
AC 2011-1328: ISES A LONGITUDINAL STUDY TO MEASURE THE IMPACTS OF SERVICE ON ENGINEERING STUDENTS

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ISES – A Longitudinal Study to Measure the Impacts of Service on Engineering Students

Abstract

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. Independent of these challenges, students' interest has exploded in extracurricular service efforts, notably through Engineers Without Borders (EWB-USA). In some institutions, this service involvement has fueled the implementation of Learning Through Service (LTS) in curricula. A growing body of evidence suggests that LTS may provide significant advantages to engineering students, but individual studies to-date have been limited in their duration and scope of assessment.

This paper outlines a three-year project that will measure various indicators related to desirable attributes of future engineers, how these indicators are impacted by LTS efforts, and how they develop over the time of undergraduate education. The collaborative effort involves a sequential but staggered longitudinal study of cohorts of students at four institutions – Michigan Technological University, Tufts University, University of Colorado Boulder, and James Madison University. Students at these institutions, diverse in size and culture, are joined by a cohort of students associated with EWB-USA student chapters from across the U.S. The LTS efforts considered in the study can be either curricular, extracurricular or both. The impacts of LTS on engineering students' traditional technical attributes as well as a mix of non-technical attributes will be studied; along the way, information on interest and persistence in engineering will be gathered.

It is expected that the study will significantly add to the growing body of evidence that LTS has positive benefits for engineering students, particularly those from underrepresented groups. Specifically, this project will:

- Create a methodology to assess the development of students' skills as well as attitudes, beliefs, and identities;
- Determine whether extracurricular and curricular LTS opportunities offer similar benefits to all students and their universities;
- Provide insight on effective engineering course and program design;
- Support the concepts espoused by various national foundations / associations / academies on the value in creating broadly- or holistically-thinking engineers;
- Create service-minded engineers, and assist communities-in-need through engineering; and
- Improve the image of engineers in the eyes of the general public, through promotion of service projects.

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^{1, 3, 4, 46}. 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, the diversity of those who participate in, and the benefits developed from engineering education. In many quarters, engineering education has recently discovered the contributions of Learning Through Service (LTS)^{28,30,63}. This awareness has often come obliquely with some of the most engaging LTS opportunities originating outside formal academic learning (i.e., the classroom). For example, since 2002, students in more than half the nation’s engineering colleges have developed student chapters of Engineers Without Borders-USA (EWB-USA) that serve developing communities through project work⁵⁰. There are few, if any, other such dramatic and widespread movements within engineering education^{15,49}, yet, with such a rapid change, a thorough understanding of best practices and outcomes, beneficial and otherwise, are lagging¹⁶. 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 efforts¹⁷. How service efforts affect the developmental processes of engineering students requires a coordinated, comprehensive, and longer-term examination.

The ISES project, also termed the Engineering Pathways Study, 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 project 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 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 will consist of a sequential, but staggered longitudinal study of engineering students at four institutions; namely Michigan Technological University, Tufts University, University of Colorado Boulder, and James Madison University. These institutions have existing LTS curricular and/or extracurricular programs and opportunities. In addition, another cohort of students associated with EWB-USA student chapters from across the country has also been assembled. From these groups, we seek to explore 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 will be 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. Motivation

Learning Through Service (LTS) is an amalgamation of various pedagogical methods, including service learning, community-service, and problem-based learning, among others. The distinguishing schema of LTS is its intentional design to incorporate service as a means to meet academic learning objectives. Additionally, the project-based element, connected to a community’s need, can serve as the primary motivator for student and faculty participation^{49,50}.

The community projects also provide a rich socio-cultural context that has been found to stimulate the process of collaborative problem-solving.

When the complementary pedagogies (project-based and service-based learning) merge, there is potential for student development on the cognitive^{22, 23, 39, 51, 58}, social^{26, 32, 61, 62}, and moral^{21, 40, 42} levels; three developmental processes that are tightly entwined, inseparable, and often triggered by each other or occur simultaneously. These constructs are based on the theories of Dewey, Piaget, Kohlberg, Vygotsky, and Kolb⁴³ to where LTS could offer a rich learning environment for engineering students.

2.1 Indicators That Influence Learning

A number of indicators have been studied that influence one's ability to learn – self-efficacy, motivation, identity, cultural competency, well-being, etc. How these relate to learning in the presence of LTS forms the basis of our evaluations. Specific indicators to be evaluated in our study are briefly reviewed below.

Self-efficacy, motivation, and retention. Research has shown that perceptions and attitudes of engineering students not only affect retention, but also differ across gender and ethnic populations⁹. For example, research has also shown 1) that compared to male students, female students began their engineering studies with a lower confidence in background engineering knowledge (i.e., science and math), lower confidence in their abilities to succeed in engineering, and lower confidence in their perceptions of how engineers contribute to society¹⁰; 2) that lower confidence levels in their abilities to succeed in engineering continued to persist for female students throughout the duration of their degree¹⁰; 3) that women often leave science, mathematics, and engineering (SME) with grades which are as high, or higher, than the averages of men who remain, and the concerns of students who switched out of SME majors were also concerns of the students who remained⁵⁷; and 4) that 40 to 60 percent of entering engineering students persist in engineering, in which women and minorities are at the low end of that range⁴⁷. The service aspect of LTS efforts initially motivates students to participate, but the cycle of overcoming problems and continual learning, indicators of increased self-efficacy and persistence, nourishes them. This is in-line with Kolb's theory that learning must begin with motivation, upon which theory, application, and analysis are founded. Our study will monitor these indicators over time to evaluate the impact LTS is having on students' learning.

Engineer identity. Engineer identity has been an under-studied research topic^{44, 60}. Recent advances in identity theory have come to recognize that people have multiple identities. For underrepresented students, it is important to investigate and examine if their "engineer identity" is triggered or is as powerful as other identities. Also important is the process of identity formation across the undergraduate experience. For example, how might the progressive strength in identity be fostered or hindered in response to influencing factors, including curricular features, social networks, social contexts, perceptions, values, etc.? Therefore, it is important to investigate if the engineer identity is triggered or strengthened during LTS experiences.

Attitudes on learning. Previous studies on achievement motivation in educational settings indicate a distinction can be made between mastery- and performance-driven goals and academic achievement^{7, 31}. Mastery goals refer to the development of mastery and learning for the sake of learning, whereas performance goals focus on the attainment of competence relative to peers. Some studies have suggested that mastery goals generate more adaptive outcomes than performance goals^{5, 29}; thus, in the presence of LTS, we will investigate engineering students' perceived attitudes towards learning and performance using existing instruments that are valid and reliable.

Cultural competency. Cultural competency is a relative measure of one's ability to interact with people from different cultures^{14, 25}. The value of cultural competency in engineering is grounded in enhancing the effectiveness in working on teams with engineers, scientists, etc. from diverse races and cultural backgrounds. Its value is also evident in understanding the needs of worldwide clients who will use the engineered product or project, define problems differently, and work across cultural boundaries. Many LTS experiences, especially those related to international efforts, require students to work in a culture entirely different than their own. The impact of such efforts on how students work in a different cultural norm is of value to understanding their learning.

Mental health. Measures of psychosocial factors can be indicative of one's well-being; i.e., mental health versus mental illness. Keyes' Flourishing Scale is a continuous assessment method that provides a categorical diagnosis of "flourishing" or "languishing" mental health of students⁴¹. Flourishing is associated with high levels of emotional, psychological and social well-being and results from experiencing "vigor and vitality, self-determination, continuous self-growth, close relationships and a purposeful and meaningful life"²⁴. Languishing is associated with poor mental health, but does not mean mental illness. However, lower mental health is associated with poor behavior and personal decisions⁴¹. LTS experiences may be a viable impetus for one to "flourish" and achieve higher well-being. For example, researchers have tested the hypothesis that a civically-promoting culture elevates civic identity and psychosocial well-being, finding that well-implemented service-learning programs can have a positive effect on the civic skills, attitudes, and behaviors of participating students⁶. How mental health changes over time, especially in the presence of LTS, is also of importance.

2.2 Current Knowledge of LTS

Student interest in curricular and extracurricular LTS efforts has created institutional momentum for integrating this approach within engineering curricula. LTS has been incorporated into first-year project courses, core engineering science courses, and senior design courses^{13, 34, 48, 55, 59}. Previous research has shown many beneficial student outcomes from well-designed LTS efforts and programs. These outcomes, or desirable attributes, include deepening of student abilities related to ABET Criterion 3 a-k^{12, 13, 27, 28, 45, 56}, cultural competency⁵⁰, critical thinking⁶, self-efficacy³⁶, sustainability⁴⁹, and leadership^{27, 30}.

However, numerous challenges with LTS projects have been identified ^{2, 16, 38} including: 1) a need for the project purpose to align with program outcomes, a challenge when communities are equal partners in the process; 2) a meaningful relationship with the community, particularly imperative to ensure that the community goals are served; 3) a project planning phase before the beginning of the course, critical to ensure a successful project; 4) site visits, very helpful so that students feel a connection, but difficult if class sizes are large or when working on international projects; and 5) implementation challenges that may exist in project delivery such as regulations, liability, local constraints, and sustainability.

As the agents of university culture, engineering faculty must accept responsibility for the much slower adoption of LTS (and other high-potential pedagogies) into engineering curricula. This project aims to provide the evidence about student gains that will help catalyze widespread adoption of LTS among engineering faculty, departments, and colleges interested in offering modern and effective curricula.

3. Project Methodology

3.1 Experimental Design

Our research effort focuses on four specific working hypotheses:

- 1) LTS increases the professional skills required for holistically-thinking engineers without decreasing technical capability.
- 2) Attributes of holistically-thinking engineers are measureable via combined assessments of technical skills and self-efficacy, identity, attitudes, and other psychosocial factors.
- 3) Extracurricular LTS efforts, such as EWB, and curricular LTS efforts provide the same benefit; i.e., there is no discernible difference in impacts from different forms of LTS.
- 4) Underrepresented students are attracted to, retained in, and persist through engineering programs at higher levels when engaged in LTS.

In brief, the research effort consists of a longitudinal study performed at four target institutions. These institutions are diverse in size, type, mission, and student socio-economic conditions (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. These faculty will be important in assisting with the local implementation of the assessment program within their institutions.

At each institution, three different cohorts will be followed (Figure 2) – Cohort E = students involved in extracurricular LTS; Cohort C = student who participate in an LTS course/program; and Cohort N = a control group of students not involved in LTS efforts. These cohorts will be the subject of semi-annual surveys aimed at quantitative (Likert-scale) measures of self-efficacy, motivation, attitudes, ABET criteria, and mental health as well as annual interviews (qualitative measures) during the project's three-year duration. At each institution, fifteen- to twenty-student cohorts will be developed - five members of a cohort randomly chosen to become interview subjects for the study (they will also take the surveys); the remaining students will only participate in the surveys. We plan to follow 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) (Figure 3). In addition to these groups, a cohort of students from across the country will be solicited from the various student chapters of EWB-USA; these students will not be interviewed. In all, we hope to have 480 students (240 in each cluster) be evaluated 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).

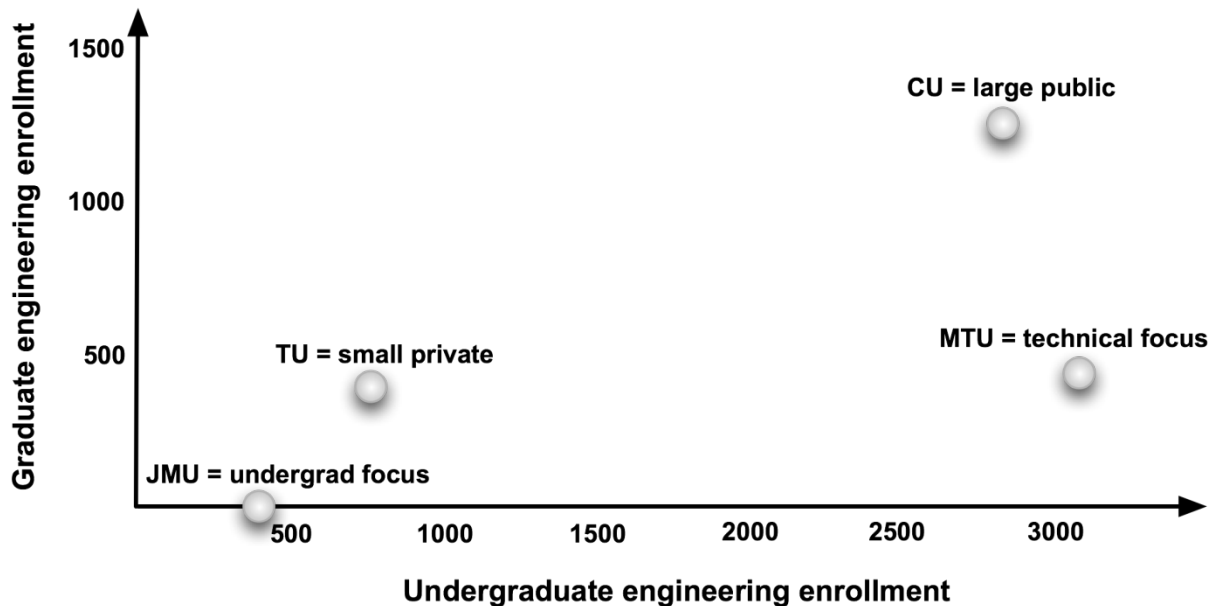


Figure 1. Target schools for this study; TU=Tufts University, MTU=Michigan Technological University, CU = University of Colorado Boulder, JMU=James Madison University provide a diversity of campus cultures, as illustrated by undergraduate and graduate enrollments.

At each participant university, a mix of LTS programs/courses was targeted for the requisite student participants in this study. Student interview participants were selected at random from the pool of applicants, with an effort to ensure adequate representation among all target groups within engineering programs (gender, ethnicity, disciplines). All universities will use EWB-USA as the target extracurricular program. Control group students (not participating in LTS) will be selected from the broader collection of students in each institution's School/College of Engineering. A final control cohort will be selected for each university's Clusters A and B to mirror the average demographic composition (gender, ethnicity, majors) of the two cohorts (curricular and extracurricular LTS) as closely as possible.

The students associated with student chapters of EWB-USA at other institutions across the country were selected, at random, to represent a broad set of institutions, though students at public institutions are predominant.

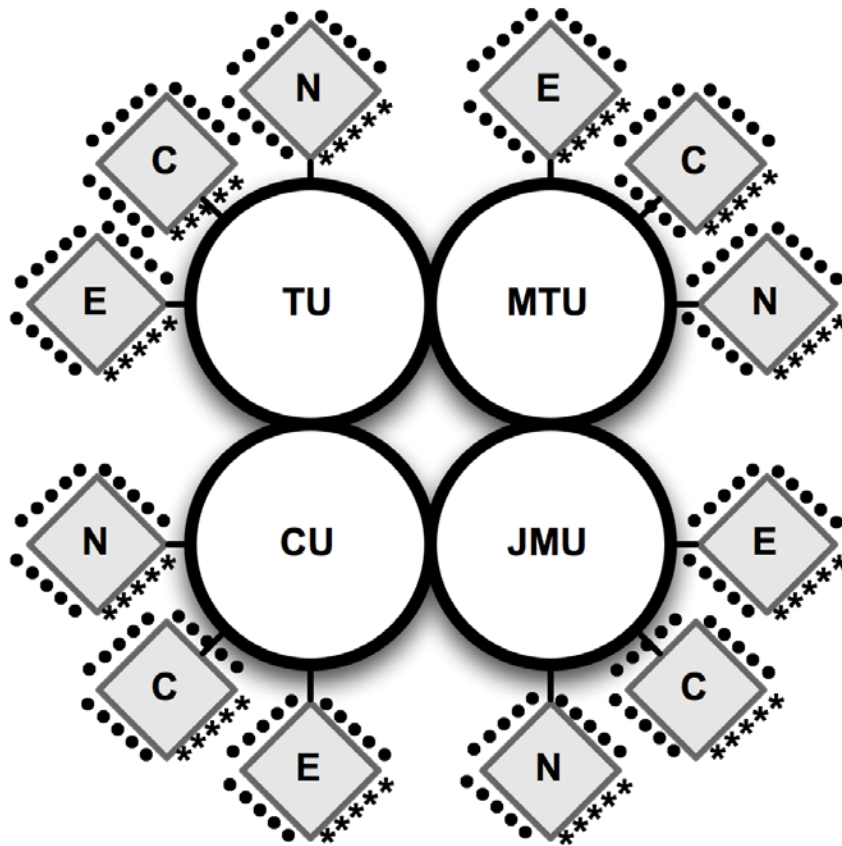


Figure 2. Cluster design. Each university (TU=Tufts, MTU=Michigan Technological, CU =Colorado, JMU=James Madison) has three student groupings (E=extracurricular LTS, C=curricular LTS, N=not participating in LTS) of fifteen to twenty students each (*=five for interviews+surveys, •=remaining for surveys only).

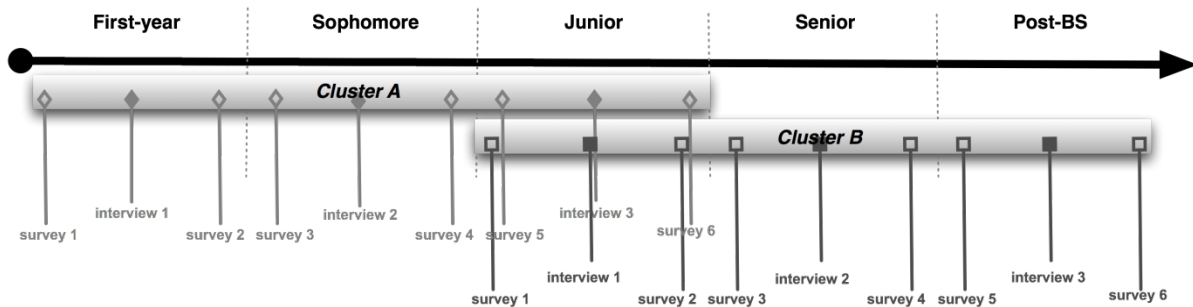


Figure 3. Project methodology depicting the first-year and junior-year Clusters, A and B respectively. Both will be followed for three years, collectively providing a first-year to post-baccalaureate understanding of the impacts of LTS on engineering undergraduate students.

3.2 Assessment Methodologies

LTS requires well-grounded outcomes-based assessment methodologies. Service-based pedagogical methods affect multiple stakeholders – students, faculty, academic institutions and the community partners^{18,35}. Our assessment efforts will center on students, though other stakeholders will influence their efforts. As such, our instruments were structured so that effects from other stakeholders on the development of measured attributes can be taken into account.

Student participants were drawn from volunteer pools (via targeted announcements on each campus), with students placed into appropriate pools based on class level and their expressed intentions for the next three years (i.e. their plan to participate in LTS, or not). Once assigned to a cohort, students remain in that cohort throughout the study, regardless of their path. For example if a control student later opts into EWB, that student still remains in the control cohort, but will be duly noted as now participating in LTS, so that later data analysis is not confounded. All student participants took a basic survey to collect demographics (ethnicity, age, gender, class level, discipline, number of hours worked in a job each week, number of hours volunteered per week, name of organization/community worked with in LTS course/program) as well as some basic feedback about the course/program (perspectives on the learning gained, attitudes towards community involvement, influence on major and profession).

A mixed-methods approach will be used to allow triangulation of results that enables us to 1) neutralize the disadvantages inherent in all types of methods, and 2) use different methods to understand the complexities of social phenomenon²⁰. 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 (approximately 25%) to be interviewed. The three-quarters taking only the surveys will be referred to as the “surveyed group” whereas the one-quarter taking the survey and being interviewed is the “interviewed group” (Table 1). The assessment protocol will require approximately one-half hour or two hours of commitment per assessment round for the “surveyed” and “interviewed” students, respectively.

Table 1. Assessment methods to be used within each indicator, as identified below, for both student focus groups (interviewed, or surveyed)

Indicators (see below)	Interviewed Group (n≈120 students/year)	Surveyed Group (n≈360 students/year)
1	Retention Self-efficacy Motivation	Retention Self-efficacy Motivation
2	Engineer identity	n/a
3	Attitudes Toward Learning Scale	Attitudes Toward Learning Scale
4	National Engineering Students’ Learning Outcomes Survey	National Engineering Students’ Learning Outcomes Survey
5	Keye’s Flourishing Scale	Keye’s Flourishing Scale
6	Intercultural Development Inventory	n/a

Student composition for both groups 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 an excessive number of participants become non-responsive after repeated contact, they will be replaced with others (similar class level) to ensure cohorts remain adequately sized. The qualitative data will be transformed in the analysis phase into quantitative terms that enable the integration of both sources of information. This approach, concurrent triangulation design, is a mixed-methods design in which researchers collect and compare both qualitative and quantitative data in a single study²⁰. For student assessments, we will seek to address the following indicators to give us insight into the impacts of LTS:

- (1) Increased self-efficacy, motivation, and retention: During this effort, we will 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-efficacy¹⁹. 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, Cluster B 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).
- (2) Increased self-efficacy, motivation, and retention: During this effort, we will 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-efficacy¹⁹. 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, Cluster B 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) Engineer identity: Through the annual interview process we will 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.
- (4) Improved attitude towards learning and performance: We will 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 University³³. This 16-item questionnaire evaluates whether respondents follow performance-driven or mastery-driven goals toward academic

achievement. The instrument will be administered semi-annually to “surveyed” and “interviewed” groups.

- (5) Strong alignment with ABET criteria 3a-k: During this effort, we will 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^{52, 53, 54}. 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.
- (6) Measures of well-being: We will include survey elements that follow Keyes’ Flourishing Scale⁴¹ to provide a categorical diagnosis of “flourishing” or “languishing” mental health of the students. The instrument will be adapted for evaluating engineering students. Subjective well-being items will be used to comprehensively assess students in terms of emotional (e.g., how often have you felt happy, interested in life, and satisfied in the past month?), psychological (e.g., measures of theoretical dimensions such as environmental mastery, positive relations with others, personal growth, autonomy, purpose in life, and self acceptance) and social well-being (e.g., across the five dimensions of social contribution, integration, actualization, acceptance, and coherence). Semi-annual application of the instrument will allow comparison of students’ mental health of the various cohorts over time.
- (7) Intercultural competence: The Intercultural Development Inventory (IDI) is a cross-culturally valid and reliable method to assess intercultural competence development³⁷. 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 adaptation⁸. 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 will only be administered four times (initially, then at the end of Years 1, 2, and 3), not semi-annually.

All surveys are available online and administered over a one month window near the beginning of the academic semesters (fall and spring). Interviews are planned to be telephone-based, and up to an hour in length. Approximately 10 to 20 interviews will be conducted per week over a one-to two-month period during the middle of each study year. While many of the indicators measured in this study are rooted in established surveys, identity will be solely obtained through

interviews. However, all indicators will benefit from the contextual richness and understanding gained from the interviews. The student interviews are also meant to create a one-on-one conversation to explore their experiences in school ³⁵. Some guiding questions include:

- Describe the project work you have been involved with through school.
- Describe your relationship with the community partner and the project.
- What did you learn about the community through this experience? Did you learn anything in the community that connected to the context of engineering? If so, how was that connection made?
- Do you think you will do anything differently as a result of this work (e.g. volunteering, major, career choices, activism, etc.)? Has this created new opportunities for you?
- What did you learn about yourself (e.g. biases, fears, the way you interact with others, etc.)?
- Did you learn anything from anyone other than your professor/adviser during this experience?
- Did you feel prepared to do this work? If not, how could you have been better prepared?
- What did you find most rewarding?
- What did you find most challenging?
- Did you discover anything about being an engineer?

Other assessment/evaluation factors to be considered include institutional and community impacts. However, our focus will not be on what these impacts are for these stakeholders as much as how they affect students' engagement in LTS. Thus, our surveys and interviews will serve to collect basic information related to their campuses (number of faculty, disciplines, type of course/program, positive and negative consequences, etc.) as well as their community partners (number and types of projects, number of community members served, positive and negative consequences, etc.).

Both project evaluation and LTS implementation assessment results will be analyzed by two external evaluators who will work with the project leaders to adapt the assessment instruments to address research hypotheses. As mentioned, we will use previously field-tested and validated instruments whenever possible, as well as comparison groups as controls to allow us to draw conclusions from our data. For example, external evaluators will use the collected data to conduct an investigation into the LTS implementation's effectiveness by examining both within-groups and between-groups effects, further identifying through factor and regression analyses those variables of participants and projects most predictive of measured effects.

4. Broader Impacts - Project Significance and Impact

This project presents a unique opportunity for a longitudinal study to track how students learn through engagement in LTS efforts, providing a knowledge base useful to educators and administrators, and directions for future educational programs. Sampling such a large number of students across many campuses will add significantly to our knowledge of the impacts of LTS and its viability as a compelling, empowering approach to education. Specific broader impacts that are expected from the work include:

- Providing research-based evidence that LTS is a viable pedagogy for engineering education AND highlight LTS as a viable research endeavor. This project provides a new dimension by using existing and newly developed assessment tools, and their accompanying results, to evaluate the over-time impacts of LTS in the development (cognitive, social, and moral) of engineering students.
- Support the concepts espoused by various national foundations / associations / academies on the value in creating broadly- or holistically-thinking engineers.
- Provide a potential pathway for students previously less attracted to engineering, including those from underrepresented groups, to enter and persist within the discipline.
- Create service-minded engineers, and assist communities-in-need through engineering.
- Improve the image of engineers in the eyes of the general public, through promotion of service activities and projects.

4.1 Measurable Outcomes

Many of the measurable outcomes are discussed in Section 3 above. Improved understanding of knowledge, skills, attitudes, and identity are expected, as well as important information regarding recruitment and retention. Outcome differences between all pairings between curricular LTS, extracurricular LTS, and control will be determined. Some of the key metrics to be measured in this study include:

- Types of students drawn to and involved in various LTS efforts (curricular and extracurricular).
- Student recruitment, retention, persistence, and graduation rates (at university and within discipline).
- LTS courses/programs offered (numbers, models, number of participants)
- Student learning outcomes from LTS participation.
- LTS impacts on how learning objectives were attained.
- Communities benefited by LTS (locations, number of projects created, project types, number of people affected).
- Post-baccalaureate activity (job, graduate school, other, type of activity).

4.2 Other Impacts

4.2.1 Community Building

With existing LTS-involved faculty scattered across many institutions, often championing LTS in isolation, a formal LTS faculty community is long overdue. The process to form a Service in Engineering Education Constituent Committee for ASEE has begun; the first step in progressing to a formal Division.. This proposed study would deliver high-demand research findings to support or refute the observational conclusions reached by many. For faculty and others interested in such an LTS community, moving from anecdote to evidence is a much-needed step towards fact-based advocacy and, hopefully, widespread adoption.

4.2.2 Project Sustainability

Like any development project, sustainability is rooted in capacity building that is resource appropriate and culturally focused. In this case, the project provides three years to catalyze the creation of a much-needed evaluation program. Knowledge, skills, attitudes and identity embody all cultures; and this project will assemble those most needed to better understand the LTS student culture, catalyzing further integration within engineering education. Once established, the LTS student assessment will expand its impact through collaborative research proposals, publications, presentations, and ultimately, refined curricular models. As curricular exemplars accumulate successes, sharing outcomes at all levels (e.g. Engineering Deans' Institute, NAE, student conferences, NSF awardee meetings, etc.) will further feed the interest in crafting LTS activity within engineering programs. All project methodologies and summaries will be posted on the STEM Digital Library for long-term use by LTS scholars, practitioners, and advocates.

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