Work in Progress: The Professional Development Track: A Cooperative Experiential Learning Approach to Academic Success for Underserved Engineering Students

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WORK-IN-PROGRESS (WIP): THE PROFESSIONAL DEVELOPMENT TRACK

A COLLABORATIVE EXPERIENTIAL LEARNING APPROACH TO ACADEMIC SUCCESS FOR UNDERSERVED ENGINEERING STUDENTS

Introduction

Capstone design courses are often discussed [1, 2, 3] as a robust option to address the mismatch between academic and professional work. These courses, traditionally geared towards seniors and centered around industry-sponsored projects, give students opportunities to apply their technical skills in broad, open-ended, and multidisciplinary contexts immediately relevant to their workforce participation. In recent years, additional courses aimed at freshman and sophomores, such as cornerstone design [4, 5, 6], have been added to engineering curricula in order to introduce professional topics earlier on in their academic careers.

However, while capstone and cornerstone design courses have been implemented across the country, new research demonstrates that professional skills, such as teamwork, project management, cultural awareness, leadership, and interpersonal communication, are still lacking in our graduating students [7, 8], and, in turn, are slowing their career advancement. For this reason, university engineering programs, as well as professional societies in engineering [9, 10], have identified the teaching of such professional skills as a goal. Unfortunately, despite this growing and collective interest in professional skills, studies [3, 11] continue to show significant gaps between what students are taught in the classroom and what they need to know to succeed in professional engineering practice.

There is well-established research that professional skills are effectively developed through continuous, experiential, and collaborative learning experiences [12, 13]. One particular example of this is the Affinity Research Group model [14], which sees engineering learning as an iterative and social process in which students achieve learning outcomes through their own experiences as members of a community brought together by a shared goal. In an Affinity Research Group, students continuously engage in experiential learning groups as they move forward in their career pathways. This allows them to not only learn from their peers, faculty, and mentors, but also help and mentor others in turn. This model of learning is particularly relevant in the case of Hispanic and first-generation students, who posses cultural work norms [15, 16] that closely match this collaborative approach.

Therefore, the authors argue that conventional capstone and cornerstone courses, no matter how well designed they are, will continue to fail to deliver and effectively teach professional skills as long as they continue to be discrete, self-contained experiences. To address this problem and inspired by the Affinity Research Group model of learning, the authors have developed the Professional Development Track (PDT) presented in this paper to be implemented at the University of California Merced. With approximately 55% Hispanic and 75% first generation students, UC Merced is uniquely positioned to address the needs of groups traditionally underserved by engineering education.

Problem description

The School of Engineering at UC Merced currently has three courses to address professional development: Engineering Service Learning, Professional Seminar, and Capstone Design. These courses present students with valuable opportunities to interact with external clients, face professional and technical challenges under realistic constraints, work effectively in teams, gain workforce-relevant experience before graduation, and build professional networks that will help them secure job offers upon graduation.

While these courses provide valuable collaborative experiential learning, the courses themselves are stand-alone experiences lacking a unifying framework. Students are not necessarily aware of the relationship between these courses and therefore are not well positioned to fully take advantage of the opportunities for professional development these courses present. At the same time, faculty do not view these courses as part of a unified and progressive track. This situation leads to suboptimal utilization of resources and unnecessary duplication of efforts. These problems are compounded by various factors including the following: (1) the different vocabulary used for the same experiences across these courses, (2) the different metrics used to measure success in the same areas, (3) the repetitive or redundant curricula, and (4) the lack of data sharing among the coordinators of these programs. The result of this disjointed, "piecemeal" approach to professional development is a suboptimal system in which students miss critical opportunities to build their professional portfolio.

For the purposes of this work, and in agreement with current research on the topic [17, 18, 19], the authors will use the list of competencies described in items *d-j* of ABET's criterion 3 as a definition of professional skills. These competencies are shown below

d) an ability to function on multidisciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues

Method

The authors have proposed the PDT (illustrated in Figure 1) within our School of Engineering to combine and expand upon existing courses to create a cohesive and cumulative trajectory with uniform goals, practices, metrics, and management strategies. Throughout the PDT, students will work on real-life engineering problems presented by industry and non-profit partners under the supervision of faculty. This unified approach will allow students to collaborate with recurring partners on projects of increasing complexity, work on the same large project in different capacities

as their experience and skills grow, and explore different areas of the engineering profession in a systematic approach. While on this track, students will receive mentorship from faculty and will be invited to participate in off-campus professional development events such as conferences and networking summits. Additionally, students will learn from each other by collaborating with their peers who are at different points along this track. Thus, every student will be (i) part of a community of practice, (ii) a mentor to other students in their group, and (iii) an engineering novice developing skills by working with professional engineers and faculty.

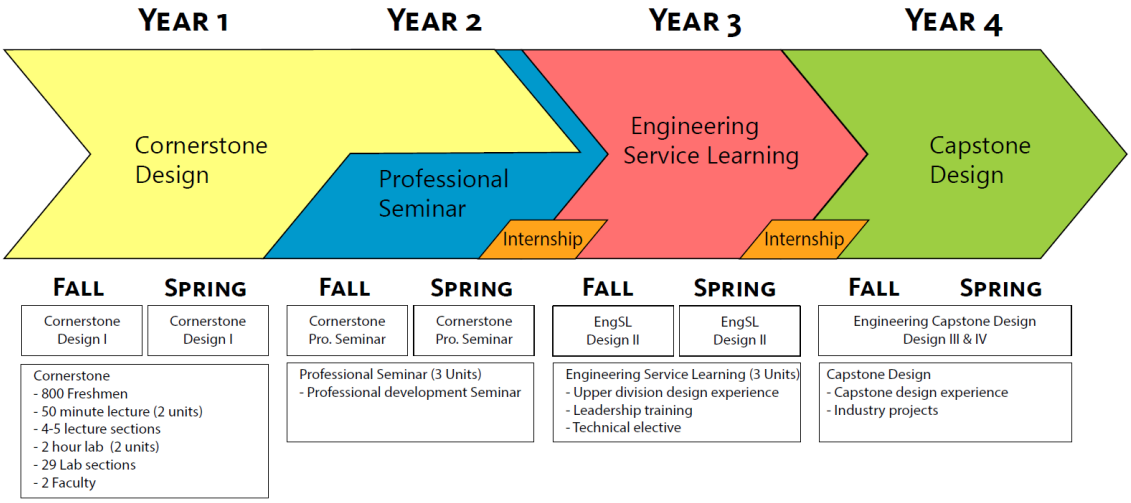

Figure 1. The Professional Development Track

Curriculum

The PDT will be implemented through four design and professional development engineering courses (ENGR 097, ENGR 191, ENGR 197, ENGR 190) as explained below. The general aim of this implementation is to ensure continuity of methods, content, and goals across all courses and to increase the workforce relevance of student learning. Significant curriculum changes include expanding course content and duration (e.g., one-semester courses expanding to become year-long), implementing new instructional technologies (e.g., hybrid courses and flipped classrooms), and promoting experiential and team-based learning as a consistent learning outcome for all PDT courses.

Engineering Service Learning (freshman year): This is a lower division Engineering Service Learning course (ENGR 097) equivalent to Cornerstone Design. In this lab- and lecture-based class, students learn about design thinking and methods, propose and implement solutions to an engineering design problem, start developing their first professional networks, and learn to work in multidisciplinary engineering teams. This course currently serves approximately 200 students per year, about 70% of which are in the School of Engineering. Traditionally, this has been an optional class, but authors intend to make it mandatory for all engineering students as part

of the general education curriculum. This will increase the number of students to approximately 600 per year. Since this will be their very first engineering design experience in the PDT, students will work under the close supervision of senior students, TAs, or faculty.

Professional Seminar (sophomore year): The Professional Seminar (ENGR 191) is a career-centered experience focused on the job application and hiring process of the engineering world. More specifically, students learn how to write stronger CVs and cover letters, how to identify job opportunities, and how to successfully navigate the job interview process. ENGR 191 currently serves approximately 400 students every year and is a mandatory class for all engineering students. To connect this course with the rest of the PDT, the authors will work closely with external clients to offer internship opportunities to select students based on their performance in ENGR 097 and ENGR 191. These internships can lead into more advanced design projects for ENGR 197, ENGR 193, and ENGR 194. Transfer students will enter the PDT at this stage.

Engineering Service Learning (junior year): This is an upper division Engineering Service Learning course (ENGR 197) which can be seen as Cornerstone Design II. This is a lab-only course that cross-convenes with ENGR 097, since both groups of students (freshman and junior) work on the same projects. This course currently serves approximately 150 students every year and is optional for engineering students. However, the authors intend to make it a technical elective and to highly encourage all students to enroll. In the PDT, the learning outcomes for ENGR 097 and ENGR 197 will be distinct: ENGR 197 will not only build on the foundations learned in ENGR 097 but will take them to next level. The technical aspects of the work (coding, prototyping, modeling, testing, etc.) and the required professional elements of the class (presentations, written communication, interaction with external partners) will be more challenging, more numerous, and more rigorous. Additionally, students in ENGR 197 will be given project management responsibilities in their teams and serve as mentors for the students in ENGR 097.

Capstone Design (both semesters senior year): This course (currently ENGR 190), centered on industry-led projects assigned to student teams, is the culminating experience for all engineering seniors and is mandatory for graduation. It currently serves approximately 200 students per year. The authors are in the process of expanding this experience into two semesters, Capstone Design I and II (ENGR 193 and 194). These two courses will build upon on the traditional Capstone content to include team management skills, design thinking, innovation paradigms, and professional skills. This additional content will be delivered in a hybrid format combined with a flipped classroom approach. Additionally, ENGR 194 will require students to present a fully developed and tested prototype in order to complete the course. Students will be given opportunities to present their work at different professional and academic venues (conferences, symposia, etc.) outside their traditional course presentations. In special cases, students may be invited to be co-authors on academic publications based on their work. The year-long Capstone experience will give students the opportunity to receive a wide spectrum of feedback, enhance their technical communication skills, and develop their professional networks.

Assessment

The PDT is designed as an integral experience and the development of professional skills will occur in a progressive manner as the student makes progress through the different courses. The program learning outcomes (PLOs) of the PDT were developed with the ABET list of professional skills in mind and they give educators the opportunity to assess the level of competence in each skills in a comprehensive manner. By the time a student completes the PDT, they will be able to:

1. Identify an engineering problem and formulate it in terms of measurable objectives and constraints
2. Identify the role of the engineering professional and examine its ethical, economical, and social implications.
3. Design a solution to an engineering problem within realistic constraints and utilizing appropriate standards
4. Assess the financial, environmental, social, and industrial impact of an engineering project
5. Work effectively in a multidisciplinary team, proposing specific roles and responsibilities to each member, communicating effectively within the team, managing conflicting schedules and expectations, and keeping track of each individual contribution to the collective effort
6. Communicate their work and their abilities to a broad audience in both oral and written formats

These PLOs are common to all courses in the PDT and competence in each one is achieved progressively. Students will begin their trajectory near the base of Bloom's taxonomy of educational objectives [20] and will move towards the top as they continue to work on the same core list of competencies. This process is shown in the table below

Table 1. Map of program learning outcomes and their progressive completion within the PDT

	COGNITIVE LEVEL					
PLO	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
1		ENGR 096	ENGR 097	ENGR 197	ENGR 193	ENGR 194
2	ENGR 096	ENGR 097	ENGR 191	ENGR 197	ENGR 193	ENGR 194
3		ENGR 096 / ENGR 097	ENGR 191	ENGR 197	ENGR 193	ENGR 194
4		ENGR 096 / ENGR 097	ENGR 197	ENGR 191	ENGR 193	ENGR 194
5		ENGR 096	ENGR 097	ENGR 197	ENGR 193	ENGR 194
6		ENGR 096 / ENGR 097	ENGR 191	ENGR 197	ENGR 193	ENGR 194

To assess these PLOs, the authors have selected a list of instruments that target not only each of the individual courses in the track but also the experience as a whole. In selecting the instruments, the authors sought to gather data not only from students, TAs, and faculty, but also from the external clients that sponsor projects. The assessment system for each course in the PDT includes some or all of the following components:

- Individual surveys at the beginning and end of the semester in which each student takes inventory of their professional skills
- Technical reports at the end of each semester submitted electronically though an online course management system
- Confidential peer evaluations by each team member before each team presentation
- Three team presentations during the semester: Preliminary Design Review, Critical Design Review, and Final Design Review, with faculty, TAs and external partners as judges
- Final poster prepared by students to present during the Final Design Review and for team participation in conferences
- Individual end of semester survey in which the external client expresses their satisfaction with the students' work

Conclusion

While this work is still in progress, the authors can say that by providing a unified and improved academic path, the PDT will ensure students are adequately prepared for the workforce upon graduation. By the time students begin the job application process during their senior year, they will already have experience with multiple engineering projects, enhanced technical communication and presentation skills, CV and cover letter writing, and interview and presentation techniques. Students will also have led professional groups, attended conferences, and engaged different audiences. They will have worked on at least one engineering project from beginning to end and will have contributed to multiple projects over time. These landmarks are essential to professional success and constitute some of the most important requirements to quickly and successfully join the workforce.

The continuous mentorship, guidance, and experience created by the PDT will allow faculty to work with specific students throughout the academic path, thereby increasing retention and graduation rates. Industry partners will benefit from an improved hiring pool of highly prepared and experienced candidates and from a constant stream of engineering solutions provided by our student teams. Furthermore, this project will help underserved populations at UC Merced succeed professionally through the incorporation of collaborative and experiential learning, thereby making engineering education more inclusive. Finally, the proposed PDT will help make the engineering profession equally attractive and accessible to all students which, in turn, will lead to a more diverse STEM workforce.

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