Capstone Projects for Self-Efficacy, Skills, and Successful Careers

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1 Introduction

Capstone experiences provide an important bridge between education and employment in engineering and providing marketable skills is a major function of the experience [1]. There is growing consensus around capstone projects as a potential site for teaching students professional skills, such as problem solving and teamwork [2]. Yet there remains a gap in skills between employer expectations and the graduates they hire [3], suggesting that not all capstone courses are providing sufficient support for developing these skills. For example, [4] found limited growth in professional skills in small, short-term project experiences.

One potential amplifier of developing professional skills is self-efficacy. The central premise behind self-efficacy theory is that having knowledge and skill is necessary, but insufficient for successful performance [5]. In addition to having the necessary knowledge and skills, a person must also be able to act in ways that perform a given task or series of tasks well. One of the key factors in being able to do so is believing that one has the capacity to behave in ways that will lead to specific outcomes, which is known as self-efficacy [6-7]. This requires self-evaluation, awareness about the social environment, and control over one's motivation and behavior.

Within undergraduate STEM education, self-efficacy has been demonstrated to be a major driver of academic achievement [8]. Research studies have begun to examine student-centered pedagogies as particularly salient ways to build students' self-efficacy [9]. [10] found that self-efficacy mediated the positive effects of active learning on student performance in a large introductory STEM course. Emerging research also suggests that self-efficacy and active learning may positively reinforce each other in supporting student success [11].

Capstones that employ project-based learning may therefore be particularly well-positioned to scaffold students' sense of confidence in their ability to accomplish more than they previously thought [12]. This paper uses three sets of analyses to examine the extent to which intensive capstone project experiences can assist in developing students' self-efficacy alongside professional skills, as well as the relative contributions of self-efficacy and professional skills to long-term career preparedness. Embedding PBL into capstone experiences may prove to be a means of improving the experience and outcomes to realize their full potential.

2 Background

Capstone programs serve as the culminating experience in the undergraduate academic tenure. Building upon cumulative academic courses, they expose students to unstructured problems to facilitate a smooth transition to professional practice and better prepare them for their future

careers [13-14]. Capstone programs were initially pioneered in response to perceived deficiencies in exposure to professional practice [15]. Consequently, their primary objective is to help prepare students for the real world by providing them with opportunities to solve complex open-ended problems, manage a project, and create value for a customer, either external or internal [16]. In the U.S., the Accreditation Board for Engineering and Technology (ABET) General Criterion 5.d. requires a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work (ABET). Capstone courses and projects are well-suited to providing such an experience. Consequently, capstones have become a de facto requirement in engineering education [16].

In a series of national surveys and international counterparts, the longitudinal state of engineering capstone design education over the past three decades has been assessed [1,16,17-19]. These surveys suggest that while the essence of the education provided through capstones remains quite similar across institutions, there are notable variations in course logistics and management [16]. According to a 2015 national survey of all ABET accredited engineering programs, 68% of respondents ran capstone classes and projects in parallel, while no program required a course without a project. The remaining programs ran a combination of classes and projects. According to the survey, 88% of the respondents noted their capstone design students were undergraduate seniors; 31% required a one-semester and 54% required a two-semester course durations. While the vast majority of the capstone design courses are structured as a team component with three or more students, 59% are advised by 1-2 faculty [19].

Assessing the efficacy of capstone projects in preparing students for their post-graduation careers requires understanding the most important skills for professional practice, and the challenges a new engineer faces. [14] point out that problem solving, communication, and teamwork are critically important for professional practice across disciplines and work contexts - further evidenced by findings a recent survey of employers [20]. Capstone design experiences can teach these skills. In a large multi-case study, [21] found that participants drew on capstone design experiences to address workplace challenges with self-directed learning (85% of participants), teamwork and communications (74%), and, to a lesser extent, technical work (45%). This pattern highlights the relative benefits of capstones for developing professional skills beyond strengthening the technical core knowledge taught in other coursework.

3 Context: Capstones at Worcester Polytechnic Institute (WPI)

In the turmoil and social upheaval of 1960s, a group of faculty at WPI pioneered a substantial change to education at WPI. At that time, education at WPI gave students little room to be creative as every student was given a prescriptive curriculum that had to be strictly followed. Engineering instruction did not include social paradigms and challenges of the time. The Plan,

adopted by the faculty in April 1970, brought radical change to education at WPI. The Plan would "create a community where both the student and the faculty member would find about them a group of people enjoying learning and attempting to solve some of the most difficult problems of the time" [22]. In this constructivist approach, learning is shaped not only through lectures where students are passive listeners, but also utilizes projects that necessitate learning of engineering domain knowledge to solve problems. The Plan rests on two major pillars, one of which is Major Qualifying Projects. These projects are required for graduation and must be conducted on a topic relevant to the student's major, typically a technological focus in engineering. Table 1 highlights the changes brought by the Plan and how it matched the qualifications to the workforce needs.

Table 1. The WPI Plan Orients Students Toward Workforce Needs

Traditional Curriculum	Curriculum in the WPI Plan
Each student is an isolated learner	Graduates are part of a team
Courses develop long, narrow "corridors" of knowledge	Professions require integration of knowledge
Students follow rigid, prescribed path – little opportunity to set personal objectives	Total responsibility for setting personal objectives
Get the "right" answers to structured problems	Ask the right questions in unstructured situations

Today, WPI students engage in Major Qualifying Projects in a variety of different ways, such as completing a capstone design project or being involved in a research project. Students typically spend an academic year (August to May) completing their projects; however, finishing them in a seven-week term is also possible, giving students substantial autonomy to schedule their project opportunities. The number of Major Qualifying Projects completed between 2000 and 2021 totaled 11,051 across all majors. A vast majority of these projects satisfied the ABET criteria to be considered capstone design projects - only 0.6% did not qualify as such. Of the full set of Major Qualifying Projects conducted during these two decades, 9.7% were advised by multiple faculty across departments, strengthening the multidisciplinary aspects of student projects.

4 Methodology

This study uses a quasi-experimental design to examine three research questions: 1) To what extent do capstone project experiences contribute to the development of professional skills and self-efficacy? 2) To what extent do professional skills and self-efficacy contribute to how well prepared students are for their careers after graduation? 3) Does self-efficacy mediate the relationship between professional skills and career preparedness? In other words, does having professional skills really matter without having the confidence and self-belief that you can use them to achieve career responsibilities to succeed? See Figure 1 for overarching design.

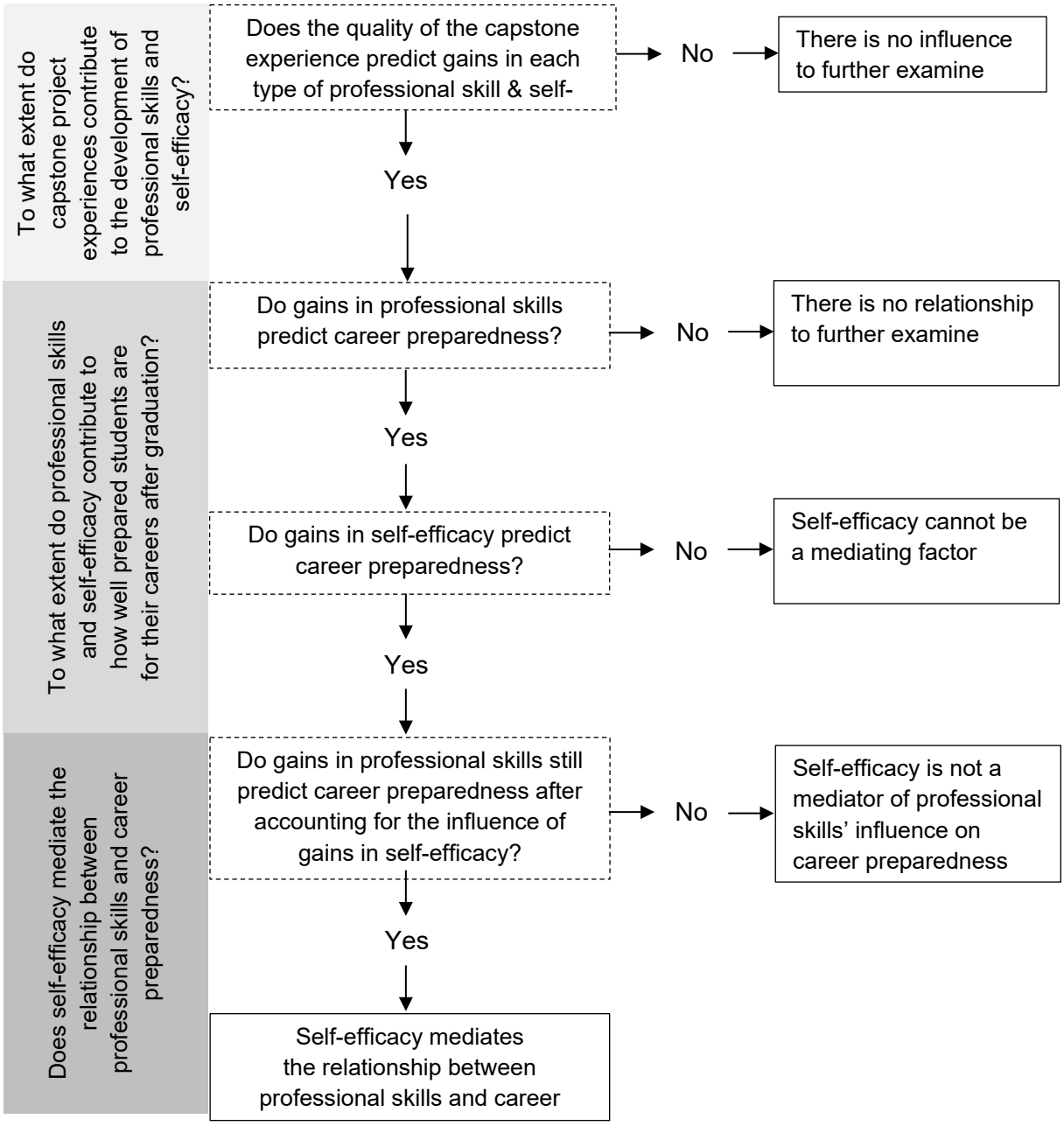


Figure 1. Methodological Decisions Guiding Sequential Design

4.1 Sample

These questions were examined with a sample of 2,101 alumni who graduated with a bachelor's degree from WPI between 1980 and 2019. Of the participants, 61% reported being men, 39% reported being women, and less than one percent reported being non-binary or gender fluid. The majority of respondents were white (89%), 6% identified as Asian, 4% identified as Hispanic/Latino (any race), 1% identified as Black/African American or African, and 1%

identified as Middle Eastern or North African. While at WPI for undergraduate studies, 62% of the sample majored in engineering fields, 35% majored in science and mathematics fields, and 3% majored in other subjects without also earning a science or engineering degree. These characteristics are largely representative of alumni demographics within these years.

4.2 Measures & Data Collection

Data were taken from an alumni survey conducted in March 2021. A survey was emailed to 15,528 alumni through Qualtrics. A reminder was emailed to those who had not yet submitted a response one week after the original invitation to participate; no further recruitment messages were sent. The survey included closed and open items that asked respondents about their educational experiences and their impact on their lives after graduation.

4.2.1 Educational Activities

This study uses several variables describing participants' experiences with educational activities while at WPI. The survey prompted respondents, "For each of the following aspects of your time as an undergraduate at WPI, indicate how and to what extent it affected you after having completed your undergraduate studies at WPI." Response options included a five-point bi-directional Likert scale from very negatively (1) to very positively (5), with an additional option to indicate "not applicable" for activities in which the respondent did not participate. The aspects included in the survey that were used in this study include courses in the major, Humanities and Arts capstone, IQP (the Interactive Qualifying Project, which is completed in the third year on a team to address a problem at the intersection of technology and society), and MQP (the Major Qualifying Project). A second question asked respondents, "What percentage of your courses included project work at WPI?" Response options were ordinal: none, about 25%, about 50%, about 75%, and nearly all. We also used an indicator qualifying whether the Major Qualifying Project was completed off campus or on campus, as both options are available to students and have, anecdotally, influenced student learning.

4.2.2 Professional Skills Development

Gains in three types of professional skills were assessed using survey items. A composite measure for each of three types of skills was constructed using items that began with the prompt, "Indicate the extent to which your project experiences (through GPS, HUA capstone (inquiry seminar/practicum or sufficiency), your IQP, and/or your MQP) enhanced your ability to…" Response options were on a five-point Likert scale from not at all (1) to very much (5). Communication skills were assessed by averaging responses to four items: write clearly and effectively, speak clearly and effectively, communicate effectively visually (by using images or graphics to convey information, data, or ideas), and deliver effective presentations. Teamwork

skills included responses to five items: interact effectively as a professional, effectively manage interpersonal dynamics, effectively function on a team, effectively manage a project, and be an effective leader. Skills using information included four items: integrate information from multiple sources; make connections across disciplines; identify, analyze, and solve problems creatively through sustained critical investigation; and develop ideas.

4.2.3 Self-efficacy

Five survey items using the same prompt were used to create a composite score measuring self-efficacy. These items included: feelings that your ideas are valuable, feelings that you could "make a difference," ability to take responsibility for your own learning; ability to succeed in business or industry, and ability to function effectively in the "real world."

4.2.4 Career Preparedness

Survey respondents were asked, "How well did your project experience at WPI prepare you for your current career?" Response options were a five-point bi-directional Likert scale from very poorly (1) to very well (5), with an option to indicate "not applicable" if the respondent was not working.

4.2.5 Alumni Demographics

Gender was self-reported and organized as an indicator variable for women. Race and ethnicity were also self-reported with the option to indicate as many as applied to the respondent. These data were reorganized into an indicator for BIPOC (Black, Indigenous, Person of Color) status, which included anyone who indicated an identity that included being Black, Hispanic, Indigenous/Native American/Native Alaskan, Native Hawaiian or other Pacific Islander, or Middle Eastern or Northern African.

4.2.6 Response Bias

We include a measure of response bias with the understanding that alumni who are more satisfied with their careers may indicate more positive experiences or attribute greater influence from their undergraduate experiences than those who are unsatisfied with their careers. This measure uses a survey item that asked, "Overall, how satisfied are you with your career thus far?" Response options were on a five-point bi-directional Likert scale from very dissatisfied (1) to very satisfied (5), with an additional option to indicate "not applicable."

4.3 Analysis Plan

To address the first research question, To what extent do capstone project experiences contribute to the development of professional skills and self-efficacy?, the first set of analyses fit the data to a series of hierarchical multiple linear regression models. Each series of models controls for the effects of pre-existing alumni attributes (including gender, BIPOC race/ethnicity, and current career satisfaction level as a measure of response bias) before assessing the additional influence of courses in the major and three types of project experiences (i.e., in courses, the required humanities and art project, and the required project on technology and society). Finally, the influence of the capstone and whether the capstone was completed off-campus are then added to account for their influence in a way that distinguishes their explanatory power from other experiences. Four sets of three models were constructed and assessed to examine each of the three professional skills of interest to this study (i.e., communication skills, skills for using information, teamwork skills) as well as self-efficacy.

To address the second research question, To what extent do professional skills and self-efficacy contribute to how well prepared students are for their careers after graduation?, the next set of analyses fit the data to two new series of hierarchical multiple linear regression models predicting career preparedness. Similar to the first phase of the study, the first model in each case also begins by controlling for the effects of gender, BIPOC race/ethnicity, and response bias. The second model diverges to add either the gains in communications skills, in skills for using information, and in teamwork skills or to add the gains in self-efficacy. These additions allow us to examine whether the development of these skills and of self-efficacy each contributes independently to career preparedness.

Finally, examining the third research question, Does self-efficacy mediate the relationship between professional skills and career preparedness?, only proceeds if the analyses addressing the second research question confirms that both professional skills and self-efficacy each influence how prepared alumni are for their careers. If this is indeed the case, the third set of analyses will begin with the hierarchical linear regression models that modeled the effects of gains in self-efficacy on career preparedness. An extension will then add a third model that includes gains in the three professional skills. The explanatory power of this model is then compared to the explanatory power of modeling career preparedness without self-efficacy. If the explanatory power has been reduced, we can conclude that self-efficacy mediates professional skills' influence on career preparedness.

Significance levels are set at $p<.05$ for all analyses.

5 Results

5.1 The Effect of Capstones on Developing Professional Skills and Self-efficacy

The first series of analyses found that the capstone experience has a moderately sized positive effect on the development of communication skills, information use skills, teamwork skills, and self-efficacy. These effects remain even after controlling for the influences of student demographics, response bias, courses in the major, and other project experiences. For each learning outcome, the first model explains a small, yet significant amount of the variance in learning gains: gender, BIPOC race/ethnicity, and response bias together explain 6% of the variance in the development of communications skills, 11% of the variance in the development of skills for using information, 8% of the variance in the development of teamwork skills, and 10% of the variance in the development of self-efficacy (see Tables 2-5).

In the second model for each series, adding the effects of other educational experiences during undergraduate studies at WPI accounts for an additional significant amount of the variance in each of the four outcomes: courses in the major, PBL in courses, the humanities and arts project, and the project on technology and society together account for a further 12% of the variance in the development of communications skills, 13% of the variance in the development of skills for using information, 10% of the variance in the development of teamwork skills, and 12% of the variance in the development of self-efficacy. All four types of educational experiences have a significant effect on the development of communications skills, skills for using information, and self-efficacy; with the exception of the humanities and arts project (which is typically completed individually), educational experiences each have a significant positive effect on the development of teamwork skills (see Tables 2-5).

In the final model for each series, the capstone experience adds further explanatory power, accounting for 2% of the development of communications skills, 4% of the development of skills for using information, 3% of the development of teamwork skills, and 4% of the development of self-efficacy. While these may represent relatively small contributions to the explanatory power of each model, they are all statistically significant (see Tables 2-5).

Furthermore, the size of the significantly positive effect of capstone quality on each learning outcomes is meaningful in a pragmatic sense (see Figure 2). Improving the capstone experience from providing a “negative” experience to a “somewhat positive” experience among this group of alumni was sufficient to improve from “some gains” in skills for using information to “good gains” (or from “good gains” to “great gains”); this is also the case for teamwork skills and self-efficacy. The impact on communications skills, while slightly less, would still move someone two-thirds of the way from “some gains” towards “good gains.” This is a meaningful return on investment in providing even a “somewhat positive” capstone experience.

Table 2. Influence of Educational Experiences and Capstone on Communications Skills

	Model 1: Pre-existing Attributes					Model 2: PBL Experiences					Model 3: Capstone				
			95% CI					95% CI					95% CI		
Effect	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***
Intercept	2.54	.12	2.3	2.79	<.01	-.11	.21	-.53	.30	.60	-.50	.22	-.94	-.07	.02
Woman	.21	.04	.13	.29	<.01	.14	.04	.06	.22	<.01	.14	.04	.07	.22	<.01
BIPOC	.11	.06	-.01	.23	.07	.04	.06	-.07	.15	.46	.04	.06	-.07	.15	.50
Response Bias	.30	.03	.24	.35	<.01	.24	.03	.19	.29	<.01	.22	.03	.17	.27	<.01
Major Courses						.23	.04	.16	.30	<.01	.18	.04	.11	.25	<.01
PBL in Courses						.17	.02	.14	.20	<.01	.17	.02	.13	.20	<.01
HUA Project						.09	.03	.03	.16	.01	.09	.03	.03	.16	.01
IQP Project						.35	.03	.28	.41	<.01	.30	.03	.24	.37	<.01
Capstone											.22	.04	.15	.29	<.01
Off-Campus											.09	.04	.00	.18	.05
R^2	.06					.18					.20				
ΔR^2	.06					.12					.02				
F for ΔR^2	48.92					73.92					22.90				
p	<.01					<.01					<.01				

Dependent Variable: Communication Skills

Table 3. Influence of Educational Experiences and Capstone on Skills for Using Information

	Model 1: Pre-existing Attributes					Model 2: PBL Experiences					Model 3: Capstone				
			95% CI					95% CI					95% CI		
Effect	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***
Intercept	2.30	.11	2.09	2.51	<.01	-.38	.18	-.74	-.02	.04	-.98	.19	-1.34	-.61	<.01
Woman	.11	.04	.04	.18	.01	.06	.03	-.01	.13	.07	.08	.03	.01	.14	.02
BIPOC	.09	.05	-.01	.19	.09	.04	.05	-.06	.13	.43	.04	.05	-.06	.13	.44
Response Bias	.37	.02	.32	.41	<.01	.30	.02	.25	.34	<.01	.27	.02	.23	.31	<.01
Major Courses						.35	.03	.29	.41	<.01	.28	.03	.22	.34	<.01
PBL in Courses						.11	.02	.09	.14	<.01	.10	.01	.08	.13	<.01
HUA Project						.09	.03	.03	.15	.01	.09	.03	.04	.15	<.01
IQP Project						.29	.03	.24	.35	<.01	.23	.03	.18	.29	<.01
Capstone											.33	.03	.27	.39	<.01
Off-Campus											-.04	.04	-.11	.03	.30
R^2	.11					.24					.28				
ΔR^2	.11					.13					.04				
F for ΔR^2	85.47					89.83					89.83				
p	<.01					<.01					<.01				

Dependent Variable: Gains in Information Use Skills

Table 4. Influence of Educational Experiences and Capstone on Teamwork Skills

	Model 1: Pre-existing Attributes					Model 2: PBL Experiences					Model 3: Capstone				
			95% CI					95% CI					95% CI		
Effect	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***
Intercept	2.45	.12	2.21	2.70	<.01	.10	.21	-.32	.52	.63	-.44	.22	-.87	-.01	.04
Woman	.21	.04	.13	.29	<.01	.15	.04	.07	.23	<.01	.16	.04	.08	.24	<.01
BIPOC	.15	.06	.04	.27	.01	.09	.06	-.02	.20	.13	.08	.06	-.03	.19	.13
Response Bias	.33	.03	.28	.39	<.01	.28	.03	.23	.33	<.01	.26	.03	-.21	.31	<.01
Major Courses						.19	.04	.12	.26	<.01	.12	.04	.05	.20	<.01
PBL in Courses						.18	.02	.14	.21	<.01	.17	.02	.14	.20	<.01
HUA Project						.05	.03	-.01	.12	.11	.06	.03	-.01	.12	.09
IQP Project						.33	.03	.26	.39	<.01	.27	.03	.20	.34	<.01
Capstone											.31	.04	.24	.38	<.01
Off-Campus											<.01	.04	-.08	.09	.95
R^2	.08					.18					.21				
ΔR^2	.08					.10					.03				
F for ΔR^2	61.14					64.70					36.08				
p	<.01					<.01					<.01				

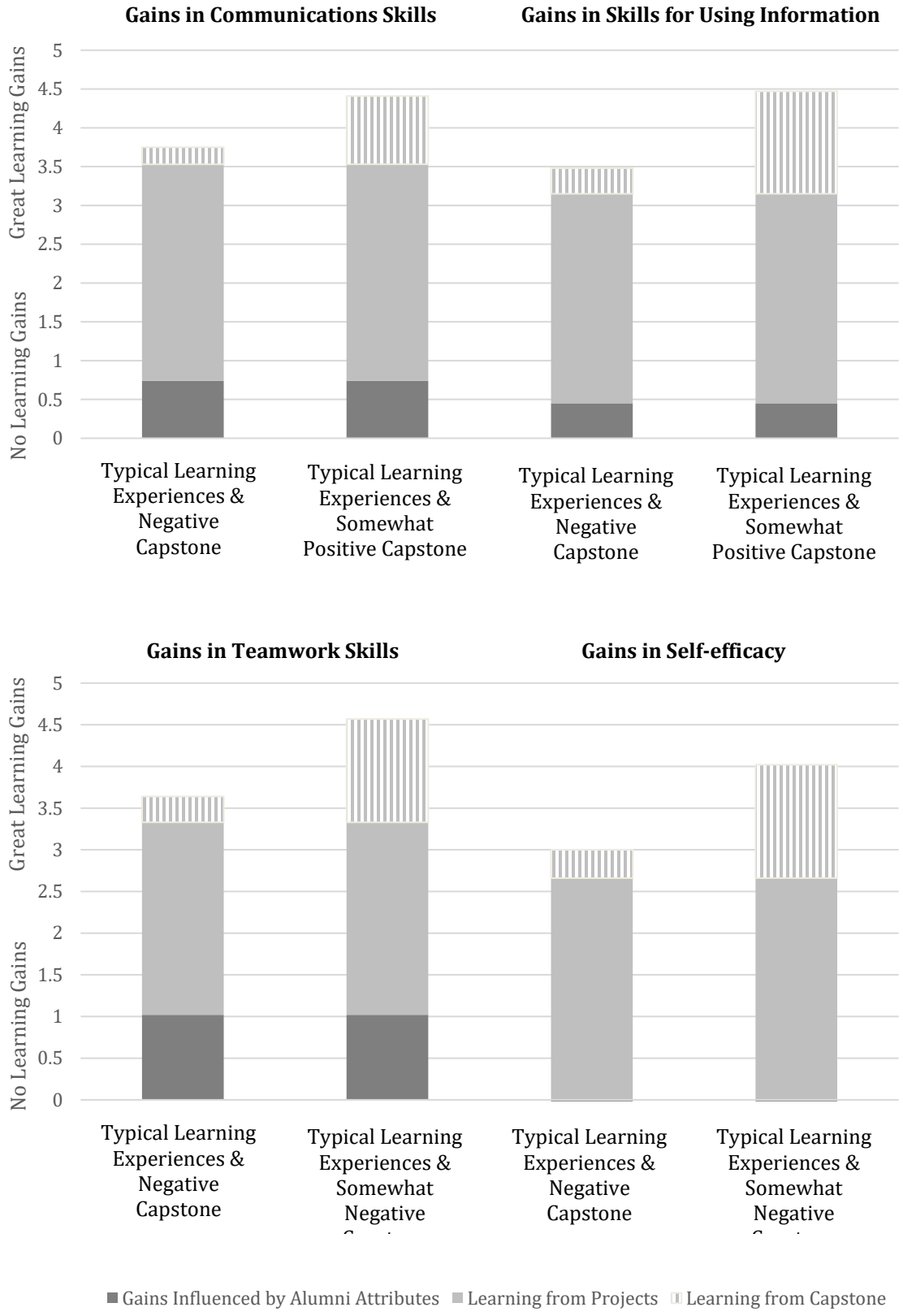
Dependent Variable: Teamwork Skills

Table 5. Influence of Educational Experiences and Capstone on Self-efficacy

	Model 1: Pre-existing Attributes					Model 2: PBL Experiences					Model 3: Capstone				
			95% CI					95% CI					95% CI		
Effect	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***P***	**β**	**SE**	**LL**	**UL**	***p***
Intercept	1.69	.12	1.46	1.93	<.01	-1.08	.21	-1.49	-.68	<.01	-1.68	.21	-2.09	-1.27	<.01
Woman	.19	.04	.11	.26	<.01	.12	.04	.05	.20	.01	.13	.04	.06	.20	<.01
BIPOC	.10	.06	-.02	.21	.09	.04	.05	-.07	.14	.48	.03	.05	-.07	.14	.54
Response Bias	.38	.03	.33	.43	<.01	.32	.03	.27	.37	<.01	.29	.02	.24	.34	<.01
Major Courses						.27	.04	.21	.34	<.01	.19	.04	.12	.26	<.01
PBL in Courses						.13	.02	.10	.17	<.01	.12	.02	.09	.15	<.01
HUA Project						.09	.03	.02	.15	.01	.09	.03	.03	.15	.01
IQP Project						.39	.03	.32	.45	<.01	.32	.03	.26	.38	<.01
Capstone											.34	.04	.27	.41	<.01
Off-Campus											.10	.04	.02	.19	.01
R^2	.10					.22					.26				
ΔR^2	.10					.12					.04				
F for ΔR^2	78.61					80.46					55.18				
p	<.01					<.01					<.01				

Dependent Variable: Gains in Self-efficacy

Figure 2. Benefits of a High Quality Capstone for Professional Skills & Self-efficacy



The conclusions from this first set of analyses demonstrate that capstone project experiences have a significant positive effect on the development of professional skills and self-efficacy.

5.2 The Effect of Professional Skills and Self-efficacy on Career Preparedness

After establishing that capstones do, indeed, positively influence the development of professional skills and self-efficacy at WPI, our next set of findings examine whether those gains translates into being better prepared for careers. As with modeling learning gains, the foundational control model explained a significant portion of the variance in career preparedness - 14% in this case (see Table 6). Adding parameters for gains in each of the three types of professional skills accounts for a further 24% of the variance in career preparedness, which is significant with a change in $F=243.95$, $p<.01$. Being BIPOC had a significant negative effect on career preparedness and response bias remained a significant effect, validating its inclusion in the control model. Gains in communication skills and in skills for using information both had significant positive effects; teamwork skills did not.

Table 6. Influence of Professional Skills on Career Preparedness

	Model 1: Pre-existing Attributes					**Model 2: Professional Skills**				
			95% CI					**95% CI**		
Effect	**β**	**SE**	**LL**	**UL**	***P***	**β**	**SE**	**LL**	**UL**	***P***
Intercept	1.91	.12	1.67	2.15	<.01	.50	.12	.27	.73	<.01
Woman	.03	.04	-.06	.11	.55	-.06	.04	-.13	.02	.12
BIPOC	-.11	.06	-.23	.01	.05	-.17	.05	-.27	-.07	<.01
Response Bias	.47	.03	.42	.52	<.01	.26	.02	.21	.31	<.01
Information Use Skills						.46	.03	.40	.53	<.01
Communication Skills						.10	.03	.05	.16	<.01
Teamwork Skills						.03	.03	-.02	.09	.22
R^2	.14					.38				
ΔR^2	.14					.24				
F for ΔR^2	107.88					243.95				
p	<.01					<.01				

Dependent Variable: Career Preparedness

In the next model, gains in self-efficacy accounted for 21% of the variance in career preparedness. This is significant with a change in $F=622.22$, $p<.01$. As with professional skills, the self-efficacy model of career preparedness also found that being BIPOC had a significant negative effect on career preparedness and a significant effect from response bias (see Table 7). In comparing the models, increasing gains in each professional skill from "some gains" to "great gains" would improve preparation for a career from "more than adequately" to "very well" or from "less than adequately" to "adequately"; the same increase in self-efficacy without improved professional skills would have a similar effect (see Figure 3).

The conclusions from this stage of the study provides grounds for continuing the assessment of whether self-efficacy fully or partially explains the impact that professional skills have on how prepared alumni are for their careers.

5.3 Self-efficacy as a Mediator of Professional Skills' Influence on Career Preparedness

The final stage of the study addresses the third research question, Does self-efficacy mediate the relationship between professional skills and career preparedness? To do so, we began with the self-efficacy model of career preparedness and extended it by adding three parameters, one for gains in each type of professional skill. When the influence of gains in self-efficacy has already been taken into account, adding the effects of gains in professional skills still explains a further 5% of the variance in career preparedness. This is significant with $F=51.17$, $p<.01$. However, it is substantially less influence than the 24% of the variance previously explained by professional skills when self-efficacy was not first included. This means 79% of the variance previously explained by gains in professional skills could also be explained by gains in self-efficacy.

6 Discusssion

Self-efficacy is often implicit in the theories of action guiding capstone design [1]. The studies described in this paper explicitly confirm the significant role of capstones in developing students' self-efficacy and its importance in preparing students for future engineering careers. This paper also extends prior research that stops short of assessing whether the self-efficacy and professional skills gained in capstones translates to career success.

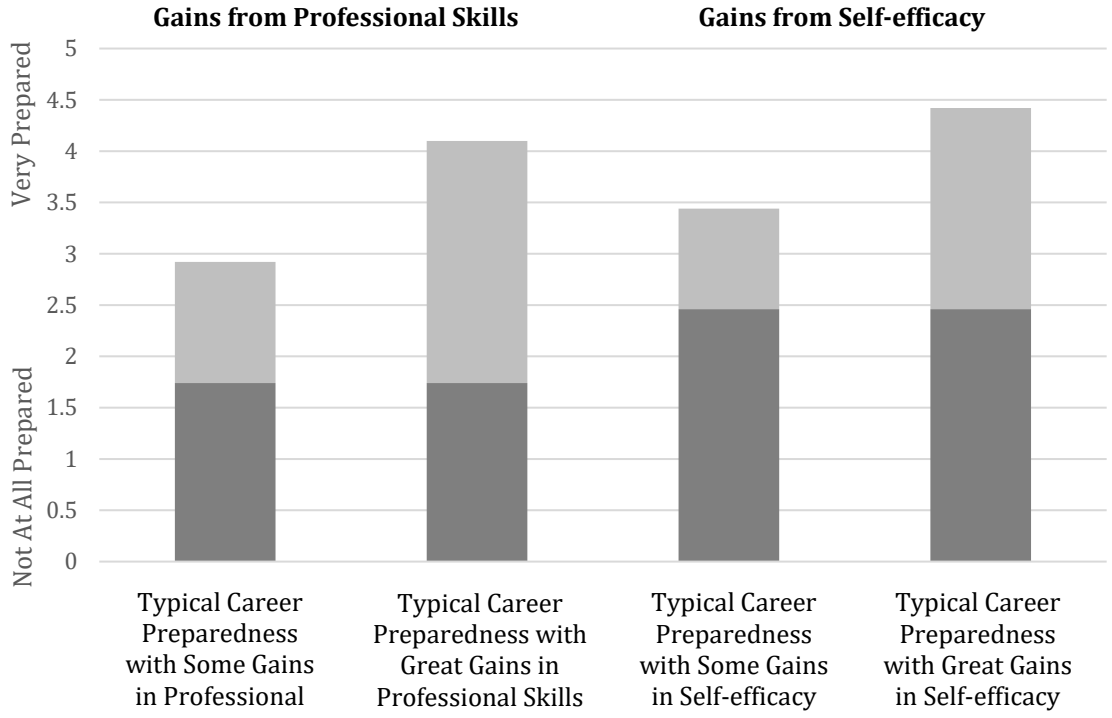
Project-based learning embedded in an intensive capstone experience is associated with benefits that address needs of several stakeholders. We discuss these implications for students, for higher education, and for employers.

Table 7. Self-efficacy as a Mediator of Professional Skills' Influence on Career Preparedness

	Model 1: Pre-existing Attributes					Model 2: Self-Efficacy					Model 3: Professional Skills				
			95% CI					95% CI					95% CI		
Effect	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***	**β**	**SE**	**LL**	**UL**	***p***
Intercept	1.91	.12	1.67	2.15	<.01	1.08	.11	.86	1.30	<.01	.58	.12	.35	.81	<.01
Woman	.03	.04	-.06	.11	.55	-.07	.04	-.14	.01	.07	-.07	.04	-.14	-.01	.05
BIPOC	-.12	.06	-.23	.01	.05	-.16	.05	-.27	-.06	<.01	-.18	.05	-.27	-.08	<.01
Response Bias	.47	.03	.42	.52	<.01	.29	.03	.24	.33	<.01	.24	.02	.19	.29	<.01
Self-Efficacy						.49	.02	.45	.53	<.01	.23	.03	.18	.29	<.01
Information Use Skills											.32	.04	.25	.39	<.01
Communication Skills											.08	.03	.02	.13	.01
Teamwork Skills											.00	.03	-.06	.05	.99
R^2	.14					.35					.40				
ΔR^2	.14					.21					.05				
F for ΔR^2	107.88					622.22					51.17				
p	<.01					<.01					<.01				

Dependent Variable: Career Preparedness

Figure 3. Relative Benefits of Professional Skills and Self-efficacy to Career Preparedness



6.1 Students

Capstone experiences are typically multifaceted and complex [1]. WPI's project-based curriculum culminating in a senior capstone project was designed to meet students' holistic educational needs, including preparation for careers after graduation (Table 1). Career preparation goes beyond completion of a sequence of stand-alone courses. To succeed in a professional environment, students need to learn technical and team-based skills, major-specific knowledge, and more broadly transferable non-technical or "life" skills [23-24].

Self-efficacy underpins several student needs. It is necessary at various levels, starting with task completion, building into higher levels of ascertaining and attaining life goals, and ultimately mastering diverse interactions with others who have different approaches, backgrounds and perspectives [5,7,25].

The capstone experience assessed in this present study is a universal student experience at WPI at the senior-level in the major field of study. Most of these projects are team-based, contain open-ended capstone design, and span three quarters to a full year. Projects can be proposed by students or faculty; many are industry-sponsored and some result in patents. The experience is integrative - teams may have students from different majors, some students bring a double-major

perspective to the project, and interdisciplinary projects are co-advised. All students formally present their work in April.

The experience provides students with direct mentorship, akin to apprenticeship for a future career. The advising approach is individualized and adaptive, and based on the composition, capabilities, and drive of each team. However, it is labor-intensive and not easily scalable; even at WPI, this approach is reserved for two project experiences rather than threaded throughout the full curriculum. The advising model at the institution guides students through a progressive process of developing self-efficacy, with first year students receiving more specific guidance and senior level students exercising greater autonomy in solving open-ended problems [26].

In the capstone experience at WPI, students learn to integrate diverse knowledge from prior fundamental coursework and new knowledge that they seek out as appropriate. Students become comfortable with ambiguity and tackling unstructured problems. They grow as they hone skills of self-direction, learning to ask the right question in both personal and technical situations. Students also become more comfortable with iteration to find suitable answers; this involves accepting failure as part of the path to success. They are more likely to succeed if they embrace opportunities to learn new skills related to the task at hand.

The ability to function effectively on a team is also critical to career preparation [14]. WPI is steeped in a culture of project-based learning (PBL). By the time students start their capstone project, they have learned general team and writing skills during earlier project experiences. The capstone experience builds on these foundational skills and leverages them in a stronger focus on major-specific skills.

6.2 Higher Education

Institutions of higher education in general, and engineering education institutions in particular, face numerous and growing challenges. Nationally, changing demographics will result in fewer students in the college age population, accompanied by the potential for reduced demand as the increasing cost of college collides with decreasing belief in the value proposition of a college degree [27]. Engineering education leaders are highly motivated to address multiple, overlapping aspects of this landscape, including:

- Increasing overall enrollment by attracting more students to engineering, for example by opening access to students with different preparation backgrounds [28];

- While “growing the pie,” also increasing diversity in the student population [29];

- Promoting retention once students are engaged in an engineering program, for example replacing the "weeding out" mentality with a supportive culture of "weaving in" [30];

- Facilitating the broadening of retention benefits across dimensions of DEIB demographics [31].

Given the links between self-efficacy and retention in STEM education [32], the significant positive effect of capstones on the development of self-efficacy described in the results section suggests that focusing efforts on providing high quality capstone experiences can support improvement in student retention. Additionally, since our results showed that benefits of PBL were observed across several aspects of demographic distribution, we may also expect to see self-efficacy benefits for students from underrepresented groups [33].

ABET accreditation falls at the intersection of institutional needs and student needs in engineering departments. The learning outcomes assessed for accreditation closely mirror those in many capstone experiences. The capstone experiences at WPI give sufficient time and faculty-student interaction for these learning outcomes to be more fully realized. It is important to note that all students in all departments at WPI must complete this capstone project - including those that are not accredited under ABET. Therefore, ABET learning outcomes are not a universal standard for all capstone experiences at the institution. Rather, these projects prepare all students for the next phase of their career or graduate studies.

6.3 Employers

STEM employers increasingly demand that institutions of higher education develop graduates who are prepared to demonstrate both content and skills that will increase the likelihood of success in the workplace [34]. Not only is workplace success expected on "day one," both graduates and employers are well served by preparation that continues to grow and evolve over the graduate's entire career. The results of this study show that PBL in capstones can help students (and institutions) meet these expectations.

7 Conclusions

This study demonstrated that PBL and capstone experiences at WPI improved student career preparation through the development of professional skills and self-efficacy. In fact, developing students' self-efficacy moderated the importance of professional skills. This suggests that explicitly attending to learning activities and environments that build self-efficacy provides a particularly good return on investment during the capstone. The implications for higher education institutions, students, and employers are significant. These findings may be

representative of capstone experiences at large; however, future studies would be needed to evaluate if the effect can be generalized across institutions and types of capstone experiences.

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