Technical Skill Development in Vertically-Integrated, Team-Based Engineering Courses: Promoting Equity Across Genders

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WIP - Professional Development in Vertically-Integrated, Team-Based Engineering Courses – Promoting Equity Across Genders

Abstract

The ability to work in teams is one of the outcomes that is sought by ABET and a wide range of industries. In order to cultivate those abilities, many programs work in teams, especially design teams within engineering. While there are many benefits of team experiences, the dynamics within engineering teams can promote or create inequities. This study examines whether equitable access to professional development is available across genders within two large team-based engineering courses at a large institution and seeks to investigate motivations and barriers to access. Team-based courses are commonly employed to help students develop professional and technical skills in the classroom while providing a bridge to professional practice, but the team structure's dependence on different team members taking on different roles and responsibilities creates the possibility that gender biases may arise in role selection and/or assignment, resulting in inequitable skill development. In particular, some data suggests that female students may be less likely to have 'technical' roles when compared to their male peers. One approach to mitigate this issue is to provide opportunities for individual skill development outside the team structure. Both of the programs in this study are large-scale, multidisciplinary, and vertically integrated, and both provide opportunities for individual skill development by conducting Professional Development sessions across a variety of professional and technical topics. This study employs both a quantitative analysis of the utilization of professional development and a thematic analysis of student focus groups to investigate differences across genders. This study has implications for a wide range of engineering programs looking to create equitable opportunities for students.

Introduction

EPICS and VIP Program History

The EPICS program was founded in 1995 at Purdue University in response to a need for engineering students to gain more practical, hands-on design experience before transitioning into their professional careers [1]. EPICS connects teams of undergraduate students with community organizations that need technology development, and the student teams work with partners to design, build, and deliver real and impactful products. The EPICS program at Purdue University has expanded beyond engineering to bring in students from more than 1200 students per year from nearly 70 different majors. EPICS teams at Purdue average 15 students per team, including students from all majors and years working together to build assets with more than 60 community organizations. EPICS has more than 120 ongoing projects at any given time, broadly categorized as environmental and sustainability, education, access and abilities, and human services. Examples include the design of aquaponic systems for urban gardening, exhibits for a local science museum, adapted toys for children with disabilities, and solar power systems for

rural communities. The program has grown and expanded to many other universities across the globe [2], as well as to K12 institutions across the United States [3].

The VIP program was initiated at Purdue University in 2001. VIP provides an opportunity for undergraduate students to earn academic credit while engaging in authentic and extended research and design projects related to active research areas of [University] faculty members and national, international, and industry-sponsored design challenges. Students can participate on interdisciplinary and vertically-integrated teams (first-year through seniors) with faculty and graduate student mentors for multiple semesters to address these real-world research and design challenges.

At Purdue, VIP became a formal program in the College of Engineering in 2019 with student enrollment growth of 334% since then. The VIP model has been adopted at more than 40 colleges and universities in the U.S. and abroad. This includes institutions of varying sizes, settings, and missions: research-focused and teaching-focused, large and small, public and private, Historically Black Colleges and Universities (HBCUs), and Hispanic serving institutions. There are more than 4,500 students enrolled in VIP per term across the globe. This expansion is due largely to the VIP Consortium, established in 2014, formalized as a non-profit in 2019, and now encompassing more than 40 institutions.

The rapid pace of technological growth in recent years has fueled an increased demand for engineers and other STEM professionals, which can be at least in part addressed by increasing the participation of women in these fields. According to the 2023 Diversity and STEM report by the National Center for Science and Engineering Statistics, while men and women represent nearly equal proportions of the total workforce, STEM occupations are not in balance, with 29% of men holding STEM jobs in comparison to 18% of women [4]. Arastoopour et al. noted three major issues that would be addressed by increasing the participation of women in engineering occupations: the economic need for more engineers, the equity issue of underrepresentation, and the community issue of inadequate input from women in engineering design [5]. Several aspects of experiential learning seem to attract women students into engineering, including the social/team-based environment, authentic context for projects [6], and intrinsic motivation of using the discipline for societal benefit [7]. Community-engaged courses, such as the EPICS program, have consistently appealed to a diverse cohort of students, particularly with respect to gender [7], as students found the course to provide context to their learning through real, hands-on projects.

Issues of Gender Roles in Project and Team-Based Learning

Project-based and team-based learning are high-impact practices with known benefits, especially in bridging the education-to-workplace divide, but can create inequitable learning experiences between team members [8] [9]. The nature of working in a team involves individual team members differentiating into various roles, enabling individuals to utilize existing expertise or gain new expertise to contribute in a unique way to the project, and facilitating the completion of different aspects of the project. For example, in an engineering project, one team member may take on a project management role, another may focus on mechanical design, and yet another on

customer relationships. By taking on these various roles, the team members practice the skills associated with those roles and gain expertise in those areas. Issues can arise when there is a disparity in roles between genders or other populations, especially with respect to ‘technical’ roles.

Within engineering student design teams, in particular, role imbalances commonly arise between male and female students. Women may be less likely to have ‘hard-tech’ roles, such as CAD design, compared to their male peers [10]. Likewise, in engineering presentations, women students present significantly less technical content and answer fewer questions than their male teammates [11]. The technical skills developed in these roles can serve as ‘gates’ to further development and identity formation, creating a positive feedback loop in which male students become adept at these skills earlier, and so migrate into these roles in projects, preventing female students from developing the associated skills [12].

Professional Development

One suggested mitigation is to provide opportunities for individual skill development outside of the team setting, to give individuals an opportunity to advance their skills without regard for team dynamics. Professional Development (PD) sessions are commonly required to maintain licensure across many professions, including Professional Engineering licensure across 37 US States [13] and much of the world. Professional Development requirements vary by governing body but typically encourage a breadth of technical and professional topics to help engineers expand their knowledge and capabilities.

EPICS and VIP are two team-based, multi-disciplinary, vertically-integrated programs that uniquely focus on team-based work while also providing Professional Development elective sessions that allow students to build their professional and technical skills. These elective PD sessions may serve to mitigate some of the skill-building inequity that arises in a team-based setting, but only if the students are taking advantage of that opportunity. Even with such opportunities available, social/societal factors or team/interpersonal dynamics may discourage women from benefitting from these skill-building sessions.

The research questions addressed here are: What differences are there between genders in the selection of professional vs technical Professional Development? How do students perceive the relative value of technical vs professional skills in their professional development? What differences arise between genders in the perception of opportunities to build technical skills in these programs? This study has implications for a wide range of engineering programs looking to create equitable opportunities for students.

Methods

The first research question seeks to investigate whether there is a difference in the selection of elective Professional Development sessions between male and female students. In order to fulfill the program’s professional development requirements, students may either select from a listing of program-delivered elective professional development opportunities or find independent learning opportunities. In the EPICS program, students must complete five hours of professional

development per credit hour they are enrolled. All students must complete a set of five required Professional Development Hours (PDHs) during their first semester in EPICS, and then use the elective PDHs to satisfy the balance of their requirements. Students taking EPICS beyond their first semester in the program may complete their requirements using all elective options.

Table 1: Professional Development Requirements in EPICS

	First Time Student	Returning Student
1 Credit Hour	5 Required PDHs	5 Elective PDHs
2 Credit Hours	5 Required PDHs + 5 ElectivePDHs	10 Elective PDHs

Students in the VIP program are required to complete three common professional development activities, including an orientation lecture as well as written and oral communication. Most students in VIP participate in an undergraduate research conference for their communications requirements, which includes an abstract and poster or research talk. Students registered for two credit hours are required to do an additional seven activities, while students in the one credit hour first-year course are only required to do the three previously described. Both VIP and EPICS post sessions and collect session registrations through a common Symplicity CSM platform.

In order to investigate trends in PD utilization, all session registrations for both programs were aggregated and then divided by gender. Each PD elective was categorized as either ‘Professional’ or ‘Technical’, and the resultant data was examined to determine trends in which types of sessions were utilized by various populations within the programs. It is recognized that these two terms do not form a perfectly dichotomous description and that many topics may not fit well under either term or may include aspects of both. Likewise, there is a known limitation in using registration data, as there may be variability in the actual attendance. Further, students can elect to use other guest lectures, online tutorials, or other PD opportunities that would not be tracked within this data set, posing another study limitation.

Results

All Professional Development session registrations from the 2022-23 academic year were aggregated and counted by gender (Table 2). There were 3,701 total registrations for PD sessions across both programs, 39.8% of which were registrations by female students. The fraction of female students was higher in EPICS than in VIP, which may be in part because the female enrollment was higher, and may in part be because the VIP program was transitioning to in-person workshops during the Fall 23 semester.

Table 2 Professional Development Session Registrations by Program and Gender

Professional Development Session Registrations				
	Female	Male	Total	% Female
Total	1474	2227	3701	39.8%
EPICS	1288	1659	2947	43.7%
VIP	186	568	754	24.7%

The total number of registrations by women of each session type, professional and technical, were divided by the total number of registrations by all genders for that type to determine the fraction of registrations by women (Table 3). For both programs, and in total, a smaller fraction of the technical session registrations were women when compared to the fraction of professional session registrations. This indicates that women found themselves relatively outnumbered by their male peers by a larger margin in technical sessions than in professional sessions.

Table 3 Percentage of Session Registrants by Gender

	Professional		**Technical**	
	Women	Men	Women	Men
Total	43.3%	56.7%	34.9%	65.1%
EPICS	48.0%	52.0%	37.8%	62.2%
VIP	26.2%	73.8%	22.2%	77.8%

To investigate whether there were gender differences in PD selection between genders, the total number of technical session registrations for each gender were divided by the total session registrations of that gender (Table 4). While both genders registered for more professional than technical sessions, the results show that women registered for technical skill sessions at a lower rate than their male counterparts in all programs. Additionally, there were differences by program; the gap between technical and professional sessions was lower for VIP.

Table 4 Percentage of PD Session Registrations that Were 'Technical' by Gender

	Female		**Male**	
	Professional	Technical	Professional	Technical
Total	63.4%	36.6%	54.9%	45.1%
EPICS	63.1%	36.9%	53.0%	47.0%
VIP	65.6%	34.4%	60.6%	39.4%

Discussion and Next Steps

While team- and project-based learning has many known benefits, a potential weakness may be that biases in role assignment or selection may be exacerbated, and this has been noted in particular with technical roles for women [10]. The programs in this study offer Professional Development sessions that may help mitigate this weakness by offering opportunities to build technical skills outside of the team environment, allowing individuals to gain skill mastery independently that can then be applied within the team setting. The first research question addressed here was whether there are differences between genders in the selection of professional and technical Professional Development sessions. This data suggests that women in the programs are enrolling in a lower percentage of PD sessions that feature technical content than their male peers, instead enrolling in sessions that develop professional skills, such as communication, leadership, and project management.

This study will continue in order to investigate the causes of this trend. Students may choose their PD sessions based on a number of factors, including role requirements, career interests, personal values, societal or interpersonal pressure, past experiences, and a host of others. Further research will employ qualitative methods to investigate how students perceive the relative value of technical and professional skills in their professional development, and whether there are differences between genders in the perception of opportunities to build technical skills in these programs. The study plans to employ focus groups with mixed programs but unmixed genders in small groups. Researchers will provide a working definition of professional and technical skills to provide a common framework for discussion. The focus groups will include a series of guiding questions to lead discussions aimed toward understanding the dynamics that result in the observed differences in PD registration between genders.

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