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Ongoing Development and Evaluation of an Engineering Service Course

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Abstract

George Fox University has a service-learning course required of all engineering program graduates. The course began in 2010 as a one-credit per semester, four-semester sequence starting in the spring of the sophomore year. This structure provided an overlap of students in their first and second year in the course. All student teams met concurrently one evening per week to work on faculty-provided projects. Each faculty member was responsible for approximately four teams. Faculty and students began each year of the program with excitement, but over time, a number of significant challenges emerged, among these the explosive growth of the George Fox University engineering program and its potential effect on the sustainability of the program. Therefore, in this paper we follow-up on our published review of the first few years of the program. Here we discuss the mechanics of these changes and their continuing effect on the overall program.

An increasing number of students necessarily required an increasing number of projects. Faculty had already expressed difficulty in managing four projects and in finding clients with appropriate engineering challenges. Faculty had also recognized that some students lacked motivation to participate in some of the provided projects, especially during their second year of the course. To meet these challenges, the course was restructured as a two-credit per semester, two semester sequence in the junior year. This cut the number of students (and therefore projects) in half. Faculty were generally assigned to oversee one team. Finally, the task of finding projects was given to the incoming juniors who became responsible to propose and present projects for instructor approval.

In addition to describing the evolution of the program, statistical analyses of student perceptions of the design process and the influence of service experiences will be presented. These longitudinal data are used in the evaluation of the program as well as the overall presentation of the design process in the engineering curriculum.

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] presented three years ago, 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.

At the beginning, we partnered with the EPICS program started at Purdue University[2,3] and patterned much of our 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 of the engineering students. The ongoing development of the Servant Engineering program at GFU has taken place in roughly six distinct phases:

- Phase 1: The instructors attempted to mimic the basic format provided to us 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 Servant Engineering program at GFU, re-emphasizing the importance of learning the engineering design process.
- Phase 4: The course was restructured from 4 semesters to 2 semesters
- Phase 5: The responsibility for finding potential projects was shifted to the students.
- Phase 6: The program was codified into a handbook and adjuncts became significantly involved.

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.

Summary of the Phases

Phase 1 (EPICS documentation)

In the spring of 2010, at the beginning of SE, there were 39 students, both sophomores and juniors, working on seven projects. The class was designed as a 1-credit class to be taken in four consecutive semesters beginning in the spring of the sophomore year and culminating the fall of the senior year. This format was chosen in the hopes that it would provide a wider range of student skills (including some seniors) to better complete particular projects and also to provide continuity on projects as students exit the program. The group size for each project ranged from 5-6 students and was purposely multi-disciplinary in their organization. The projects were provided by faculty members to fit into the following four tracks: education outreach, community service, appropriate technology for overseas, and assistive technologies. There were two faculty advisers: one responsible for three groups and the other for four groups. Teams met weekly on Monday nights and industry professionals were invited to come and work with and/or help advise teams.

The project documentation methodology was essentially copied from original EPICS sources.[6] At the time of implementation, these resources involved a design process document, design document template, project management document, and an individual memo. (Note that EPICS has since updated their project management documents.) It should be noted that the EPICS model at Purdue involved a weekly, lecture-style classroom component where much of this content was taught. The Servant Engineering program was implemented in a lab-style environment. Students were expected to learn the design process as part of their service/design experience under the guidance of a faculty member and professionals.

Assessment of the course was provided via open-ended written reflections. Students indicated that the documentation requirements were overwhelming the service and design aspects of the course. In spite of their frustration with the documentation, students indicated that they valued the service aspect of the course.

The instructors' assessment mirrored that of the students. The focus of the course was incorrect. In the pursuit of providing resources to help students not waste time, the instructors felt students spent an exorbitant amount of time documenting rather than engaging in the design process.

Phase 2a (Limited documentation)

Before the beginning of the second semester of Servant Engineering (fall 2010), the instructors decided to scale back on the documentation. The individual memo was streamlined to simply reflect the tasks expected and include a link to documentation supporting what had been accomplished. Furthermore, a new "team meeting" was expected for each project group. Initially, the course met for two hours on Monday evening and students were expected to work for three extra hours during the week. The instructors altered the structure of the three extra hours by requiring students to meet as a team for 1.5 hours at some time during the week (and still perform another 1.5 hours on their own). The end result of these two changes (virtually eliminate the documentation requirements other than a scaled-down individual memo, and introduce the team meetings) made students more accountable for their work and also allowed them to spend more time working and less time documenting. As a result, great progress was made on a number of projects. Both students and faculty advisers were encouraged. However, this was a bit of a mirage.

Phase 2b (Limited effectiveness)

With the start of the third semester of Servant Engineering in the spring of 2011, the course experienced its first transition of personnel—the seniors had moved out and a new group of sophomores joined each project. The class now had 52 students (up from the prior 39) participating. To better utilize each team member, instructors decided that project teams would be reduced to 3-4 students per project, resulting in 8 additional projects. To properly advise the extra projects, two additional instructors were added to the course.

The semester began well as there was a lot of initial excitement from both the students and the instructors continuing from the prior semester. However, as the new semester progressed, the instructors began to experience a significant degree of stress. Managing the projects became more and more difficult as students did not seem to have a clear direction on what they were doing. Some of the original projects continued performing well, but others began to flounder, and the newer projects seemed to have a difficult time getting underway. The students still seemed engaged and were working hard—in fact, they felt that they were making progress. However, as the instructors began to probe deeper into the workings of different projects, it became clear that the students were eager to purchase parts and build solutions for problems that did not necessarily match the original intent.

As the semester came to a conclusion, it was evident that something needed to change. The freedom that the students received from the lighter documentation load resulted in a wild, yet uncontrolled frenzy of activity. The instructors recognized that it was not the freedom of the second semester that produced some great results, but the foundation laid by the drudgery of the first semester's documentation work that forced students to engage with the details of the engineering design cycle—specifically the problem definitions and specifications. Spending time committing these areas to print and having the team and project adviser iterate over the details, put the teams on a proper course. At the conclusion of the third semester, the projects were off course and something needed to change.

Phase 3 (Google Apps documentation)

To solve the issues of limited documentation and structure that existed at the end of Phase 2, the instructors attempted to craft a system that would both serve the unique needs of the program, yet reengage much of the structure that the EPICS' resources had set in place during Phase 1. The instructors were still very concerned about reducing the documentation burden on both students and themselves, while still providing a mechanism whereby a project adviser could rapidly assess the state of a given project.

"Design document"

To provide the overall project management, a Google Site template was developed with a bulleted item format to guide students through each phase of the design process. The online nature of the site provided a location for convenient links back to a shared Google Collection (folder) with both Google-based documents/spreadsheets (which allow for easy collaboration) and other documentation (drawings, legacy documents, etc.).

Individual memo and Project management

Due to the generation of paperwork for the individual memos as well as the need for group-level evaluation, the instructors sought a convenient and robust online tool to support the course documentation. The implementation of the Google Apps platform, recently adopted by the university, provided several benefits. The documentation experience significantly improved for both students and instructors, as the Google Apps platform required only one sign-in for the various documentation tools and avoided the need for uploading/downloading Microsoft Word documents. The ability to discriminately share documents and sites was a key feature and was further simplified by making Google Groups for both the students in the course and the instructors. (The Groups feature allowed for ease in maintaining the appropriate sharing while cycling students in and out of the program).

Each group received a "Reporting Form" (a single Google Spreadsheet) that included tabs for a Gantt chart of the overall project progress, weekly group-level tasks, and weekly team member tasks. The sheets for group and team member tasks include columns for hours worked, percentage of task progress, reference links to a design notebook and other work, and instructor feedback. In addition, at the top of each team member sheet, a link to that team member's "Assessment Form" was provided. The instructors had recognized, mainly from student comments, that the course structure did not provide students with feedback on their academic progress. The Assessment Form provides students with an instructor's "letter grade" and additional notes of their progress on a weekly basis. The grade is evaluated based on a rubric from EPICS.

During Phase 3, surveys were given to students with exposure to the SE program to evaluate the effectiveness of the service-based learning. The surveys focused on student engagement with the engineering design process and the impact of service learning experiences on achieving engineering learning objectives. Overall, students showed increased confidence in the design process only after the first year in the program. For the engineering learning objectives survey, students indicated that service-based learning provided more influence in their achievement of professional outcomes than technical outcomes. An analysis of these surveys were presented in our first paper.[1]

The Essays

At the end of spring 2012, students were asked to submit a short essay that detailed three things they would change about SE. Fifty students responded. The significant results of these essays were collected and the statements were categorized into the following topic areas:

1. Course load - over half of the students identified an issue with some aspect of how the course was loaded. The corporate meeting time was too long and the amount of course credit was not high enough for the amount of work expected.
2. Projects - Almost half of the students stated issues with the particular projects. They felt that the projects were not matched well with their areas of interest of particular skill sets.
3. Documentation - 40% of the students expressed frustration with the documentation. These frustrations included the expected "too much paperwork," but they also indicated the desire for more help with the documentation and the desire to provide better documentation.
4. Oversight - 40% of the students expressed a desire for more oversight on their project—either from the professionals coming to help, or the faculty members. Another aspect included here was the desire for better communication with the clients, again, echoing the need to better understand their specific task.

The instructors of the course had expressed similar concerns, but for slightly different reasons. The current SE model included all of the students from two separate years in the engineering program—essentially including half of the entire engineering program in this one particular course. With a first-year population of 73 students in 2013, the Servant Engineering instructors knew that the coming number of students would soon outpace the number of quality projects that they could provide and would also overwhelm their ability to manage these projects. After careful reading of student essays and much deliberation, the instructors implemented some rather sweeping changes in the format of SE.

Phase 4 (Juniors-only 2012-13)

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. This had the obvious effect of also cutting the number of teams in half and thus, the number of projects.

At the same time, the common Monday night meeting schedule was changed. In the past, Monday night had been reserved for compulsory weekly corporate meetings. In Phase 4, only the first and last Monday nights of the semester were planned for orientation and presentations, respectively. Throughout the semester, students spent three hours each week on SE. Then, for one hour they would meet with their advisor to present the work they had completed, ask questions, and receive feedback. If time remained, they would plan the following week's work. Unlike in the past, this meeting could occur any time during the week when all participants could attend. This allowed instructors to have more direct oversight over their SE teams. Faculty were also limited to no more than two teams at a time. These changes were not without concern. Two of the initial "pillars" of the SE program were eliminated—the idea of overlapping student teams and the chance for students to work with professionals at the Monday night meetings. The expectation was that the oversight provided by direct faculty engagement with a team and quality time spent with that team would provide more continuity and leadership than had been provided in the past.

Feedback from these changes were tremendously positive. Students had more and better dedicated attention from their advisors, and advisors were better able to stay up on where a given project was at in the design cycle. The flexibility of the meeting time limited evening sessions and allowed some students to take a class that typically met at the same time as SE on Monday evenings. Faculty did not notice a discernible effect in student work when moving from the 2-year model to the 1-year model. Yet, they did recognize that by advising a limited number of projects (two at the most), continuity for multi-year projects was maintained, which the student overlap in the 2-year model had previously provided.

However, there was still concern being expressed by students and faculty about the quality of projects and students' desire to work on projects to which they were assigned. One approach postulated was to assign students the task of finding projects. There were deliberations about the potential effectiveness of such an idea, but all theoretical discussion was abandoned and the faculty opted for a more empirical approach. It was decided that in the following year, students would take the responsibility of obtaining SE projects.

Phase 5: Student Proposed Projects (2013-14)

At the end of the 2013 spring semester, the SE teams gave a presentation regarding their project progress and whether or not that project would need to be continued in the following year. All sophomores were required to attend these presentations to get a feel for the type of projects that had been done and to become aware of ones that might be ongoing. At the end of the presentations, students were charged with finding potential projects over the summer. A project proposal would need to be cleared by a faculty member as a "potential" project. Each proposal could be sponsored by 1-4 students and every student was required to be part of at least one proposal. Existing projects could be proposed, but only by one group (whichever proposing group was accepted by the faculty advisor for that project). Students were allowed to submit more than one proposal.

At the beginning of the fall semester, each of these proposal teams presented their proposals to the SE faculty. During the proposal presentations all of the instructors sat in the audience and each group was given a specified time to present. Students were to follow the methods used in the O'Reilly Ignite conferences.[7] These are five minute presentations, 20 slides, 15 seconds per slide, with the slides set to auto-advance. This kept presentations short and ensured that students practiced and would not take more than five minutes. Students were encouraged to not tell a story but to sell the idea of a project. It needed to be professional, introduce the problem, talk about existing solutions or approaches to the problem, talk about the general idea, why the proposed solution is different/unique, and give a basic plan for what the team hopes to achieve during their year of SE (knowing that the full solution could go well beyond a single year). In addition to the five minutes for the presentation, teams had an additional five minutes for setup/tear down. Each team formed outside of the classroom until called on. This was done so that they faculty could have some discussion in between each presentation.

This presentation format maintained a consistent pace through all the presentations making them engaging enough for the instructors to sit through 13 straight. Unfortunately, the five minutes for setup/tear down was not enough for each team to set up their computer and for the instructors to have discussions on each project. As a result, it was noted that future project proposal talks would require teams to submit their presentations ahead of time so that they could be pre-loaded onto the same computer prior to the presentation meeting.

The faculty determined which proposals would be accepted based on the quality of the proposal, its viability, its compatibility with the mission of SE, and its fit with a faculty adviser. Students whose projects were not selected were distributed among the other teams by the SE faculty.

This method worked surprisingly well. Some of the proposals were continuations of existing projects. Other proposals came from students involved with a local service organization, students with contacts in another country with a need, or inquiries to the program from various sources that instructors had passed on to students.

Another key addition during this phase was the implementation of CATME[8] to provide more quantitative feedback on individual contributions. In the past, instructors were making individual contributions and teamwork evaluation in conjunction with work produced. To focus in on the development of teamwork qualities, CATME provided numerical-based feedback on how team members were performing. In addition, students were notified that all members of a team would be given an initial grade based on the overall team progress on the project. That team score could then be altered positively or negatively by the results of the CATME surveys. During this inaugural run, surveys were generated for students to complete every month.

At the end of the fall and spring semester, SE teams presented their work. Presentations were given in the same Ignite style as their proposals at the beginning of the academic year. Again, sophomores were required to attend the spring presentations in order to see what kind of projects were done and to give them ideas for projects to propose in the fall.

The faculty believed that quality of the projects improved, as they tended to be more doable projects. They may have been less challenging, but they were more appropriate for juniors to complete in one year. We believe the key variable in this process is that the "shark tank" vets projects so that we find sufficiently challenging projects. Also, finding projects like this removes the need to have students on a project for multiple years and neutralizes the benefit of the cohort overlap.

Phase 6: Refining Process / Inclusion of Adjuncts (2014-15)

As the engineering program has continued to grow, the need for more faculty necessitated the hiring of some adjunct professors. This was an effective way to reintegrate professionals into the program and provide more outside contact with our engineering students. However, the larger number of faculty made it more difficult to provide consistency between projects. During the summer 2014, a SE handbook was created to provide students and new instructors with comprehensive instructions about every aspect of SE. Each aspect of the program was clearly identified, including the schedule, mission, time expectations, assessment criteria, how to conduct meetings, individual vs. team responsibilities, project reporting, purchasing instructions, instructions on how to give presentations, poster guidelines, and templates for all documentations. Additionally, all of the information regarding developing and submitting a project proposal were included so that the handbook could be used by sophomores before entering the program.

The manual has proven very effective for the professors and adjuncts in the program. That said, by the end of the fall semester, it was clear that students were not referring to the manual when they had questions or they were just preparing presentations and/or documents that did not meet the guidelines set forth in the manual. As a result, a driver's license-like quiz on the manual's content will be created, and students will need to pass it before being considered for a passing grade.

Due to feedback from students, the frequency of CATME surveys was decreased from each month to twice a semester—once at the mid-term and again at the end of the semester.

Analysis of Surveys

As with our previous paper, we used two surveys to assess student self-efficacy with engineering design and their perceived influence of service experiences on engineering learning objectives. Since the fall of 2012, all students in the GFU engineering program have completed the surveys in the first month of the fall semester each year they are in the program. 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. During SE (Juniors)

e. Just after SE (Seniors)
f. At graduation

A multivariate analysis of variance (MANOVA) was used to determine if any significant differences were present between student groups for both surveys. Once differences were confirmed, a Tukey HSD (Honestly Significant Difference) post hoc analysis was applied to determine between which groups these differences existed.

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 the surveys' questions in 2012 and sophomore answering the surveys' questions in 2013?) The Wilks' Lambda indicated no statistically significant differences between students taking either survey in different years.

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

Factor†	***SE Coding***	***Mean***	***Std. Deviation***	***Pairwise contrast***
Self-Efficacy	a-2 yrs before SE	5.6	2.4	<b, <c, <d, <e, <f
	b-1 yr before SE	6.6	1.6	>a, <e, <f
	c-Just before SE	6.8	1.8	>a, <e, <f
	d-During SE	7.4	1.3	>a
	e-Just after SE	8.0	1.2	>a, >b, >c
	f-Graduation	8.1	1.1	>a, >b, >c
	Total	6.9	2.0	
Motivation	a-2 yrs before SE	7.3	1.8	<e
	b-1 yr before SE	7.6	1.3	
	c-Just before SE	7.8	1.6	
	d-During SE	7.8	1.1	
	e-Just after SE	8.1	1.3	>a
	f-Graduation	8.0	1.4	
	Total	7.7	1.5	
Outcome Exp.	a-2 yrs before SE	6.0	2.3	<b, <c, <d, <e, <f
	b-1 yr before SE	6.8	1.7	>a, <e, <f
	c-Just before SE	6.8	1.8	>a, <e, <f
	d-During SE	7.4	1.3	>a
	e-Just after SE	7.9	1.2	>a, >b, >c
	f-Graduation	8.1	1.1	>a, >b, >c
	Total	7.0	1.9	
Anxiety	a-2 yrs before SE	4.9	2.3	<c, <d, <e, <f
	b-1 yr before SE	4.6	2.0	>d, >e
	c-Just before SE	3.9	2.3	<a, >e
	d-During SE	3.1	2.0	>a, >b
	e-Just after SE	3.0	1.9	>a, >b, >c
	f-Graduation	3.4	2.4	<a
	Total	3.9	2.3	

Note. † - Wilks' Lambda = .788, $F(20, 1520) = 5.66$, $p < .001$

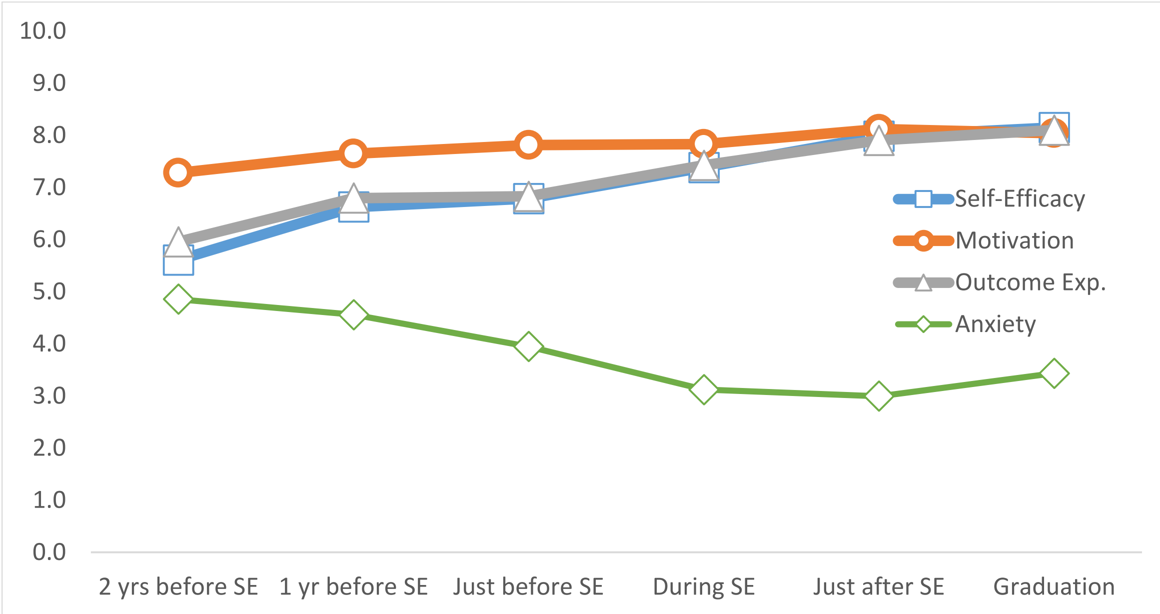

Figure 1: Mean response for each of the engineering design process questions by each year in the program relative to Servant Engineering. Data is from Table 1.

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. In the validation of the instrument, 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. For a-2 yrs from SE through f-Graduation, the number of respondents were 111, 74, 91, 70, 85, and 41, respectively, for a total of 472. There were 79 female (16.7%) and 393 male (83.3%) respondents.

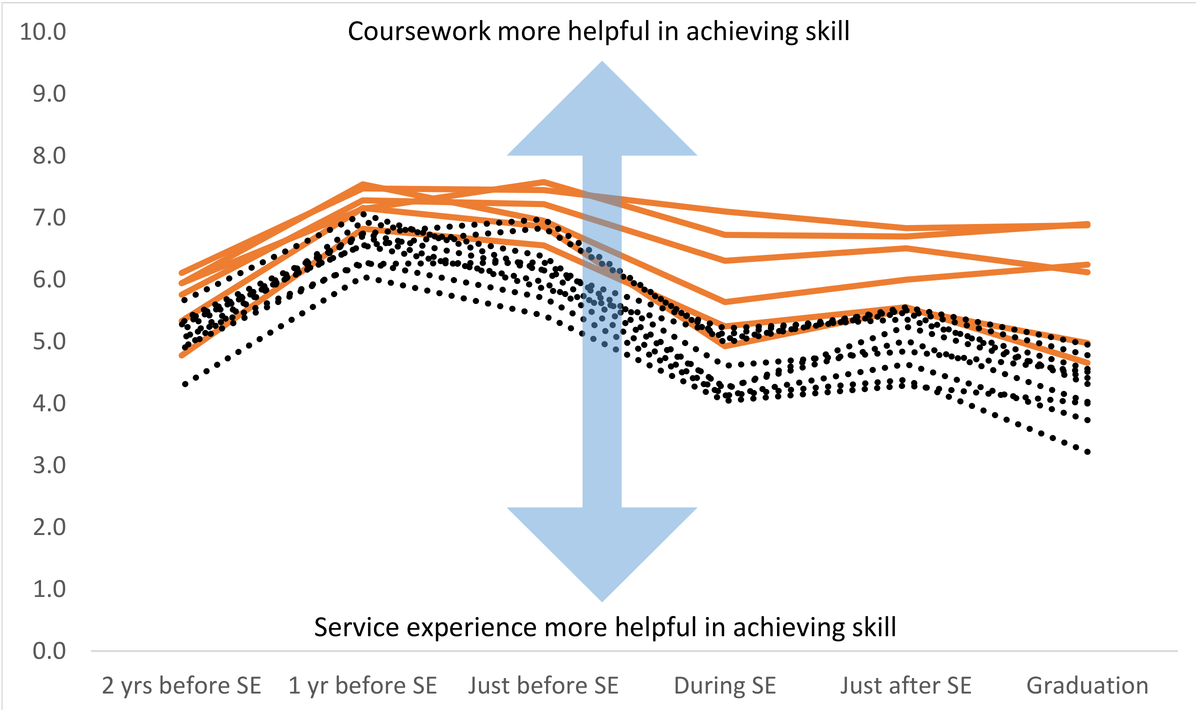

Figure 2: Mean response for each of the technical (solid line) and professional (dotted line) learning objective questions by each year in the program relative to Servant Engineering.

The results of the data analyses presented in Figure 1 and Table 1 indicate that overall, students remained consistently motivated toward engineering design with only students starting their senior year showing a significantly higher motivation than 1st year students. Student response toward engineering design self-efficacy and outcome exp. trended very similarly and showed the same statistical significance between each year in the program. The start of the junior year (and possibly SE) seemed to be a turning point for increased confidence in engineering design. As for Anxiety, a turning point occurs during the junior year when students reported less anxiety toward engineering design than in the two years prior to SE and at the start of junior year.

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 was given.[5] 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 were reported for professional skills (0.910) and technical skills (0.848) indicating high reliability for the two factors. Students evaluated each learning outcome presented in Table 2 on a 10-point Likert scale, where a 7 indicates 70% of a student's learning derives from coursework and 30% from service experiences. For a-2 yrs from SE through f-Graduation, the number of respondents were 53, 63, 85, 69, 83, and 41, respectively, for a total of 394. There were 61 female (15.5%) and 333 male (84.5%) respondents.

Results of the analysis are presented in Figure 2 and Table 2. Noting the trends shown in Figure 2, sophomores and juniors (prior to taking SE) show a clear shift for all the objectives from “2 yrs before SE” toward coursework learning. We believe this shift is due to the fact that most students who are “2 yrs before SE” are first-year students and they are ignorant of the engineering experience. For their first two years in the engineering program, all of their learning experiences in the program come through coursework. Then, once they are finished with SE, for all technical objectives, students remain at statistically similar levels except for “Design a system, component, or process to meet desired need” and “Apply techniques, skills, and modern engineering tools in practice” for which they shift back toward service experiences by graduation. After students are finished with SE or by graduation, they have a statistically significant shift toward service experiences for all professional objectives.

Note that graduating students rated all but one of the learning objectives at a similar level as freshmen. The only learning objective graduating students rated with a statistical significance toward service experiences was “Operate in the unknown”.

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

Learning Objective[†]	***P/T***[‡]	***SE Coding***	***Mean***	***Std. Deviation***	***Pairwise contrast***
Apply math science and engineering knowledge	T	a-2 yrs before SE	5.9	2.4	<c
		b-1 yr before SE	7.1	2.3	
		c-Just before SE	7.6	2.6	>a
		d-During SE	6.7	2.6	
		e-Just after SE	6.7	2.2	
		f-Graduation	6.9	1.9	
		Total	6.9	2.4	
Design a system, component, or process to meet desired need	T	a-2 yrs before SE	5.3	2.8	<b, <c
		b-1 yr before SE	7.2	2.6	>a, > d, >e, >f
		c-Just before SE	6.9	2.9	>a, > d, >e, >f
		d-During SE	4.9	2.6	<b, <c
		e-Just after SE	5.5	2.6	<b, <c
		f-Graduation	5.0	2.6	<b, <c
		Total	5.9	2.8	
Design an experiment	T	a-2 yrs before SE	5.9	2.7	<b
		b-1 yr before SE	7.5	2.4	>a, >d, >e
		c-Just before SE	7.0	3.1	>d
		d-During SE	5.6	2.8	<b, <c
		e-Just after SE	6.0	2.6	<b
		f-Graduation	6.2	2.6	
		Total	6.4	2.8	
Analyze and interpret data	T	a-2 yrs before SE	6.1	2.5	<b, <c
		b-1 yr before SE	7.5	2.1	>a
		c-Just before SE	7.4	2.7	>a
		d-During SE	7.1	2.0	
		e-Just after SE	6.8	2.4	
		f-Graduation	6.9	2.1	
		Total	7.0	2.4	
Apply techniques, skills, and modern engineering tools in practice	T	a-2 yrs before SE	4.8	3.1	<b, <c
		b-1 yr before SE	6.8	2.8	>a, >d, >f
		c-Just before SE	6.6	3.1	>a, >f
		d-During SE	5.2	2.7	<b
		e-Just after SE	5.6	2.7	
		f-Graduation	4.7	2.7	<b, <c
		Total	5.7	3.0	
Conduct (or simulate) an experiment	T	a-2 yrs before SE	5.8	3.0	<b, <c
		b-1 yr before SE	7.3	2.4	>a
		c-Just before SE	7.2	3.0	>a
		d-During SE	6.3	2.6	
		e-Just after SE	6.5	2.3	
		f-Graduation	6.1	3.0	
		Total	6.6	2.7	

Note. [†] - Wilks' Lambda = .712, $F(80, 1770) = 1.62$, $p = .001$
[‡] - *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***	***Mean***	***Std. Deviation***	***Pairwise contrast***
Communicate effectively with others	P	a-2 yrs before SE	4.3	2.3	<b
		b-1 yr before SE	6.0	2.9	>a, > d, >e, >f
		c-Just before SE	5.4	3.2	>d
		d-During SE	4.0	2.5	<b, <c
		e-Just after SE	4.3	2.4	<b
		f-Graduation	4.0	2.5	<b
		Total	4.7	2.8	
Operate in the unknown (i.e. open-ended design problems)	P	a-2 yrs before SE	5.3	2.9	>f
		b-1 yr before SE	6.6	2.7	>d, >e, >f
		c-Just before SE	6.0	3.2	>d, >e, >f
		d-During SE	4.1	2.7	<b, <c
		e-Just after SE	4.4	2.7	<b, <c
		f-Graduation	3.2	2.6	<a, <b, <c
		Total	5.0	3.0	
Function within a team	P	a-2 yrs before SE	4.9	2.7	
		b-1 yr before SE	6.3	2.9	>d, >e, >f
		c-Just before SE	5.7	3.0	>d, >f
		d-During SE	4.1	2.4	<b, <c
		e-Just after SE	4.6	2.7	<b
		f-Graduation	3.7	2.6	<b, <c
		Total	5.0	2.9	
Engage in critical, reliable, and valid self-assessment (i.e. reflection)	P	a-2 yrs before SE	5.0	2.3	
		b-1 yr before SE	6.3	2.6	>d, >e, >f
		c-Just before SE	6.3	3.0	>d, >e, >f
		d-During SE	4.6	2.7	<b, <c
		e-Just after SE	4.8	2.5	<b, <c
		f-Graduation	4.5	2.3	<b, <c
		Total	5.3	2.7	
Persevere to complete an engineering design task	P	a-2 yrs before SE	5.2	2.7	<b, <c
		b-1 yr before SE	6.7	2.9	>a, > d, >f
		c-Just before SE	7.0	3.0	>a, > d, >e, >f
		d-During SE	5.0	2.6	<b, <c
		e-Just after SE	5.6	2.5	<c
		f-Graduation	5.0	2.4	<b, <c
		Total	5.8	2.8	

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***	***Mean***	***Std. Deviation***	***Pairwise contrast***
Maintain a strong work ethic throughout an engineering design project	P	a-2 yrs before SE	5.3	3.1	<c
		b-1 yr before SE	6.6	2.9	>d, >f
		c-Just before SE	6.8	3.0	>a, > d, >e, >f
		d-During SE	5.0	2.6	<b, <c
		e-Just after SE	5.5	2.3	<c
		f-Graduation	4.3	2.7	<b, <c
		Total	5.7	2.9	
Understand the impact of your engineering design/solution in a societal and global context	P	a-2 yrs before SE	5.6	2.4	
		b-1 yr before SE	7.1	2.5	>d, >e, >f
		c-Just before SE	6.2	3.4	>d, >f
		d-During SE	4.3	2.8	<b, <c
		e-Just after SE	5.0	2.8	<b
		f-Graduation	4.0	2.6	<b, <c
		Total	5.4	3.0	
Identify potential ethical issues and dilemmas of a project	P	a-2 yrs before SE	4.9	2.4	<b, <c
		b-1 yr before SE	6.9	2.5	>a, > d, >e, >f
		c-Just before SE	6.4	3.3	>a, >d, >f
		d-During SE	4.2	2.6	<b, <c
		e-Just after SE	5.2	2.8	<b
		f-Graduation	4.4	2.5	<b, <c
		Total	5.4	2.9	
Knowing what you want to do after graduation (get a job, go to graduate school, etc…)	P	a-2 yrs before SE	5.0	2.6	<b
		b-1 yr before SE	6.7	2.8	>a, > d, >e, >f
		c-Just before SE	6.2	3.0	>f
		d-During SE	5.2	2.7	<b
		e-Just after SE	5.4	2.6	<b
		f-Graduation	4.6	2.6	<b, <c
		Total	5.6	2.8	
Recognize the need for life-long learning	P	a-2 yrs before SE	5.4	2.6	
		b-1 yr before SE	6.7	2.5	>d, >f
		c-Just before SE	5.9	3.1	
		d-During SE	5.1	2.4	<b
		e-Just after SE	5.5	2.4	
		f-Graduation	4.8	2.5	<b
		Total	5.6	2.7	

Conclusion

From the surveys, we can see two main, overarching results of SE and the engineering program as a whole. Throughout all the changes that occurred in SE, students' self-reported views on their self-concepts toward engineering design and the value of coursework vs. service experiences did not show any change that was statistically significant. Therefore, in spite of some significant changes to the structure and the personnel involved, students continued to show improvement in their perception of engineering design and maintained a balanced view toward the value of learning gained from coursework and service experiences.

And as the learning objective results showed, students enter and exit the engineering program with a relatively balanced view of the learning gained from coursework and service experiences. This seems reasonable because of the existence of SE in the GFU engineering program. Future analysis could be done on similar programs where a SE program either does not exist or it is integrated in a different way.

Over the past five years, the SE program has gone through a myriad of changes. It has seen a variety of documentation and reporting methodologies. It has moved from corporate grouped meetings to local team meetings. It has moved from a model of multiple teams per adviser to a strict limit on teams advised and limited professional involvement. It has moved from faculty finding projects to students finding projects. It has moved from a four semester sequence to a two semester sequence. It has gone from a one credit per semester course to a two credit per semester course. It has gone from a sophomores, juniors, and seniors in overlapping cohorts to juniors without overlap. It has gone from a more ad-hoc administration methodology to a highly structured experience. And through all of these changes the data has shown no statistically significant change in how students self-report their self-concept toward engineering design and how they achieved learning objectives.

Additionally, the results of the surveys increase our confidence that any future changes to the program will 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.

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