AC 2012-4404: IMPACTS OF SERVICE ON ENGINEERING STUDENTS

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Impacts of Service on Engineering Students

Abstract
This paper presents preliminary findings of a longitudinal study in which undergraduate engineering students are evaluated to better understand the effects of service on engineering education. Two student clusters were assembled from freshmen and juniors, with sub-cohorts derived from students engaged in curricular, extracurricular, both, or no learning through service (LTS) experiences. Participating students were recruited from four institutions: small private, medium public, small technical, and large public universities. A fifth pool was comprised of students engaged in Engineers Without Borders – USA at more than twenty universities across the nation. Participants were randomly assigned to one of two methodological groups: (1) online survey of 150 questions (n=254), or (2) online survey plus 30 minute interview (n=120). Participation is planned for three years, biannually; this paper shares some findings from the first year, Spring and Fall 2011. The online survey collected demographic information along with a self-assessment on several topics: self-efficacy, motivation, satisfaction, retention, engineer identity, attitudes on learning, cultural competency, mindset, and well-being. The interview followed similar themes, but allowed greater depth of understanding students’ perceptions and experiences. Gender demographic analysis reveals that extracurricular LTS is comprised of 50% males and 50% females, curricular LTS is 77% males and 23% females, Both LTS is 56% males and 44% females, and No LTS is 69% males and 31% females. Service clearly attracts women. The paper further details early comparisons among the cohorts using the quantitative analysis of all survey participants, supplemented with commentary from early interview analyses.

1. Introduction
Over the last few years, concerns have escalated among many national organizations that technical expertise is no longer solely sufficient for the development of future engineers. Additionally, in the United States engineering programs continue to struggle to attract students, especially women and minorities, despite decades of strategies to change these patterns. The need for a “paradigm shift” is recognized; one that broadens the attributes provided by engineering education, as well as the diversity of those who participate in, and benefit from, it. In many quarters, engineering education has recently discovered the contributions of Learning Through Service (LTS). This awareness has often come obliquely with some of the most engaging LTS opportunities originating outside academia. For example, since 2002, students in more than half the nation’s engineering colleges (190 universities to date) have started chapters of Engineers Without Borders-USA in order to serve developing communities through project work. There are few, if any, other such dramatic and widespread movements within engineering education, yet, with such a rapid change, a thorough understanding of best practices and outcomes, beneficial and otherwise, are lagging. Evidence does exist suggesting the value that LTS efforts provide to engineers, but it is usually limited to evaluations from one-time or short-term efforts. How service efforts affect the developmental processes of engineering students requires a coordinated, comprehensive, and longer-term examination.

This project is the first step in the desired long-term examination. The project is aimed at evaluating how attributes of future engineers are obtained through LTS and how these attributes
develop over the time of undergraduate education. The intellectual merit of this proposed project is that the study will add to the growing body of evidence that LTS has a positive benefit on an engineer’s ability and desire to learn, particularly engineers from underrepresented groups. Furthermore, the broader impacts of this study will provide evidence that service-based methodologies, as a pedagogical strategy, enhances learning and other attributes such as self-efficacy, identity, epistemology, and general well-being for all students.

The evaluation consists of a sequential, but staggered longitudinal study of engineering students at various institutions that have LTS programs – both curricular and extracurricular. We are exploring the impacts of LTS on engineering students’ learning; specifically related to traditional technical attributes (e.g., ABET Criteria 3a-e) as well as a mix of non-technical attributes (e.g. global awareness, social context of problems, self-efficacy, identity, civic development, intercultural sensitivity, and psychosocial well-being); along the way, much needed information on recruitment, interest and persistence is being gathered. A secondary purpose (broader impact) is to understand how LTS in engineering education can be utilized as a strategic component of the “paradigm shift” needed to broaden the attributes from, accessibility to, and interest in engineering education.

2. Methods

In brief, the research effort consists of a longitudinal study performed at four target institutions: a small private (SPr), a mid-sized public (MPu), a large public (LPu), and mid-sized technical (ST) universities. These institutions are diverse in size, type, mission, and student socio-economic conditions, in addition to the size of engineering programs (Figure 1). In addition to their academic cultural differences, these institutions have experience with the integration of LTS in their curricular and extracurricular activities, as well as the presence of strong LTS faculty champions.

Figure 1. Target schools for this study; SPr, MPu, LPu, and ST (small private, mid-sized public, large public, and small technical universities, respectively) provide a diversity of campus cultures, as illustrated by undergraduate and graduate engineering enrollments.
2.1 Participants
At each institution, three different cohorts are followed – students in extracurricular LTS, students who participate in an LTS course/program (curricular LTS), and a control group of students not involved in LTS efforts. These cohorts take semi-annual surveys (quantitative measures) and annual interviews (qualitative measures) during the project’s three-year duration which began in Spring 2011. Within each cohort, a subset were randomly chosen to become interview subjects for the study. Two staggered clusters of student cohorts; one a first-year cluster (followed for three years to their junior year) and the other a junior-year cluster (followed through post-graduation) are followed. In all, 254 students have volunteered for the study and will be followed over the three-year project duration for the previously-noted attributes with results used to evaluate the impact of LTS from multiple perspectives (e.g., student experience, location, program/course and institution types).

Students are associated with their cohort at the commencement of the study regardless of their pathway forward; cohort composition will remain unchanged throughout the study (other than through attrition due to non-responsive participants). Students that leave the university will still be tracked, if possible. If participants become non-responsive after repeated contact, the student will be replaced with another (similar class level) to ensure cohorts remain adequately sized.

2.2 Research Design
Service-based pedagogical methods affect multiple stakeholders – students, faculty, academic institutions and the community partners. Our assessment efforts focuses on students, though other stakeholders will influence their efforts. As such, our instruments are structured so that effects from other stakeholders on the development of measured attributes can be taken into account.

2.3 Measures
A mixed-methods approach is used to allow triangulation of results that enables us to 1) minimize the disadvantages inherent in all types of methods, and 2) use different methods to understand the complexities of social phenomenon. In our effort, surveys (a quantitative method) and interviews (a qualitative method) will be combined along with traditional metrics, such as class assignments and grades. As noted earlier, surveys will be administered to all students with only a subset (25%) to be interviewed. Table 1 shows the assessment measures used for the three-quarters taking only the surveys (survey group) and the one-quarter taking the survey and being interviewed (interview group). The assessment protocol requires approximately 30 or 90 minutes of commitment per assessment round for the “surveyed” and “interviewed” students, respectively.
Table 1. Assessment methods used as identified below, for both student focus groups (surveyed, or interviewed)

<table>
<thead>
<tr>
<th>Surveyed Students</th>
<th>Interviewed Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.) Demographics</td>
<td>1.) Demographics</td>
</tr>
<tr>
<td>2.) Self-efficacy</td>
<td>2.) Self-efficacy</td>
</tr>
<tr>
<td>3.) Attitudes toward learning</td>
<td>3.) Attitudes toward learning</td>
</tr>
<tr>
<td>4.) Engineering learning outcomes</td>
<td>4.) Engineering learning outcomes</td>
</tr>
<tr>
<td>5.) Well-being</td>
<td>5.) Well-being</td>
</tr>
<tr>
<td>6.) Mindset</td>
<td>6.) Mindset</td>
</tr>
<tr>
<td>7.) Work and life</td>
<td>7.) Work and life</td>
</tr>
<tr>
<td></td>
<td>8.) Engineer identity</td>
</tr>
<tr>
<td></td>
<td>9.) Intercultural competency</td>
</tr>
</tbody>
</table>

2.4 Procedure

As mentioned in Table 1, we seek to address the following indicators to give us insight into the impacts of LTS:

(1) Demographics: while others are monitored, critical features in this paper include LTS participation, gender, year of study, and major discipline.

(2) Increased self-efficacy: During this effort, we assess student self-efficacy, motivation, and retention rates over time, and examine differences as a result of participating in LTS experiences. Self-efficacy and motivation will be evaluated through a survey based on a recent model for engineering design self-efficacy\(^{18}\). As the evaluation is performed repeatedly over the three-year project duration, we will have the ability to measure retention in engineering disciplines and university education over time. We will pay particular attention to those underrepresented in engineering (i.e., women and minorities). As a summative measure of these indicators, graduating students will also be surveyed for graduation rates (by the fifth year of academic study) and post-baccalaureate activity (e.g. employment, graduate school, type of discipline/employer/work).

(3) Improved attitude towards learning and performance: We investigate engineering students’ perceived attitudes towards learning and performance using the Attitudes Towards Learning (ATL) scale, available through the Center of Assessment and Research Studies at James Madison University\(^{19}\). This 16-item questionnaire evaluates whether respondents follow performance-driven or mastery-driven goals toward academic achievement. The instrument will be administered semiannually to “surveyed” and “interviewed” groups.
(4) Engineering learning outcomes: During this effort, we use an existing instrument (National Engineering Students’ Learning Outcomes Survey – NESLOS) that was developed by Pierrakos and extensively used to measure students’ perceived learning outcomes during a variety of learning experiences\(^\text{20-22}\). NESLOS was derived from extensive STEM education literature as well as ABET criteria 3a-k. This validated instrument has been used to assess students’ learning outcomes and skill gains as a result of participating in undergraduate research, industry internships (co-ops), and capstone design experiences. To date about 800 students have participated in the use of this instrument which includes over fifty learning outcomes pertinent to problem identification, the application of scientific tools, experimentation, analysis and evaluation, ethical and societal issues, project management, team and communication skills, improved attitudes, and other professional skills. Semi-annually, as well as at the beginning and end of LTS experiences, NESLOS will be administered to engineering students as a means of measuring learning outcome and skill gains. It is anticipated that NESLOS results will provide insight into LTS driven learning outcomes.

(5) Measures of well-being: We include survey elements that follow Keye’s Flourishing Scale to provide a categorical diagnosis of “flourishing” or “languishing” mental health of the students\(^\text{23}\). The instrument will be adapted for evaluating engineering students. Subjective well-being items are used to comprehensively assess students in terms of emotional, psychological and social well-being. Semi-annual application of the instrument will allow comparison of students’ mental health of the various cohorts over time.

(6) Mindset: Dweck established the importance of mindset on a variety of learning, professional, and personal outcomes\(^\text{24}\). We include several questions within the survey instrument to evaluate whether student participants have a fixed- or growth-oriented mindset.

(7) Work and life: We adapted questions from a recent national survey by The Work Foundation to probe student participants’ attitudes toward career, employers, personal life, and work-life balance\(^\text{25}\).

(8) Engineer identity: Through the annual interview process we assess students’ identity with respect to LTS through the lens of identity theory. Recent advances in identity theory have come to recognize that people have multiple identities. In addition, for underrepresented students, it is important to investigate and examine if their “engineer identity” is triggered or is as powerful as other identities. Ethnographic techniques will be used on the “interviewed” group to discern how students refer to themselves and to other engineers. Evaluating identity over time will also allow us to examine the process of identity development across the undergraduate experience.

(9) Intercultural competence: The Intercultural Development Inventory (IDI) is a cross-culturally valid and reliable method to assess intercultural competence development\(^\text{26}\). The IDI is suggestive of the student’s proficiency at working with others who view the world differently.
The IDI yields quantitative results, placing the student along a spectrum of intercultural sensitivity from ethnocentrism to ethnorelativism in stages of denial, defense, reversal, minimization, acceptance, and adaptation (Bennett, 1993). The IDI is available as an online 50-question tool, but requires a qualified administrator for use. While the IDI provides quantitative data, its results are difficult to interpret without further awareness of the test subject; hence the IDI will only be administered for the students being interviewed. Due to its cost ($10/test), it is only be administered four times (initially, then at the end of Years 1, 2, and 3), not semi-annually. Collectively, the online survey is comprised of nearly 150 individual questions, whereas the structured interview has nearly 20 questions.

3. Results
The scope and early stage of this study prohibit an exhaustive presentation of data for this paper. Highlights from participation in addition to a few questions within the eight foci of our assessment (see Table 1 above) are presented below. Interview responses are not presented in this paper.

3.1 Participation
Nearing the end of its first year, this study has completed two rounds of assessment (Round 1 in Spring 2011, Round 2 in Fall 2011) and has maintained good participation with attrition rates of 8% and 17% in the interviewed and surveyed groups, respectively. The current LTS participation of various cohorts is provided in Table 2.

Table 2. Demographic breakdown of engineering student participation in various forms of Learning Through Service (LTS) as of Round 2 of assessment (Fall semester of sophomore year for Freshmen cohort, and senior year of Junior cohort; n=207)

<table>
<thead>
<tr>
<th>Demographic</th>
<th>No LTS yet</th>
<th>Curricular LTS</th>
<th>Extracurricular LTS</th>
<th>Both types of LTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshmen (n=115)</td>
<td>0.9%</td>
<td>89.6%</td>
<td>98.3%</td>
<td>85.2%</td>
</tr>
<tr>
<td>Junior (n=92)</td>
<td>6.5%</td>
<td>51.1%</td>
<td>89.1%</td>
<td>46.7%</td>
</tr>
<tr>
<td>Male (n=120)</td>
<td>5.0%</td>
<td>71.7%</td>
<td>92.5%</td>
<td>66.7%</td>
</tr>
<tr>
<td>Female (n=87)</td>
<td>2.3%</td>
<td>59.8%</td>
<td>97.7%</td>
<td>68.9%</td>
</tr>
</tbody>
</table>

The numbers of engineering students who indicate that they have not participating in any form of LTS is rapidly decreasing, now at 3.9%, as compared to the condition of our group at the start of the study (nearly 25% indicated “No LTS”). Fortunately, the LTS participation questions ask frequency of participation (none, once, few, many times). Experience should matter to the various outcomes being assessed. Students who expressed a “once” response may indicate exploration of university offerings or in the case of curricular LTS, involuntary participation; therefore all students who indicated “none” or “once” in responses to both curricular and extracurricular
participation were lumped into the “No LTS” category. This constitutes 22.7% of our students participants, and this group is used in the data analyses that follow. Additionally, no further distinction will be made in this analysis between curricular and extracurricular LTS. While the study aims to examine outcomes between these types of offerings, further data analysis will be needed prior to commenting on such impacts. If a student indicated “few” or “many” times of involvement in either curricular or extracurricular LTS they are associated with the LTS group in further analyses below.

The academic field of study is captured by our assessment. They majors of LTS students and No LTS students are presented in Table 3. Lastly, the ratios between these two categories are presented for each disciplinary field to evaluate if certain majors tend to be more (>1) or less (<1) interested in LTS.

Table 3. Disciplinary composition of engineering students actively participating in LTS versus those not participating in LTS

<table>
<thead>
<tr>
<th>Discipline</th>
<th>No LTS (n=47)</th>
<th>LTS (n=162)</th>
<th>Ratio (LTS:No LTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomedical engineering</td>
<td>4%</td>
<td>8%</td>
<td>2.0</td>
</tr>
<tr>
<td>Chemical engineering</td>
<td>4%</td>
<td>6%</td>
<td>1.5</td>
</tr>
<tr>
<td>Civil engineering</td>
<td>16%</td>
<td>15%</td>
<td>0.94</td>
</tr>
<tr>
<td>Computer engineering</td>
<td>2%</td>
<td>2%</td>
<td>1.0</td>
</tr>
<tr>
<td>Electrical engineering</td>
<td>7%</td>
<td>6%</td>
<td>0.86</td>
</tr>
<tr>
<td>Environmental engineering</td>
<td>7%</td>
<td>11%</td>
<td>1.4</td>
</tr>
<tr>
<td>Mechanical engineering</td>
<td>22%</td>
<td>26%</td>
<td>1.2</td>
</tr>
<tr>
<td>Other</td>
<td>38%</td>
<td>27%</td>
<td>0.71</td>
</tr>
</tbody>
</table>

3.2 Self-efficacy

There are 52 questions within the self-efficacy domain (0-100 scale, “I cannot do this” to “highly certain I can do this”). The question with largest gap between LTS and No LTS students asks students to rate their success at selecting the best possible engineering design among alternatives. LTS students score 9.8% higher. The self-efficacy sub-scale that results in consistently higher scores among LTS students is “perceived success”. Self-confidence, motivation, and incentive sub-scales are more mixed, yet in general LTS students are higher scoring.

3.3 Attitudes toward learning

The attitudes assessment has sixteen individual questions (seven point Likert scale, “not at all true” to “true”). Within these questions, LTS student responses are consistently more positive about learning. One example is the response to “I want to do as little work as possible in my
engineering courses this semester.” LTS students score this 35% LTS lower versus their No LTS peers.

### 3.4 Engineering learning outcomes
This assessment has fifty-one, five-point, Likert-style questions. Differences between the cohorts is generally minor and mixed. One of the greater differences is found in the response to being able to “recognize the need to consult an expert from a discipline other than my own when working on a project.” LTS students report scores 15% greater, on average, than No LTS students.

### 3.5 Well-being
Twelve seven-point Likert questions are in this assessment. An example includes “our society is becoming a better place.” LTS students report a 41% greater frequency of thinking this is true. Sadly, though, this is the lowest scoring question within the entire evaluation, students have a very low opinion of the state of world affairs.

### 3.6 Mindset
There are two possible mindsets, according to Dweck, fixed and growth\(^2^4\). The four questions within this assessment (two positively worded, two negatively worded) were summed to evaluate which domain each student resided. Table 4 reveals little difference between the LTS and No LTS groups.

<table>
<thead>
<tr>
<th>Mindset</th>
<th>LTS</th>
<th>No LTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>35.4%</td>
<td>32.4%</td>
</tr>
<tr>
<td>Growth</td>
<td>64.6%</td>
<td>67.5%</td>
</tr>
</tbody>
</table>

### 3.7 Work and life
Twenty-two questions (mixed styles) are asked involving work, career, professional and personal lives. The responses to one question, “what is more important in your life and career?” are presented in Table 5. The LTS and No LTS groups show little difference.

<table>
<thead>
<tr>
<th>More Important</th>
<th>LTS</th>
<th>No LTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money</td>
<td>11%</td>
<td>9%</td>
</tr>
<tr>
<td>Personal fulfillment</td>
<td>89%</td>
<td>91%</td>
</tr>
</tbody>
</table>
Table 6 reveals the responses to a second question in this assessment, the top three factors when selecting a job (among seventeen possible options).

**Table 6.** Responses to the question “what are the most important factors you consider when selecting a job?” (n=209)

<table>
<thead>
<tr>
<th>Rank</th>
<th>No LTS</th>
<th>LTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type of work (49%)</td>
<td>Work/life balance (45%)</td>
</tr>
<tr>
<td>2</td>
<td>Compensation and benefits (45%)</td>
<td>Type of work (40%)</td>
</tr>
<tr>
<td>3</td>
<td>Work/life balance (43%)</td>
<td>Passion for the objectives of the organization (28%)</td>
</tr>
</tbody>
</table>

**3.8 Engineer identity**

While the engineer identity is explored primarily through interviews, a few questions target students perceptions as to what an engineer is. One question focuses on civic engagement, and responses presented in Table 7 show a stark difference in how LTS engineering students operate in their communities. Not surprisingly perhaps, volunteerism seems to be a critical characteristic of engineers who have experienced considerable LTS.

**Table 7.** Participant responses to the question “during college have you volunteered for an organization doing community or social projects?” (n=209)

<table>
<thead>
<tr>
<th>Volunteer</th>
<th>LTS</th>
<th>No LTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>89%</td>
<td>30%</td>
</tr>
<tr>
<td>No</td>
<td>11%</td>
<td>70%</td>
</tr>
</tbody>
</table>

**3.9 Intercultural competency**

The Intercultural Development Inventory is administered once a year, and only to the interviewed students (n=120). An initial analysis is depicted in Figure 2. General findings are that age and LTS involvement make a difference; juniors score higher, as do LTS participants. Additionally, LTS students are entering a minimization cultural view whereas No LTS students have a cultural defense view. The LTS impact is greatest for younger students.
4. Discussion

Based on the work to date (near the end of Year 1 of 3) and the data presented above, a few key observations are discussed in this section.

A continuing challenge in this, and every, longitudinal study is the continued participation of students. Following campus-wide solicitations, the study extended invitations to 480 engineering students, 254 completed the Round 1 survey, 207 completed Round 2. On a better note, 120 of the above 480 were invited to be in the interview pool, 120 completed Round 1 interviews, and 110 completed Round 2. While participants are well-compensated for their time ($30 per year for online survey, $100 per year for interviewed), it is clear that engineering students have a fairly high “not worth it” threshold. If nothing else, we better understand the time demands on our students. Another challenge with our student pool is the substantial migration of students from the “No LTS” to “LTS”. While this is an encouraging sign for LTS, it makes it increasingly difficult to have a control group. One further challenge is the rarity of students only doing curricular LTS; nearly all are involved in both curricular and extracurricular. Many of these issues will dissipate; as the study progresses, it will increasingly focus on longitudinal pathways for individuals rather than group averages. Our main interest is to track the choices and outcomes of individual participants make regardless of their shifting affiliations. Through this we should be able to identify chronologies of choices and their effects.

The demographic data reveal a few surprises to date. Women are interested in community engagement. Administrators and faculty (and employers) should rightly take note. However, men are not far behind in interest. A characteristic of the Millennial Generation perhaps, these students want to integrate project, people, and purpose with their academic lives. Equally intriguing are initial indicators of the influence of disciplinary learning cultures. Environmental and bio-

Figure 2. Intercultural development inventory spectrum (ethnorelative: denial, defense, minimization, ethnorelative: acceptance and adaptability) with average scores of student sub-cohorts (First-year vs. Junior year; and LTS vs. No LTS)
medical engineering are well-represented within LTS, not surprising due to their high percentages of female students, yet neither field has gender ratios similar to the LTS to No LTS ratios presented. Clearly both fields attract students wishing to volunteer for service experiences. Other fields, notably electrical engineering and civil engineering, are under-represented. If this is representative of national patterns, both fields, which are rich in service possibilities, may benefit from reviewing messaging and academic offerings.

From much of the online survey to date, a pattern seems to be emerging: there are relatively little differences in self-assessment in engineering knowledge and abilities between the LTS and No LTS cohorts. There are differences, several significant at the 90% level, in attitudinal attributes both internal (e.g. I want to do as little as possible in class) and external (e.g. the world is getting better). It is not yet clear if LTS is an influencing agent, or simply a benefactor of attracting such-minded people.

Interestingly, like knowledge, there are no differences in mindset between LTS and No LTS. Mindset is thought to be central to learning outcomes. Growth mindset people tend to relish challenges, fixed mindset people get easily discouraged by challenges. It appears engineering benefits from having a healthy majority of growth mindset students, this maybe a prerequisite in navigating the academic obstacles to becoming an engineering student in the first place. Future evaluation will begin to map this mindset with dialogue about engineering experiences from the interviews.

The work and life results provide additional insight about this generation of engineering students. Similarities between cohorts underscore the inward focus of these students, type of work is important, yet, so is work-life balance. Perhaps the latter explains the challenges in maintaining participation in a study like this. One interesting difference is the importance of compensation by the No LTS cohort, whereas the “resonance” of their employer’s mission is critical to LTS students. The latter point should be a note of attention to universities, and especially the employers of these students.

One clear difference between cohorts is the role of engineers in volunteer work. Volunteerism is part of the LTS engineer “DNA”. Longitudinal analysis in the coming years will see if this is a result or cause of LTS engagement.

Lastly, intercultural competency showed marginal improvements both with time in school and among LTS participants. It is too early to tell if LTS causes the move towards ethnorelativism, or whether more interculturally open-minded people tend to gravitate towards community engagement.
References

13. Personal communication