Implementing Human-Centered Design into an Engineering Service Course: Development and Evaluation

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Abstract

Since 2010, George Fox University has required all engineering program graduates to complete a service-learning course. Initially, projects were identified by key faculty with a focus on clients. This process proved difficult to maintain, and students were not engaged in selecting the project. Three years ago, the program shifted to student-discovered projects. During the summer, students watched videos that provided a brief instruction on how to find a project for the course. Over the next two years, faculty determined that these student-identified projects were frequently not good matches for the course. To remedy this, faculty decided to set aside the first several weeks of the semester to walk students through a process to identify meaningful projects. This process was derived from the Human-Centered Design course developed by IDEO. During the summer, students identified areas of societal interest and were grouped during the identification stage to find a project.

In addition to describing the evolution of the program, a statistical analysis of student perceptions of the engineering design process and the influence of service experience is presented. These longitudinal data indicate that student perceptions remained consistent throughout all updates to the program.

The details of this paper will provide information to other programs in their development of similar courses. Through the discussion of ongoing areas of concern, those implementing similar programs will gain exposure to issues that are sure to arise.

Introduction

The Servant Engineering (SE) program at George Fox University (GFU) began in spring 2010. As discussed in the authors' first paper on this program [1], the SE program grew out of both the engineering program's and the university's mission to develop graduates with a service mentality. Additionally, the engineering program's focus on hands-on design-and-build experiences naturally engaged students to discover how they could serve using the engineering skills they were learning.

In the beginning, the initial instructors collaborated with the EPICS program started at Purdue University [2], [3] and patterned much of the GFU program from theirs. The EPICS program at Purdue was an elective for students. However, the faculty of GFU felt that the service-learning opportunity was important enough to create a sequence of courses that would be required of all engineering students. The SE program at GFU developed in roughly nine distinct phases:

- Phase 1: The instructors attempted to mimic the basic format provided by the Purdue EPICS program.
- Phase 2: Much of the EPICS structure was shed to create a much leaner system, focusing primarily on performing the engineering service tasks.

- Phase 3: The EPICS structure was re-implemented in a manner that was more effective for the SE program at GFU, re-emphasizing the importance of learning the engineering design process.
- Phase 4: The course was restructured from four semesters to two semesters.
- Phase 5: The responsibility for finding potential projects was shifted to the students as a summer project.
- Phase 6: The program was codified into a handbook and adjuncts became significantly involved.
- Phase 7: Project identification was moved from a summer project for students to an 11-week process in the Fall. This process was modeled on a human-centered design course.
- Phase 8: Faculty advisor involvement increased during the human-centered design process of the first semester.
- Phase 9: In an effort to gain more buy-in from faculty and continuity for larger, multi-phased projects, the source of project ideas was shifted from students to faculty advisors.

During Phase 3 we began two yearly surveys [4], [5] to help validate the ongoing effectiveness of the course implementation. The first survey allows students to self-assess their engagement with the engineering design process. The second survey assesses students' perceived influence of service experiences on engineering learning objectives. A statistical analysis of the survey responses is included below.

Phases 1-3

In the spring of 2010, when Servant Engineering began, there were 39 students, both sophomores and juniors, working on seven projects. The class was designed as a 1-credit class to be taken over four consecutive semesters beginning in the spring of the sophomore year and culminating the fall of the senior year. Faculty were responsible for identifying "ready-to-go" project opportunities with specific clients. Students would meet in their groups one night per week, and professionals (typically alumni) were encouraged to contribute. There were 2-3 faculty with these professional helpers who would roam amongst the teams to keep things running. The project methodology was copied directly from the EPICS source documentation [6]. During this phase, professors and students felt like they spent more time in documentation rather than engineering. In 2011, the instructors removed much of this documentation, and teams found themselves floundering and losing direction. Iterating further, the instructors designed their own documentation structure loosely based on the EPICS material that better suited the GFU program.

From our assessment of students' self-concepts, we learned that the course was providing a valuable influence in students' perception of self-efficacy, motivation, outcome expectancy, and anxiety towards the design process. It has also enhanced student understanding of some key learning outcomes. We discuss the process and the survey analysis for that year extensively in our 2012 ASEE paper [1].

Phases 4-6

At the end of spring, 2012, the instructors solicited significant feedback from students in the form of essays and faculty meetings. Based on these essays from students, and consistent with the belief of faculty, a number of things needed to change. Students expected more course load, wanted some say in the projects that were available to work on, indicated that documentation could still be reduced, and wanted more faculty oversight. The course was heavily redesigned to meet these requests for the beginning of fall, 2012.

The course was changed from four 1-credit courses to two 2-credit courses. These two courses would be taught in the fall and spring of the junior year. The course would still be required of all students, but by moving to a one-year model, the number of students in the course at one time was effectively cut in half.

The change to 2-credit courses increased the significance of the course to students, which translated to students giving it more emphasis in their weekly studies. In addition, these changes enabled a structure where faculty could provide more of the requested oversight. Teams met with a single faculty advisor on a weekly basis at a "normal" class time. However, this came at the expense of making it difficult for alumni professionals to be as involved.

In 2013, we switched from faculty finding the projects to student-discovered projects. There were two primary reasons for this shift: 1) to promote student engagement with their projects and 2) to alleviate the growing burden on faculty of finding specific projects. Students who were preparing to enter the course in the fall of 2013 were charged with finding potential projects over the summer. A faculty member reviewed each project proposal to confirm it was a "potential" project. Each project proposal could be sponsored by 1-4 students, and every student was required to sponsor at least one proposal. These proposals were then presented to the faculty at the beginning of the fall semester where the best were chosen and the others discard. The student sponsors from discarded projects were distributed among the chosen teams.

This same methodology was used in the 2014-2015 academic year, but with the growing enrollment, it was necessary to expand the pool of faculty instructors. We were able to find a significant number of professionals who were willing to serve as adjuncts, and most were available during students' daily class times. Engaging more professionals brought a number of new ideas into the program that were beneficial to both faculty and students.

Further details of these phases and the statistical results of the survey data are discussed more extensively in our 2015 ASEE paper [7]. One of our key findings was that, across multiple years and a myriad of changes, the data showed no statistically significant change in how each cohort of students self-reported their self-concept toward engineering design and how they achieved learning objectives. The results of the surveys increased our confidence that any future changes to the program would not detract from students' learning experience. One could infer that the benefits obtained from a service-learning experience come from simply *having* that program rather than any particular implementation detail. This finding was important for us as, while we continued the same program throughout the 2015-2016 academic year, faculty began identifying and expressing areas that needed improvement if not wholesale change.

Phase 7: Human-Centered Design (2016-2017)

After the conclusion of the spring semester in 2016, a few meetings took place that included the faculty and professionals serving as adjuncts to discuss the efficacy of the program. The largest area of concern among the group was their perception of the quality of the projects that the students were proposing. While many of the students were inventive and eager, there was still a lack of quality in the project ideas—many were far too ambitious for the students' level of engineering skill, many were ill-defined, and often there were existing solutions available. The desire to have specific clients often contributed to low quality projects. Students would go out looking for projects and interact with family members, friends, organizations, etc. who had what they considered needs, but they understood neither the role of engineering in general nor the abilities of engineering students. As the project formed the basis of a full year of coursework, a poorly defined or inadequate project could render the entire year an exercise in frustration—potentially for students, clients, and/or faculty. It turned out that teams spent significant time in the fall semester attempting to define the project, sometimes gutting it and starting over. The faculty decided that SE should move to a model where the first weeks of the fall semester would be spent in an organized way—teaching students how to identify a project effectively.

That summer (2016), four faculty met together to study the human-centered design (HCD) materials from IDEO [8], [9]. These four members became a core team to lead the students through this model. They developed a six-week schedule to take students through a HCD process to identify their projects. For their summer assignment, students were now surveyed to identify an area of societal need. Based on their responses, the core faculty grouped students into teams, and then took them through the HCD process—meeting as a large group during the regular class time on Mondays, Wednesdays, and Fridays for the first six weeks. Generally, two days per week were spent in a classroom setting with the rest of the time being team meetings. The core faculty would migrate between rooms to interact with student teams and help keep them on track.

These six weeks consisted of the following:

- Week 1: Introduction to Human-Centered Design - design exercises to show the difference between human-centered design and more standard processes
- Week 2: The Inspiration Phase - framing a design challenge, choosing a design challenge, planning research, building an interview guide
- Week 3: Conducting research and preparing for presentations
- Week 4: Ideation Methods - finding themes, clustering, creating insight statements
- Week 5: Selecting a Project - storyboarding, brainstorming, selecting best ideas, gut check
- Week 6: Project Proposals - complete project proposal presentations, team assignments, mechanics for the rest of the semester

At the completion of the six weeks, students presented their project proposals to the full Servant Engineering faculty. The each faculty member chose the project proposal that they were interested in leading, and the teams then set to work on the projects—meeting once per week with their faculty advisor for the remainder of the fall semester and throughout the spring semester.

Feedback from both the students and the core faculty consistently indicated that the HCD schedule moved too quickly. Teams did not have enough time to research before the project proposal presentations. The research phase is one of the key phases of the HCD process. Not being able to interact with an adequate number of individuals in the research phase reduced much of the benefit of this method, as students were still primarily identifying projects on their own.

We also recognized a reversion to a former failed aspect of Phases 4-6—having more teams than advisors to guide them. By this time, the program had grown considerably and there were 16 teams. It was difficult for the four faculty to adequately monitor and advise each team. As a result, students were largely identifying their own projects.

While students seemed engaged with the HCD process led by the four core faculty, the rest of the faculty were generally unengaged in the process. They were invited to come and observe what the students were learning. However, other things frequently came up to prevent them from participating. The lack of consistent engagement led to some confusion when the students went from the 6-week HCD course to begin working with the faculty member. There was no history between the students and the faculty and decisions that were made by the students were not clearly understood by faculty members. While this phase was an exciting change, there was still much to fix.

Phase 8: Human-Centered Design - the Redo (2017-2018)

To ameliorate the issues identified in the previous phase, a number of changes were made. The HCD course was redesigned to add in more research time and slow down the HCD process. Thus, the HCD instruction expanded from six weeks to ten weeks. The core faculty primarily presented on Mondays, student teams met together to do work on Wednesdays, and then students met with their advisors on Fridays. All full-time faculty who had not taught in the program were required to attend the Monday meetings (and the rest were strongly encouraged).

The 10 weeks consisted of the following:

- Week 1: Introduction to Human-Centered Design: design exercises to show the difference between HCD and more standard processes.
- Week 2: Choosing a Design Challenge
- Week 3: Prepare Research Plan
- Week 4: Research
- Week 5: Research and Clustering
- Week 6: Stories, Clustering, and Insights
- Week 7: Insights and How Might We’s: define three strong project ideas from the research
- Week 8: Project Selection: brainstorming, selection, gut check
- Week 9: Storyboarding and Prototype Idea
- Week 10: Prototyping your Project

These simple changes provided a significant difference in the student and faculty experience. Faculty were involved in their team’s project from the beginning. Teams had more time to conduct research and weekly faculty guidance from their advisor. These simple steps generally led to stronger project ideas and strong engagement from students.

However, some factors started to emerge that concerned the core faculty. It was still difficult to find meaningful projects that students could accomplish in a single academic year. Multi-year projects, or sub-projects, were difficult to handle since teams completely changed each year. Student engagement started strong, but the junior year is a difficult one. Once other courses started to pick up, student engagement tended to wane. It was during this time that the core faculty noticed something else significant—the faculty advisors had no real engagement with the projects either. These were student projects—not faculty projects or co-developed projects. Faculty were not involved in the selection process in a significant way, and projects were disjointed from year to year. These issues tended to affect both faculty and students from ongoing engagement with the project.

Phase 9: Shifting the Genesis of the Project Idea (2018-2019)

To remedy this lack of engagement, the genesis of project identification was shifted from students to faculty. The belief was that if faculty were engaged, they could motivate students to stay engaged as the semester became more difficult. Faculty could also continue a project from the previous year, providing continuity for themselves and the program as a whole. Faculty could also undertake larger projects, with subsystems developed in different years. Instructors learned from prior years that students want involvement in project selection. So, the core faculty asked, "How might we engage both faculty and students in project selection?"

To make this process work, faculty were first polled for project areas of interest. These project areas were then provided to students during the summer. Students ranked their interest in each of the project areas and were placed on teams accordingly. Thus, both faculty and students were involved in the identification process. The full project discovery mechanism continued in the first 10 weeks of the semester, using the same model as before, but faculty were much more engaged in guiding the project to their areas of interest, all within the context of HCD. Faculty had the power to help steer students to particular areas of interest, and define bounds within which students would still explore the HCD process.

At the time of this writing, this process is nearing the end of its first year of implementation. Initial feedback seems very positive, but some questions are already emerging. What do advisors do when they have a strongly defined problem, or how do teams do the HCD process when the project is already well defined? We will explore these questions in the future.

Analysis of Surveys

As with our previous papers [1], [7], we assessed our students' self-efficacy with engineering design and their perceived influence of service experiences on engineering learning objectives via two validated surveys [4], [5]. Since the fall of 2012, we have annually asked all students in the GFU engineering program to complete the surveys in the first month of the fall semester. Response data is shown in Tables 1 and 2. Student responses were grouped by their year in the program relative to SE:

a. 2 yrs before SE (typically Freshmen)
b. 1 yr before SE (typically Sophomores)
c. Just before SE (Juniors)
d. Just after SE (Seniors)
e. Within one month of Graduation

For both surveys, a multivariate analysis of variance (MANOVA) was used to determine if any significant differences were present between student groups. Once differences were confirmed, a Tukey HSD (Honestly Significant Difference) post hoc analysis was applied to determine between which groups these differences existed. With the addition of three more years of data from our previous paper, we chose to change our threshold for significance from $p < 0.001$ (footnoted in Tables 1 and 2 in each of our papers) to $p < 0.05$. We have indicated any statistically significant differences in the *Pairwise contrast* column of Tables 1 and 2.

We also applied a two-factor MANOVA to the data to determine if any statistical significance existed between student responses at the same time in the program but answering the survey in different years. (For example, was there a statistical difference between sophomores answering survey questions in 2012 and sophomore answering survey questions in 2016?) There were no statistically significant differences for the self-efficacy survey, Wilks' $\Lambda = 0.91$, $F(68, 3256) = 1.18$, $p = 0.15$, $\eta^2 = 0.09$. There were also no statistically significant differences indicated for the influence of service experiences on engineering learning objectives survey, Wilks' $\Lambda = 0.69$, $F(256, 8269) = 1.08$, $p = 0.19$, $\eta^2 = 0.31$.

Engagement with design process

A 36-question, online instrument developed and validated by Carberry, Lee, and Ohland, assesses student self-concept of self-efficacy, motivation, outcome expectancy, and anxiety toward the engineering design process using the following respective questions [4]:

- Rate Your Degree of Confidence (Self-Efficacy)
  (0=cannot do at all; 5=moderately can do;10=highly can do)
- Rate How Motivated You Would Be to Perform the Following Tasks (Motivation)
  (0=not motivated; 5=moderately motivated;10=highly motivated)
- Rate How Successful You Would Be in Performing the Following Tasks (Outcome Exp.)
  (0=cannot expect success at all; 5=moderately expect success; 10=highly certain of success)
- Rate Your Degree of Anxiety In Performing the Following Tasks (Anxiety)
  (0=not anxious at all; 5=moderately anxious; 10=highly anxious)

After each question, the nine tasks ("conduct engineering design," and eight steps in the design cycle [4]) were listed along with a 10-point Likert scale. During the validation process, the instrument developers confirmed that the average of the responses to the eight steps in the design process correlated to the response for "conduct engineering design." The Cronbach's α values for reliability ranged between 0.940 and 0.967 with a mean of 0.957. For the results presented in Table 1, the average of the responses for the eight steps of the design cycle was used. There were 147 female (20%) and 703 male (80%) respondents.

The results of the data analyses presented in Figure 1 and Table 1 indicate that students have higher Motivation to do engineering design after SE. Student response toward engineering

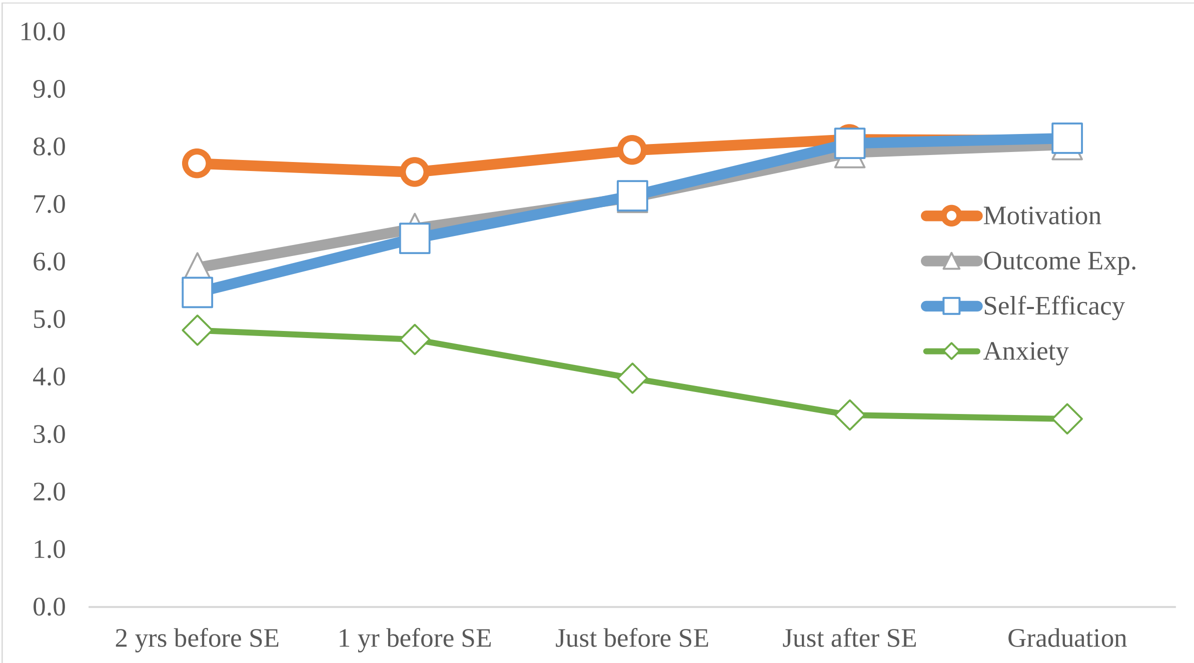

Figure 1: Mean response for each of the engineering design process questions by each year in the program relative to Servant Engineering. Data is from Table 1.

design Self-Efficacy and Outcome Expectancy trended similarly and showed the same statistical significance of increasing each year in the program until their senior year. As for Anxiety, SE seems to be a turning point as students in the two years prior to SE reported their Anxiety was significantly higher than students starting SE, and students in their senior year reported significantly lower Anxiety. There was no significant change in Anxiety from the start of senior year to just before graduation.

Reviewing standard deviations, Motivation (std. dev. ~ 1.3) and Anxiety (std. dev. ~ 2.3) remain relatively constant throughout the program, while Self-Efficacy and Outcome Exp. both decrease similarly throughout the program: from approximately 2.4 to 1.1. These results seem to indicate students are relatively unified in their motivation to do engineering design (as might be expected for students who have chosen it as their major). As for Anxiety, the results seem to indicate that students come to engineering with more variation in their confidence to do engineering design and that this variation in confidence does not change throughout the program. The decrease in standard deviation for Outcome Exp. and Self-Efficacy provides evidence that the engineering program experience is directing students from various levels of confidence to a more unified level of confidence in perform engineering design.

Table 1: Student self-concept of self-efficacy, motivation, outcome expectancy, and anxiety toward the engineering design process. Mean values are plotted in Figure 1.

Factor †	***SE Coding***	***n***	***Mean***	***Std. Dev.***	***Pairwise contrast***
Self-Efficacy	a-2 yrs before SE	188	5.49	2.46	<b, <c, <d, <e
	b-1 yr before SE	151	6.36	1.80	>a, <c, <d, <e
	c-Just before SE	164	7.27	1.16	>a, >b, <d, <e
	d-Just after SE	173	8.04	1.06	>a, >b, >c
	e-Graduation	188	8.15	1.09	>a, >b, >c
	Total	864	7.07	1.92	
Motivation	a-2 yrs before SE	188	7.85	1.41	
	b-1 yr before SE	151	7.52	1.46	<d, <e
	c-Just before SE	164	7.85	1.16	
	d-Just after SE	173	8.13	0.99	>b
	e-Graduation	188	8.11	1.19	>b
	Total	864	7.91	1.28	
Outcome Exp.	a-2 yrs before SE	188	5.96	2.42	<b, <c, <d, <e
	b-1 yr before SE	151	6.53	1.82	>a, <c, <d, <e
	c-Just before SE	164	7.19	1.21	>a, >b, <d, <e
	d-Just after SE	173	7.87	1.07	>a, >b, >c
	e-Graduation	188	8.04	1.17	>a, >b, >c
	Total	864	7.13	1.81	
Anxiety	a-2 yrs before SE	188	4.81	2.47	>c, >d, >e
	b-1 yr before SE	151	4.57	2.31	>d, >e
	c-Just before SE	164	4.01	2.06	<a, >d, >e
	d-Just after SE	173	3.40	2.13	<a, <b, <c
	e-Graduation	188	3.27	2.10	<a, <b, <c
	Total	864	4.01	2.31	

Note. † - Wilks' $\Lambda = 0.66$, $F(16, 2533) = 23.15$, $p < 0.05$, $\eta^2 = 0.34$

Service experiences contribution to learning outcomes

To evaluate the impact of the Servant Engineering experience on technical and professional learning outcomes, a validated instrument developed by Carberry and Swan [5] was given to students. The outcomes evaluated on the instrument include the a-k of ABET's Criterion 3 and learning outcomes from the 2005 report from the National Academy of Engineering Center for the Advancement of Scholarship on Engineering Education. The instrument's authors separated these outcomes into categories based on engineering subject matter knowledge (technical) and personal skills (professional). The Cronbach's α values reported for professional skills (0.910) and technical skills (0.848) indicate high reliability for the two factors. Students evaluated each learning outcome presented in Table 2 on a 10-point Likert scale, where, for example, a 7 indicates 70% of a student's learning derives from coursework and 30% from service experiences. There were 138 female (17.8%) and 637 male (82.2%) respondents.

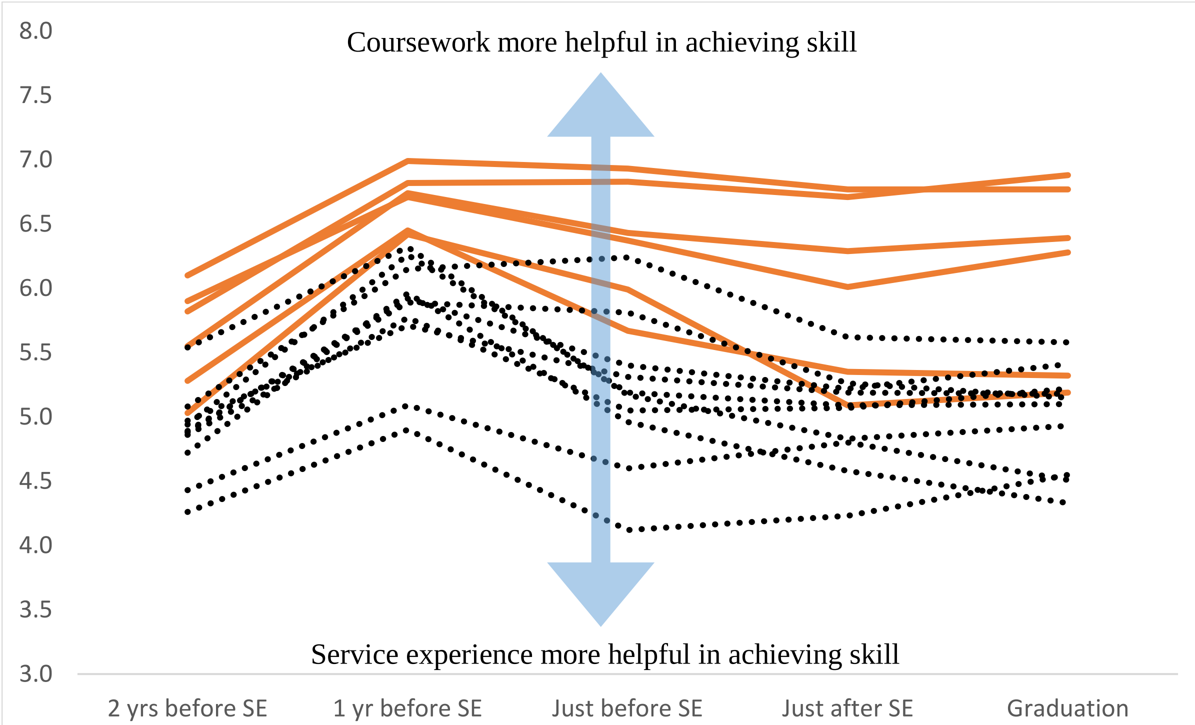

Figure 2: Mean response for each of the technical (solid line) and professional (dotted line) learning objective questions by each year in the program relative to Servant Engineering.

Results of the analysis are presented in Figure 2 and Table 2. Noting the trends shown in Figure 2, all of the student responses shifted toward coursework learning at some point between their first year in the program and the start of SE. The only learning objectives that did not have a statistically significant shift toward coursework learning prior to SE were…

- "Design an experiment" (T)
- "Communicate effectively with others" (P)
- "Function within a team" (P)
- "Engage in critical, reliable, and valid self-assessment" (P)
- "Understand the impact of your engineering design/solution in a societal and global context" (P)

Compared to their responses "Just before SE," none of learning objective responses significantly shifted toward service experiences by graduation.

Note that at graduation, seniors rated all but two of the learning objectives at a statistically similar level as freshmen. They weighted both "Apply math, science, and engineering knowledge" and "Conduct (or simulate) an experiment" more toward coursework than service experiences.

Table 2: Engineering learning outcomes (technical) for each class and statistically significant relationships from a Tukey post hoc analysis. Mean values are plotted in Figure 2. See text for additional information.

Learning Objective†	***P/T***‡	***SE Coding***	***n***	***Mean***	***Std. Dev.***	***Pairwise contrast***
Apply math, science, and engineering knowledge	T	a-2 yrs before SE	120	5.82	2.41	<b, <c, <d, <e
		b-1 yr before SE	137	6.82	2.46	>a
		c-Just before SE	156	6.83	2.23	>a
		d-Just after SE	167	6.71	2.09	>a
		e-Graduation	190	6.88	2.06	>a
		Total	770	6.64	2.27	
Design a system, component, or process to meet desired need	T	a-2 yrs before SE	120	5.28	2.73	<b
		b-1 yr before SE	137	6.45	2.69	>a, >d, >e
		c-Just before SE	156	5.67	2.68	
		d-Just after SE	167	5.35	2.52	<b
		e-Graduation	190	5.32	2.57	<b
		Total	770	5.59	2.65	
Design an experiment	T	a-2 yrs before SE	120	5.90	2.76	
		b-1 yr before SE	137	6.71	2.70	
		c-Just before SE	156	6.37	2.41	
		d-Just after SE	167	6.01	2.61	
		e-Graduation	190	6.28	2.63	
		Total	770	6.25	2.62	
Analyze and interpret data	T	a-2 yrs before SE	120	6.10	2.61	<b, <c
		b-1 yr before SE	137	6.99	2.43	>a
		c-Just before SE	156	6.93	2.22	>a
		d-Just after SE	167	6.77	2.13	
		e-Graduation	190	6.77	2.21	
		Total	770	6.73	2.31	
Apply techniques, skills, and modern engineering tools in practice	T	a-2 yrs before SE	120	5.03	3.07	<b, <c
		b-1 yr before SE	137	6.42	2.89	>a, >d, >e
		c-Just before SE	156	5.99	2.84	>a, >d
		d-Just after SE	167	5.09	2.70	<b, <c
		e-Graduation	190	5.19	2.56	<b
		Total	770	5.53	2.83	
Conduct (or simulate) an experiment	T	a-2 yrs before SE	120	5.55	2.73	<b, <c, <e
		b-1 yr before SE	137	6.74	2.66	>a
		c-Just before SE	156	6.43	2.53	>a
		d-Just after SE	167	6.29	2.27	
		e-Graduation	190	6.39	2.48	>a
		Total	770	6.30	2.54	

Note. † - Wilks' $\Lambda = 0.80$, $F(64, 2837) = 2.63$, $p < 0.05$, $\eta^2 = 0.20$
‡ - *T* = technical skill; *P* = professional skill; (Cronbach's α value)

Table 2 (cont.): Engineering learning outcomes (professional) for each class and statistically significant relationships from a Tukey post hoc analysis. See text for additional information.

Learning Objective	***P/T***	***SE Coding***	***n***	***Mean***	***Std. Dev.***	***Pairwise contrast***
Communicate effectively with others	P	a-2 yrs before SE	120	4.26	2.55	
		b-1 yr before SE	137	4.90	3.15	
		c-Just before SE	156	4.12	2.66	
		d-Just after SE	167	4.23	2.30	
		e-Graduation	190	4.55	2.29	
		Total	770	4.43	2.59	
Operate in the unknown (i.e. open-ended design problems)	P	a-2 yrs before SE	120	4.72	2.83	<b
		b-1 yr before SE	137	5.96	3.00	>a, >c, >d, >e
		c-Just before SE	156	4.96	2.84	<b
		d-Just after SE	167	4.58	2.67	<b
		e-Graduation	190	4.33	2.61	<b
		Total	770	4.87	2.82	
Function within a team	P	a-2 yrs before SE	120	4.43	2.72	
		b-1 yr before SE	137	5.09	2.99	
		c-Just before SE	156	4.60	2.54	
		d-Just after SE	167	4.80	2.47	
		e-Graduation	190	4.51	2.44	
		Total	770	4.69	2.63	
Engage in critical, reliable, and valid self-assessment (i.e. reflection)	P	a-2 yrs before SE	120	4.97	2.26	
		b-1 yr before SE	137	5.71	2.54	
		c-Just before SE	156	5.31	2.44	
		d-Just after SE	167	5.19	2.26	
		e-Graduation	190	5.18	2.16	
		Total	770	5.27	2.33	
Persevere to complete an engineering design task	P	a-2 yrs before SE	120	5.08	2.84	<b, <c
		b-1 yr before SE	137	6.15	2.99	>a
		c-Just before SE	156	6.24	2.61	>a
		d-Just after SE	167	5.62	2.45	
		e-Graduation	190	5.58	2.26	
		Total	770	5.75	2.62	
Maintain a strong work ethic throughout an engineering design project	P	a-2 yrs before SE	120	4.89	2.90	<b, <c
		b-1 yr before SE	137	5.89	3.11	>a
		c-Just before SE	156	5.81	2.81	>a
		d-Just after SE	167	5.26	2.44	
		e-Graduation	190	5.15	2.29	
		Total	770	5.41	2.69	

Table 2 (cont.): Engineering learning outcomes (professional) for each class and statistically significant relationships from a Tukey post hoc analysis. See text for additional information.

Learning Objective	*P/T*	*SE Coding*	*n*	*Mean*	*Std. Dev.*	*Pairwise contrast*
Understand the impact of your engineering design/solution in a societal and global context	P	a-2 yrs before SE	120	5.54	2.63	
		b-1 yr before SE	137	6.32	2.80	>c, >d, >e
		c-Just before SE	156	5.17	2.89	<b
		d-Just after SE	167	4.83	2.58	<b
		e-Graduation	190	4.93	2.49	<b
		Total	770	5.31	2.71	
Identify potential ethical issues and dilemmas of a project	P	a-2 yrs before SE	120	4.94	2.31	<b
		b-1 yr before SE	137	6.26	2.91	>a, >c, >d, >e
		c-Just before SE	156	5.19	2.90	<b
		d-Just after SE	167	5.09	2.60	<b
		e-Graduation	190	5.10	2.43	<b
		Total	770	5.31	2.66	
Knowing what you want to do after graduation (get a job, go to graduate school, etc…)	P	a-2 yrs before SE	120	4.86	2.55	<b
		b-1 yr before SE	137	5.77	2.94	>a
		c-Just before SE	156	5.05	2.81	
		d-Just after SE	167	5.07	2.51	
		e-Graduation	190	5.22	2.40	
		Total	770	5.21	2.65	
Recognize the need for life-long learning	P	a-2 yrs before SE	120	4.88	2.69	<b
		b-1 yr before SE	137	5.92	2.60	>a
		c-Just before SE	156	5.40	2.57	
		d-Just after SE	167	5.22	2.57	
		e-Graduation	190	5.41	2.24	
		Total	770	5.38	2.54	

Conclusion

Since its inception, the Servant Engineering program has gone through multiple iterations. Students participate in a design process that is more akin to what they will experience in industry. Most recently, the addition of a human-centered design module provides a way for students to identify needs and address them appropriately. To support this module, additional faculty involvement and a focus on design exploration have been emphasized.

In every iteration of the SE program, students employed both the engineering design process and professional skills. Completing a two-factor analysis on our survey data from the past seven years, we found statistically significant changes to student responses toward engineering design after their time in SE. However, the difference in student responses from cohort to cohort was not statistically significant after their time in SE. This consistency seems to indicate that SE has provided a valuable learning experience for students regardless of the structure employed. It appears our data continues to support the conclusion from our previous paper: “the benefits obtained from a service-learning experience come from simply *having* that program rather than any particular implementation detail” [7].

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