Engineering Pathways Study: Lessons Learned in Its Development and Implementation

Dr. Chris Swan, Tufts University

Chris Swan is the Associate Dean of Undergraduate Curriculum Development in the School of Engineering and an associate professor in the Civil and Environmental Engineering department at Tufts University. He has additional appointments in the Department of Education, Jonathan M. Tisch College of Citizenship and Public Service and Center for Engineering Education and Outreach at Tufts. He has been an active member of the American Society for Engineering Education, having served at various officer posts for the Environmental Engineering Division (2003–7) and the Community Engagement Division (2011 – present). His current research interests in engineering education focus on project-based learning and service-based pedagogies. He also does research on the impact of temperature (heating and/or freezing) on engineering properties of soils and on the development of reuse strategies for waste materials.

Prof. Kurt Paterson P.E., James Madison University
Mr. Timothy Henry Hellickson, Tufts Center for Engineering Education and Outreach
Abstract

The Engineering Pathways Study focused on measuring how desired attributes of future engineers are impacted by a student’s involvement in service or community engagement (CE) efforts and how these attributes develop over the time of a students’ undergraduate education. The three-year project consists of a sequential, but staggered, study of engineering students; primarily from four institutions. Cohorts were developed based on students’ level of involvement in curricular and extracurricular service-based activities; i.e., ranked from none to high. The project has used various quantitative and qualitative instruments to explore the impacts of CE on engineering students’ learning; specifically, traditionally 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). The two major components of the study consisted of semi-annual rounds of administering an on-line survey (for all participants) and telephone interviews (conducted with a sub-set of participants). An additional instrument to measure intercultural sensitivity was administered to the interview sub-set on an annual basis. Overall, the project had an initial, total participant number of over 250 (including 120 interviewed), but attrition lead to less than 175 (89 interviewed) continuing their participation throughout the three years.

This paper focuses on the insights or ‘lessons learned’ during the study’s development and implementation, with a focus on how to maintain participation rates. Specifically, insights discussed in this paper include methods in 1) recruitment and retention of student participants, 2) compensation of participants, and 3) maintaining participant interests in each round of the study. Other insights discussed include maintaining consistency in the survey and interview instruments while also allowing changes in the items used. The longitudinal nature of the project also forced the project team to address continuing participation of students who changed majors from engineering or who had graduated and did not provide post-graduation contact information. Recommendations for future longitudinal studies are also provided.
1.0 Introduction

Many national organizations have recognized that technical expertise is no longer solely sufficient for the development of future engineers and that change in engineering education is needed to address this need. This paradigm shift requires an engineering education that 1) broadens the attributes provided by it, 2) the diversity of those who participate in it, and 3) a more holistic-approach to illustrate all the benefits developed from it. One dramatic and widespread movement within engineering education is community engagement (CE). Yet, a thorough understanding of the outcomes, beneficial and otherwise, still exists. Evidence does exist suggesting CE does provide value to engineering students, 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.

The Impact of Service on Engineering Students project, also termed the Engineering Pathways Study (EPS), represents one of the recent attempts in a long-term examination of CE. The three-year project is aimed at evaluating how attributes of future engineers are obtained through CE and how these attributes develop over the time of undergraduate education. The study consisted of the evaluation of 1) developing protocols for quantitative (on-line surveys) and qualitative (interviews) measures for attributes desired in engineering; 2) compare ‘attainment’ or ‘level’ of these attributes between students who have participated in CE efforts (curricular and extracurricular) and those who have not; and 3) evaluate changes in attainment/level over time.

The study was administered to over 250 engineering students from various institutions throughout the U.S. Student participants were to be grouped according to their level of community engagement. Primarily, we sought to explore the impacts of CE 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). A secondary purpose (broader impact) was to understand how CE 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. The study’s final round recently occurred, and the study’s collected data is currently undergoing various analyses. However, a number of issues presented themselves during the study’s implementation of the study.

This paper focuses on the insights or ‘lessons learned’ during the study’s development and implementation, with a focus on how to maintain participation rates. Specifically, insights discussed in this paper include methods in 1) recruitment and retention of student participants, 2) compensation of participants, and 3) maintaining participant interests in each round of the study. Other insights to be discussed include maintaining consistency in the survey and interview instruments while also allowing changes in the items used and/or increasing the number of indicators to be explored. The longitudinal nature of the project also forced the project team to address continuing participation of students who changed majors from engineering or who had graduated and did not provide post-graduation contact information. Finally, the paper provides recommendations for future longitudinal studies.
2.0 Motivation

For the purposes of this work, community engagement (CE) is taken as an amalgamation of various pedagogical methods, including service learning, community-service, and project-based learning, among others. The distinguishing aspect of CE in engineering education is the intentional design of the effort to incorporate service as a means to meet academic learning objectives. Previous work has shown that CE has the potential for student development on the cognitive, social, and moral levels with the educational or psychological constructs of CE based on the theories of Dewey, Piaget, Kohlberg, Vygotsky, and Kolb. In engineering, CE efforts are usually projects that connect a community’s need to technical requirements. Often, CE efforts can serve as the primary motivator for student and faculty participation. The community projects also provide a rich socio-cultural context that has been found to stimulate the process of collaborative problem-solving.

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. 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, cultural competency, critical thinking, self-efficacy, sustainability, and leadership.

Community engagement (CE) in engineering education is defined as a form of active, experiential learning where students, instructors, and the community/client work collaboratively on projects that benefit a real community need. This definition provides an umbrella under which many previous definitions and descriptions of service-based learning activities can be housed, but is grounded in three interrelated elements that have been traditionally used to describe such learning activities; namely,

1. The CE efforts must be authentic with the project initiated by the learners or by the affected community.
2. The service must be intentional and appropriately developed, i.e., it is grounded in the needs of the community and developed jointly by all stakeholders, most specifically the learners and the affected community.
3. The learning is the primary goal in carrying out the project and is enhanced by the service nature of the effort. Therefore, the learning must be planned and assessed, especially through the use of structured, critical reflection.

As a pedagogical approach, CE most strongly is connected to service-learning (S-L). Though Furco (2003) stated that at least two hundred different definitions of service-learning have been published, the distinguishing factor of between S-L and community-service is that S-L is intentionally designed to meet learning (often academic) objectives. Other components common in service-learning definitions include 1) the need for student reflection on the value of the effort, 2) the connection and integration of the effort with the community, and 3) the attainment by participants of the desirable outcome of civic or social responsibility.

The benefits of CE projects are well documented in the literature. A longitudinal study on over 22,000 college students who participated in a variety of service efforts – from curricular-
based service-learning to participation in various community service activities – suggest 1) CE provides significant positive impacts for a variety of outcomes including academic performance, leadership, and self-efficacy; and 2) course-based service-learning efforts has a stronger impact on many of these outcomes than a student’s participation solely in community service efforts.5

3.0 Description of EPS Study
The EPS project has been previously described in the literature42, 51. Though a brief description of the project follows, the reader is referred to these references for more detailed information. The study required participants to take an on-line survey comprised of a number of instruments to evaluate student learning and attitudes. A sub-set of participants would also be interviewed. Participants were recruited primarily from four target institutions (Figure 1). The various institutions were diverse in size, type, mission, and student socio-economic conditions. A fifth ‘institution’ of participants was created from members of student chapters of Engineers Without Borders (EWB) throughout the U.S.

As planned, 480 students would be accepted as EPS participants. Students would be recruited through various faculty existing at these institutions or through the EWB-USA national newsletter. Participants would receive compensation (via an electronic gift card through Amazon.com) for their participation for each of the six rounds of the study that they completed – one each spring and fall of the 3-year study (Spring 2011 through Fall 2013). It was anticipated that approximately 75% of the participants (360) would be designated as ‘survey only’ participants, only required to take the multi-item, on-line survey. The other 120, designated the ‘interviewed’ group, would take the survey, be interviewed, and take an evaluation for cultural competency (see below for more discussion of the indicators).

![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.](image-url)
For each of the four institutions noted in Figure 1, it was desirable to follow three different groups or cohorts; a) students involved in extracurricular CE; b) student who participate in an CE course/program; and c) students not involved in CE efforts (control group). These cohorts were subjected of semi-annual on-line surveys aimed at quantitative (Likert-scale) measures of self-efficacy, motivation, attitudes, ABET criteria, and mental health. A sub-set of students at each institution were also selected for semi-annual interviews (qualitative measures) and also had to complete the IDI cultural competency evaluation annually during the project’s three-year duration. Two staggered clusters of student were created; one a cluster of first-year students (followed for three years to their junior year) and the other a cluster of junior-year students (followed through post-graduation).

3.1 Study Indicators Used in the Study

The EPS study focused on a number of indicators previously found to influence one’s ability to learn – self-efficacy, motivation, identity, cultural competency, well-being, etc. These indicators were explored through a number of instruments briefly reviewed below.

1. **Strong alignment with ABET criteria 3a-k.** The National Engineering Students’ Learning Outcomes Survey (NESLOS) was used to measure students’ perceived learning outcomes. The 51-item NESLOS was derived from extensive STEM education literature as well as ABET criteria 3a-k,44,45,46.

2. **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,4,6,24,26. We investigated engineering students’ perceived attitudes towards learning and performance using the 16-item Attitudes Towards Learning (ATL) scale, available through the Center of Assessment and Research Studies at James Madison University.

3. **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 populations,7,8,38. A 31-item instrument, based on students’ self-efficacy for engineering design, was used to evaluate students perceptions and attitudes on self-efficacy and motivation.

4. **Mental health.** Measures of psychosocial factors can be indicative of one’s well-being; i.e., mental health versus mental illness. A 12-item instrument, using Keye’s Flourishing Scale, was administered to provide a categorical diagnosis of “flourishing” or “languishing” mental health of students,5,18,33. Community engagement may be a viable impetus for one to “flourish” and achieve higher well-being. How mental health changes over time, especially in the presence, lack of presence, of CE, is also of importance.
5. **Mindset, work and life.** The importance of mindset on a variety of learning, professional, and personal outcomes has been recently established\(^\text{23}\). Several on-line survey items were included to evaluate whether participants have a fixed- or growth-oriented mindset. In addition, questions were added that probed participants’ attitudes toward career, employers, personal life, and work-life balance\(^\text{55}\).

6. **Engineer identity.** Engineer identity has been an under-studied research topic \(^\text{36, 52}\). Recent advances in identity theory have come to recognize that people have multiple identities. Therefore, it is important to investigate if an engineer identity is triggered during CE efforts and if that identity is strengthened or weakened during such experiences. An evaluation of identity was done through responses in the interview protocol.

7. **Cultural competency.** Cultural competency is a relative measure of one’s ability to interact with people from different cultures \(^\text{11, 19}\). It is hypothesized that many CE experiences, especially those related to international efforts, require students to work in a culture entirely different than their own. An evaluation of cultural competency, via the Intercultural Development Inventory (IDI), was performed only on with ‘interviewed’ cohort.

**3.2 Expected Participant Levels and Study Process**

The study was developed to have 480 students (240 in each cluster) be evaluated over the three-year project. All participants would take the on-line survey protocol. A subset of 120 students (approximately 60 from each cluster) would also be interviewed (twice a year) and IDI evaluations. A summary of the indicators performed and the schedule of round implementations is shown in Table 1.

**Table 1. Schedule of Indicators Performed on the EPS Participants**

<table>
<thead>
<tr>
<th>Indicator/Instrument</th>
<th>Targeted Group</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>‘Interviewed’</td>
<td>‘Surveyed Only’</td>
</tr>
<tr>
<td>PRESOLS - National Engineering Students’ Learning Outcomes Survey</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Attitudes Toward Learning Scale</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Self-efficacy and Motivation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flourishing Scale</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mindset, Work, and Life</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
By combining all of these instruments into a single, on-line survey effort would lead to a diverse, but immense, protocol. If done with care and attention by the participants, this protocol could provide a number of multi-dimensional statistical tests and analyses.

The interview protocol consisted of 30 questions related to the participants views and opinions about a) the attitudes they had about engineering, b) the knowledge gained in their studies, c) the effectiveness of their studies in creating successful engineers, d) the satisfaction they felt about their area of study and/or the direction of their profession, and e) thypes of projects (with or without CE aspects) that they have been engaged in. It was expected that the completion of the protocols would require approximately one-half hour of commitment for ‘surveyed only’ participants and up to two hours of commitment for ‘interviewed’ participants.

Student composition for both groups will remain unchanged throughout the study (other than through attrition due to non-responsive participants). In addition, once participation began, students remained in that cohort throughout the study, regardless of their path. 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 study.  

4.0 Issued Encountered in EPS Study

4.1 Student recruitment/retention

As stated previously, student participants were drawn from volunteers solicited via targeted announcements on each campus. The students associated with student chapters of EWB-USA at other institutions across the country were solicited through a broad announcement via EWB-USA. This initial solicitation occurred during the Fall of 2010 with the expected launch of the on-line survey and interview protocols expected in Spring 2011. The solicitation stated the purpose of the study, its goals and aim and duration. The solicitation also stated that study participants would be financially compensated - $20 per round if designated a ‘surveyed only’ participant and $50 per round if designated a ‘interviewed’ participant. Students were placed into appropriate clusters and cohorts pools based on class level and their expressed intentions for the next three years (i.e. their plan to participate in CE activities, or not). All interested 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 CE 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 the engineering profession).

This initial solicitation led to approximately 425 responses – approximately 235 first-year students and 190 juniors. This was below the desired 480, but the response level was deemed sufficient to continue with the study without making a follow-up request for more participants. Therefore, all 425 responses were accepted as participants in the study and notified of their
acceptance. The 120 ‘interviewed’ participants were selected at random from the entire pool of prospective participants, with an effort to ensure adequate representation among all target groups within engineering programs (gender, ethnicity, disciplines). These students were also notified. When the first round of the study occurred in Spring 2011, only 254 participants responded. However, all 120 of the interview participants responded. The authors believe this immediate attrition of approximately 170 potential participants from the ‘surveyed only’ was due to the two primary reasons:

1. Students who did not get the higher compensation associated with being in the ‘interviewed’ group decided to no longer participate in the study, and
2. The on-line survey instrument consisted of too many items (approximately 176 requested responses) for participants to complete in a timely manner; thus making their effort not worth the compensation.

Attempts were made in subsequent rounds of the study to prevent further attrition. These efforts included a) reducing the number of items that required responses in the on-line survey and b) increasing the compensation level of ‘survey only’ participants. In addition all 254 participants from Spring 2011 (Round 1) were invited to participate in all subsequent rounds. With these modifications, the attrition rate from the first round reduced to 69% of the initial round (from 254 to 173 total participants). Figure 2 provides a plot of number of survey questions over time compared to the number of study participants who successfully completed the on-line survey.

**Figure 2** Number of Study Participants ('Survey Only' + 'Interviewed') Compared to Number of Questions in On-line Survey in Each Round of Study

It is clear from this plot that attrition continued throughout the study until the later rounds (Spring and Fall 2013) when compensation for participation increased for both the ‘survey only’ and ‘interviewed’ groups (Figure 3).
Lesson Learned: While not definitive, the study results, as illustrated in Figures 2 and 3, indicate the level of financial compensation plays a significant role in recruitment and retention of participants in the study.

In addition to financial compensation, was enhanced by reducing the number of questions in the on-line survey in subsequent rounds. This was done by removing certain questions from specific instruments for rounds 2 through 5 (Fall 2011 through Spring 2013). In the final round, all questions/items used in any previous round were included. The impact of removing certain questions from an existing instrument will be a focus of future data evaluation. However, though questions were initially reduced to decrease a participant’s time to complete the survey; reducing survey fatigue, additional questions were also added each round as more attributes were measured. For example, questions for Mindset, Work, and Life indicators were added in subsequent rounds of the study.

Lesson Learned: Creating an appropriate survey length is important in retaining participants. A balance needs to be made between survey length, variety of questions, and compensation level.

4.2 Incentives for continued participation

As noted previously, the level of participant compensation increased over time. In addition to these increases, ‘mega-prizes’ were introduced each year; made available to selected participants (via lottery) who completed 2 consecutive rounds. The mega-prizes ranged from an additional one-time compensation of $100 to $250 gift cards or products such as an I-Pad tablet. Participants were made aware of these rewards prior to taking part in subsequent rounds. It is unclear if the presence/availability of these rewards enhanced participation and retention.

![Figure 3: Number of Study Participants ('Survey Only' + 'Interviewed' Groups) Compared to Financial Compensation for Each Round of the EPS Study](image-url)
However, one of the major concerns with compensation was the delay in getting it to the participants in a timely manner. There was no direct connection between the participants and the compensation vehicle (Amazon.com) as each completed survey need to be verified. In addition, participant interviews could occur up to 8 weeks after they had completed the on-line survey, leading to a significant lag time between a when a participant started a round and when they completed all parts of it.

Lesson Learned: Mechanisms for compensation to participants need to seamless with participants’ completion so that it occurs within days and not weeks of a participants completion.

Other issues that occurred during the study period included:

1. Changes in participant’s contact information could lead to ‘lost’ participants who could no longer be contacted.
2. Miscommunications during data collection during study when participants would only partially complete the on-line survey and believe that they should be compensated.
3. Participants incorrectly listed as ‘survey only’ instead of ‘interviewed’ groups leading to incorrect levels of compensation (or in some cases making both lists and receiving two levels of compensation).
4. On rare occasions, participants became confused about, or would not understand the level of compensation they were entitled to; e.g., believing that they should be receiving both the ‘survey only’ and ‘interviewed’ compensations.

5.0 Discussion, Summary, and Conclusions

In summary, the EPS study was successful to gather extensive data that could illustrate the impact of service (community engagement) on engineering students – both in academic and personal development. The multi-indicator efforts which included both quantitative and qualitative data collection over a three-year period shows promise to add significantly to the evidence regarding the positive benefits of community engagement. Analyses to evaluate how community engagement impacts various indicators of student learning are on-going.

Therefore, the focus of this presentation was on the implementation of the study. In this respect, the overall recruitment efforts did not meet the target value of 480 students. However, retention efforts proved successful with approximately 70% of the participants retained throughout the study period. In addition, some participants expressed interest in participating in a continuation of this or similar studies. The opportunity to extend the study to years significantly beyond graduation would truly enhance the data. Based on the procedures established in the current study, it is clear that the compensation level and length of commitment in each round are important aspects to consider.

5.1 Areas of Improvement

Whether extending the current study, or conducting a different longitudinal study, the following recommendations should be considered.

a. If compensation of participants is to be done;
   i. the level of compensation should be set to be an incentive for all participants
ii. The process to compensate participants needs to provide payment immediately.

iii. Alternative forms of compensation should be considered to entice those participants who may desire something different. Alternatives can include multiple vendors or non-monetary forms of recognition.

b. The protocols to be used should remain consistent throughout the study.

c. In an effort to prevent survey fatigue, it may be better to keep the survey lengths smaller and ask participants to complete various instruments (if applicable) in a shorter time frame.

d. If possible, communication with participants, even between rounds, should be pursued.

6.0 Acknowledgements

This material is based upon work supported by the National Science Foundation under Grants Nos. 1025207 and 1025220. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

7.0 References


