The WPI Capstone Project: Evolving Off-Campus and International Experiences

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This paper provides an overview description and discussion of the WPI fourth year project requirement known as the Major Qualifying Project, or simply MQP. Topics covered include a description of the requirement, implementation paradigms, an evolving base of project opportunities and programs, and global capstone program development challenges.

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Introduction

In 1970 the WPI faculty voted to include a requirement that *all* WPI undergraduates complete at least two major projects as part of their graduation requirements. The first project was designed to "challenge students to relate social needs or concerns to specific issues raised by technological developments".[1] The second project, known as the Major (area) Qualifying Project, or simply MQP, was designed to challenge students to "solve problems or perform tasks in the major field with confidence, and [to] communicate the results effectively".[1] Below, we provide a description of the MQP requirement, implementation paradigms, an evolving base of project opportunities and programs, and global capstone program development challenges.

The MQP Requirement

Each qualifying project is expected to represent at least 9 credits (3 courses) of project work. The MQP in particular is expected to "demonstrate application of the skills, methods, and knowledge of the discipline to the solution of a problem that would be representative of the type to be encountered in one's career" - in other words, a significant project in a student's major field of study.

This description of the MQP requirement, created almost 40 years ago, is remarkably similar to the current ABET Criterion 5 requirement which states:

> Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.[2]

It is important to remember, however, that at WPI the MQP is not just a requirement for ABET accredited departments. Rather, the MQP was developed as part of a plan to fundamentally change the structure of higher education by melding concepts such as teamwork and independent learning into a comprehensive, projects based undergraduate educational program. Thus, while capstone engineering projects are now commonplace, a focus on projects based education, coupled with a real world emphasis, has been a cornerstone of the WPI undergraduate educational plan for *all* program students for almost 40 years. Regardless, the remainder of this paper will focus on ABET accredited programs.

MQP Implementation

MQP activities can encompass research, design and application, can involve analysis or synthesis, can be experimental or theoretical, can emphasize a particular subarea of a major or combine several interdisciplinary areas, and can be individual or, much more likely, team based. Further, because MQP activities are not packaged and delivered as part of a classroom/course structure, students have a wide range of terms and opportunities available to them to complete the requirement, encompassing the full academic year and summer.

For on campus projects WPI maintains an on-line data base of faculty and corporate sponsored projects. In the spring of the third year of study, students are encouraged to review the proposed projects and discuss the projects they are interested in with the faculty sponsor. Off campus project opportunities are generally associated with a "center" (examples below). Students interested in working at a project center typically apply in the fall of their third year, are interviewed, and are eventually selected to participate prior to the start of their fourth year of study.

Project Advising

Every full time, tenure track WPI faculty member is expected to act as an MQP advisor to one or more project teams each academic year. The concept of all faculty being involved in faculty advising is in contrast to the more common (but not universal) approach where only a few department faculty are responsible for an entire capstone project course.

For on-campus projects, individual advisors set their own schedules for project team meetings. The most common approach is to have at least one formal weekly meeting, and many more informal meetings between the advisor(s) and team members.

For residential off-campus projects, a faculty advisor may be in residence for the duration of the project period and have sole responsibility for daily, evening, and weekend meetings with the students teams. For residential centers without an on-site faculty advisor, a faculty advisor is present at a minimum during the start up week and final project presentation week. For all off-campus centers, residential or otherwise, a mentor from the industrial sponsor serves as the primary on-site project co-advisor. This individual is by design and by choice in nearly daily communication with the team, facilitates solving logistical problems, and provides guidance to the team members for the duration of the on-site project period.

Project Activities

Experience dictates that students write a proposal as their first activity of the MQP. In so doing, the students perform background research to understand the problem, learn to explain the problem in a clear and well defined manner, and start to learn the material that they will need to know to successfully complete their project.

Core Project Work

Activities during this phase of the project are dependent on the particular type of project undertaken and may include laboratory experimentation, software development, signal measurement, device design and analysis, construction of a product or device, performance evaluation, life cycle determination, accuracy measurements, safety evaluations, and so forth. It is, however, important to point out that student teams from accredited programs need to include a significant level of "design" to satisfy the requirement for a "major design experience" (ABET).

Final Report and Presentation

Every MQP team is required to write a detailed and comprehensive final project report. This report presents an opportunity to stress professional documentation standards, whether they be standards detailed in any one of a number of different style books or even specified as if the team was submitting a research proposal or journal manuscript where the style and format are detailed and easily obtained.

WPI designates a "Project Presentation Day" in the final quarter (D term) of the academic year when every project team is expected to present their results. Both on- and off-campus teams make short, professional presentations of their project goals and objectives, methods, analysis and design, and results. In many departments, these presentations are used as an opportunity to sub-select those teams judged the "best" and which are then asked to participate in a follow-on combined written/oral project presentation competition.

Project Centers

The concept of a "project center" is that of advisors and students working together on a cluster of similarly themed projects with the support of a sponsor. Center operations range from residential, one term, on-site opportunities (e.g. London, Silicon Valley, Nancy France, China) to one-term commuting opportunities (Lincoln Labs, Gillette) and even on-campus corporate sponsored opportunities with weekly visits to the corporate site (General Dynamics). A few of our centers are described below.

Lincoln Laboratories

WPI has had a project center sponsored by Lincoln Labs (LL) since 2002. The students selected to work at this center are assigned to projects composed of two or three students who then work full time, on-site, on their assigned project during the first quarter of their senior year (A term). Since Lincoln Labs (LL) is relatively close to WPI, the students commute on a daily basis.

The students selected for LL were initially prepared for their LL experience by requiring them to attend a preparation project in the last term of their junior year. Over time, this requirement has been dropped because many of the students now work as interns at LL during the summer preceding their project work. Although not all selected students are offered internships a sufficient number of students participate in the summer internship program that it was decided to drop the preparation project requirement and instead rely on the experience gained during the summer by the student interns.

Wall Street and London

The Wall Street/London project centers are unique because of their focus on financial, banking and investment project topics. Capstone project opportunities exist for many different types of majors, including CS, ECE, Physics, MA, Management IT,

Management Industrial Engineering (IE), Engineering Management and other majors. Sample projects include the following.

- At Lehman Brothers, a CS student helped design and automate a system to display the risks associated with lending and to display specific risks associated with different credit situations.
- At J P Morgan, a CS student and a Management student focused on data contamination. The CS student focused on the software side of the contamination issue while the Management student focused on the source of the contamination (data entry, software, network, or hardware) and ways to alleviate this in the future.
- In London, a team of ECE students worked on the design and implementation of an reconfigurable FPGA system that could be used to significantly speed up the analysis and modeling of certain computationally intensive financial studies.

It is interesting to note that the preparation course for these predominantly engineering and science students, involves learning about financial markets and investing, and all forms of money transactions including stocks and bonds[3] - the language of financial markets and institutions.

Gillette

The Gillette South Boston Manufacturing Center (SBMC) has been sponsoring primarily mechanical engineering capstone projects for the past 12 years. These projects tend to be machine design problems involving mechanism analysis and design, materials considerations, stress and deflection analysis, and dynamic modeling.

These projects run in B term of the senior year with students commuting most weekdays to Gillette. A preparation course is required in A term, during which the student teams are tasked with learning the details of the machine or component that Gillette has identified as problematic.

The first few days of on-site project work involves making instrumented measurements that can be used to modify the dynamic model so that it exactly matches the observed behavior that needs to be improved or fixed. Over the next several weeks of on-site work, each team works diligently to propose and analyze multiple solutions to the problem and, once an acceptable solution has been found, implement the solution with the support of the Gillette engineering staff mentors. Once the change is implemented additional measurements are made to determine if the machine performance matches the predicted improvements.

From the Gillette perspective, the advantages are that they obtain solutions to problems and excellent engineering candidates. From the WPI perspective, like most corporate project centers, the students work on real problems with real machinery and design constraints, with real engineers (often WPI grads themselves), and gain priceless hands-on experience.

Silicon Valley

The Silicon Valley (SV) project center provides one-term project opportunities for CS, ECE and Interactive Media and Game Development (IMGD) majors. Recent project sponsors included SRI International, eBay, and NVIDIA as well as many smaller companies.

An intriguing aspect of the SV projects is that the student team members often have to address issues that are not commonly encountered during an on-campus project. Examples include protection of intellectual property, working with media departments to standardize branding, and even creating physical designs that in some manner reflect the culture and image of the sponsor.

Nancy France[1]

In the Chemical Engineering department, students have the opportunity to complete their MQP in Nancy, France at the l'Ecole Nationale Supérieure des Industries Chimiques (ENSIC), a research center composed of five separate laboratories focused on the Physical Chemistry of Macromolecules, the Physical Chemistry of Reactions, the Thermodynamics and Separation Processes, and Chemical Engineering Sciences. Projects are chosen based on consideration of the interests and majors of the applicant students. While fluency in French is not required to participate in this center, preference may be given to French speaking students and all students are strongly encouraged to study French as a way to enhance their learning and living situation.

International Centers

Conference papers describing representative international capstone design project centers in Canada (Hart et al), China (Rong), Ireland (Wyglinski et al) and Panama (Plummer) are included in this proceedings as part of the panel this paper is associated with.

Project Outcomes

Although WPI has been focused on projects based education for well over thirty-five years it was only in 2009 that outcomes were approved for the MQP. Specifically; *students who complete an MQP will*:

[1] http://www.wpi.edu/Academics/GPP/Centers/france.html

1. Apply fundamental and disciplinary concepts and methods in ways appropriate to their principle area of study.
2. Demonstrate skill and knowledge of current information and technology tools and techniques specific to the professional field of study.
3. Use effectively oral, written and visual communications.
4. Identify, analyze and solve problems creatively through sustained critical investigation.
5. Integrate information from multiple sources.
6. Demonstrate an awareness and application of appropriate personal, societal and professional ethical standards.
7. Practice skills, diligence and commitment to excellent needed to engage in lifelong learning.

Individual departments are encouraged to add area specific outcomes.

Future Challenges

Adding a global element to the capstone design requirement is not a trivial undertaking. A significant infrastructure is needed to support global programs. Factors such as risk management (e.g. Mello conference paper), program cost, medical and health issues (particularly in third world nations), transportation, student behavior, student and advisor preparation and a myriad of other issues need to be considered and managed.

In addition, developing a meaningful global *capstone* experience is difficult since the projects generally require significant technical support and mentoring, often only available in an educational or laboratory environment. Identifying such international opportunities can be difficult, may require an articulation agreement, and in our experience are simply more difficult to develop on a large scale and available to all majors.

By contrast, non-classroom, *non-capstone* global projects are relatively easy to identify and such programs have historically been proven relatively easy to implement on a large scale, as evidenced by the number of (primarily) non-engineering schools that support such programs. Indeed, it is worth pointing out that for the most recent WPI graduating class (May, 2009, commencement class).

- 69% of the graduates took part in an off-campus project experience
- 52% of the graduating class participated in an international project

In other words, a very large faction of graduating WPI students, across all disciplines, have engaged in one or more off-campus, sponsored or other type of non-campus based project experience, and in fact many have been in a global setting. However, the vast majority of these students obtained their global experience by satisfying the third year project requirement (i.e. the IQP, relating technology and society) at an off campus project center. While the number of students who satisfied their capstone (MQP) requirement in an international setting is increasing, it is not yet at the point where a large fraction of the WPI students can do so.

For WPI, the advantage is that the university has an infrastructure in place for supporting global capstone projects as they are developed, and a culture of faculty who all have had the experience of advising both capstone, and non-capstone projects. Extending the concept of a center to include capstone projects is a natural step for the faculty and, in fact, is occurring as opportunities are identified to do so. The aforementioned companion papers detail a few of these centers, describe how they were developed and are currently operating, and explain the advantages of international capstone project centers and activities.

Summary and Conclusions

The highly integrated nature of the WPI curriculum, based on projects, teamwork, opportunities for global experiences, and a myriad of off-campus and corporate sponsored capstone project opportunities, represents a unique environment that, to our knowledge, is not replicated elsewhere. In the words of Professors Richard Vaz and Peder Pedersen[5],

> "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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