Outcomes and Evaluation

All WPI senior design projects, regardless of location, provide students the opportunity to work on a large-scale, open-ended problem in their major fields. Furthermore, they all involve extensive formal documentation and presentation of results. As such, they both address and provide evidence for such learning outcomes as⁶:

- The ability to apply math, science, and engineering
- The ability to design and conduct experiments, analyze and interpret data
- The ability to design a system, component, or process to meet desired needs
- The ability to identify, formulate, and solve engineering problems
- The ability to use techniques, skills, and modern engineering tools necessary for engineering practice
- The ability to communicate effectively

When completed overseas at a project center, these teams of students working closely with professionals from the host culture will experience daily life in that particular culture. Additionally, they will be addressing real-world problems that typically require considerable background research and a fast learning curve. As a result, the students also gain and demonstrate⁶:

- A broad education necessary to understand the impact of engineering solutions in a societal and global context
- A recognition of the need for, and an ability to engage in, lifelong learning
- A knowledge of contemporary issues

Since these projects feature such a rich set of learning outcomes, the Department of Electrical and Computer

Engineering at WPI has developed a variety of assessment approaches for continual improvement. The faculty advisors provide students with detailed evaluations of their work and formal project reports, which are archived in the WPI library. Students, faculty advisors, and sponsor liaisons complete evaluations of the project's learning outcomes. An independent faculty committee reviews all project reports on a biennial basis. Finally, all students deliver oral presentations of their project work that are evaluated by faculty. Moreover, the top projects are then entered into the *WPI Provost MQP Competition*. Note that both 2008 Limerick projects received "honorable mention" in the most recent competition.

Future Developments

Prior to 2009, the Irish economy was one of the fastest growing economies in all of Europe. However, with the global economic recession in 2009, much of the economic growth in Ireland quickly slowed down. Consequently, many companies began cutting back on expenses or went out of business. Similarly, government funding from both the European Union and the Irish Government became increasingly difficult to secure. Consequently, new methods are needed to obtain the financial support to conduct these projects.

One approach is to leverage existing research interactions and collaborations with Irish project sponsors in order to obtain research funding from governmental sources. For instance, the 2009 projects focused on topics that not only yielded successful capstone design experiences, but also research publications as well^{7,8}. Thus, combining international research collaboration with senior capstone design experiences can enable the continuation of these rewarding projects and provide these students with a better understand of the impact of engineering within a global context.

Conclusion

Senior-level capstone design projects are commonly recognized as vehicles for providing students with an integrative experience in their major field. They can, however, also provide the opportunity for meaningful international experiences, especially when they take place outside of classroom settings. WPI's Global Perspective Program sends teams of students overseas to complete real-world senior design projects for external sponsors. Colleges and universities looking for ways to integrate broad educational outcomes such as global awareness into engineering programs would be well advised to consider looking beyond the traditional course-driven curricular structure. When engineering students participate in real-world design experiences in international settings, they gain more than an

understanding of the design process; they learn about the profession, the world, and themselves.

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