AC 2012-3475: A MULTI-DIMENSIONAL MODEL FOR THE REPRESENTATION OF LEARNING THROUGH SERVICE ACTIVITIES IN ENGINEERING

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A Multi-Dimensional Model for the Representation of Learning Through Service Activities in Engineering

1. Introduction

Learning through Service (LTS) is a rapidly growing pedagogy in engineering education. The implementation of LTS programs has been, in part, a reaction to a paradigm shift that has taken place in undergraduate engineering education; the rebalancing of the development of professional skills (sometimes called "soft" skills) in addition to technical skills. This shift was largely a response to the 1994 report of the Engineering Deans' Council and the Corporate Roundtable of the American Society for Engineering Education[1], and also to the National Academy of Engineering's *The Engineer of 2020*.[2] The 1994 Green Report[1] asks engineering educators to "reexamine their curriculum and programs to ensure they prepare students for the broadened world of engineering work." This includes accelerating the implementation of programs that help engineering graduates develop teamwork, communication and leadership skills while enhancing students' appreciation of culture and diversity, global perspective, and the societal, economic, and environmental impacts of engineering decisions. While strong analytical skills will continue to be as important, according to *The Engineer of 2020* future engineers will need to exhibit:

- practical ingenuity
- creativity
- good communication
- project management
- leadership
- high ethical standards
- and strong sense of professionalism.

Future engineers must also be dynamic, agile, resilient, and flexible to deal with the uncertain and changing character of the world in which they work. And finally, they must be lifelong learners who continue to update their knowledge base and skills throughout their careers.

A decade ago ABET's Engineering Criteria 2000[3] formalized the incorporation of professional skills into the undergraduate curriculum. The ABET Criterion 3, Student Outcomes, requires programs to demonstrate among other things competency in teamwork, communication and understanding the impact of technology on society and the environment. Through adoption of the Washington Accord, other countries have followed suit and learning outcomes similar to those expressed in ABET 2000 Criterion 3 are becoming universal.

Responding to the need to develop the skills and competencies outlined above, many engineering educators have begun to implement various forms of experiential learning. In this paper we focus on *service learning*, a proven type of experiential learning in which students are engaged with community service, for academic credit or as a co-curricular activity. Learning through Service (LTS) programs take many forms:

- Purdue University's EPICS (Engineering Projects in Community Service), a vertically-integrated, multi-year and multi-disciplinary service-learning program that has now spread to over 20 universities.

- Service-learning embedded into the entire engineering curriculum such as at the University of Massachusetts-Lowell, and Worchester Polytechnic Institute.

- Stand-alone courses such as *Introduction to Engineering Design* at Western Michigan University, *Engineering Strategies and Practice* at the University of Toronto, or *Global Engineering Outreach Projects* at Brigham Young University.

- Community-inspired research and design projects such as the D80 Center at Michigan Tech.

- Co-curricular or extracurricular group design projects sponsored by organizations (e.g. Engineers without Borders, or Tetra). These types of projects exist at many schools.

In September 2011, engineering educators who have been engaged in LTS gathered on the campus of the University of Colorado for a summit. The summit was organized by the Engineering Faculty Engagement in Learning Through Service (EFELTS) project which has as a goal "to evaluate the impacts on faculty currently engaged in LTS efforts and to empower additional faculty to implement LTS."[4]   Some of the goals of the summit were to explore why faculty are involved in LTS; how they do what they do; and what they would recommend to a new generation of LTS faculty.

This paper from some of the summit participants describes a model for LTS in engineering that was developed through discussion at the meeting. As this group discussed the goals listed above, one of the first questions was "What qualifies a program as Service Learning?" which led to another question, "What are the characteristics of LTS?" and further, "How can LTS programs be categorized and evaluated to both help new programs start up and to help ongoing programs to scale up?" The model described herein is an attempt to answer the above questions. The goal of the model is to describe LTS programs in a way that allows us to compare and contrast the characteristics of these programs that exist in various forms at many universities. It provides a characterization of the many different ways LTS has been implemented. The model can be used to assist educators and administrators who are new to this pedagogy by giving them a check list for designing their own program; guiding them thoughtfully through the choices they need to make in the design process.

2. Background

Learning through Service not only assists students in the development of ancillary skills, but can also fundamentally change the nature of the learning experience. There is a substantial body of literature on service learning and the many ways it can benefit and deepen the learning process (e.g. the Michigan Journal of Community Service Learning and the International Journal for Service Learning in Engineering). As such, there are already some models which attempt to describe types of service learning programs, and how this approach relates to learning theory. We will not provide an exhaustive literature survey here, but simply touch on two models, one

from learning theory and one from the LTS literature, which pertain directly to the model we have developed.

Some of the differences between service learning and a traditional university learning experience can be understood through the conceptual framework of Jarvis's Learning Process model.[5] Jarvis describes who a person is currently as their lifeworld, and defines learning as a change in their lifeworld. This change comes about through an experience they have. The experience has meaning for the person which is social constructed; i.e. their perception of the experience is shaped by their current lifeworld. The person then acts on the meaning of this perceived experience through emotional response, thought and refection, and action (e.g. negotiating meaning with others, or testing ideas through action). The result is the incorporation of the experience into their lifeworld complete with the meaning, emotion, and ideas that they have attached to it. This changes their lifeworld. This is learning according to Jarvis's model. In comparison, traditional engineering university learning experiences often embed technical concepts and skill development in social situations that are inauthentic to actual engineering practice and lack cultural/political context. A student might, for example, associate studying calculus with the professor they had (for better or worse) and the people they sat with in lecture, because this is the social context in which they experienced calculus. From this experience calculus may be perceived as a tool for solving textbook problems for the purpose of achieving a good grade. Alternatively, service learning provides an experience in a potentially rich cultural and technical context. It is often active (requires action to negotiate meaning) and requires reflection. There is an emotional/social element to the learning experience that is quite different than traditional university learning experiences. All of these things in Jarvis's model work together to produce a broader impact on the student's lifeworld. Jarvis's model is useful for reflecting on the differences between traditional and LTS pedagogy, and the similarities and differences amongst LTS programs in some dimensions. It can also provide a guide on how to increase the impact of the learning experience. Some aspects of Jarvis's model are reflected in our proposed model for LTS programs. However, a learning model alone is not sufficient for fully coming to grips with designing or operationalizing (i.e. implementing) an LTS program.

A model which comes from the LTS literature, and therefore was formulated more specifically for this pedagogy is Butin's four models for community engagement.[6] Butin's models actually describe four goals commonly associated with community service learning: technical, cultural, political, and anti-foundational. These models reflect the differences in learning goals identified by faculty who use service learning:

- Technical; LTS is used primarily to increase content knowledge and retention of knowledge.

- Cultural: LTS is used primarily to enhance "civic engagement and cultural competency"; i.e. change the internal understanding of self and one's role in society.

- Political: LTS is used with the goal of political activism; this is closely tied to a social justice agenda.

- Anti-foundational: LTS is used to produce "cognitive dissonance"; i.e. the goal is to disrupt the student's underlying assumptions about the world and themselves to motivate learning.

Many LTS programs in engineering embrace more than one of these models, and seek to find a balance between technical learning goals and cultural, political, and/or anti-foundational goals. This balance is reflected in the model we propose.

3. Description of the Model

Our group formulated a model which characterizes 12 dimensions of LTS programs in engineering. This model provides a basis for comparing and contrasting programs. In addition, it can be used as a check list for developing a new LTS program, evolving an existing LTS program, integrating LTS into a curriculum, or assessing the quality of an LTS program.

The dimensions are formulated to capture the qualities of current LTS programs that are present across a wide breadth of engineering institutions. As such the dimensions need to encompass the broad variety of existing programs as well as take into account future developments in this pedagogy. The dimensions fall into 4 key categories: Academic, Program Design, Management, and Technical-Social Balance.

Table 1. Academic Characteristics

None	⇐	1. Learning Outcomes	⇒	Clear, rigorous, both technical and non-technical
None	⇐	2. Deliverables	⇒	Substantial, many
Little	⇐	3. Assessment	⇒	Rigorous, well aligned
Purely experiential	⇐	4. Civic Outcomes	⇒	Reflective, civic outcomes assessed
		⟺		
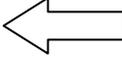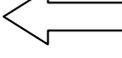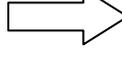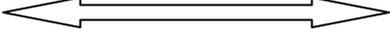
Four academic dimensions were identified as shown in Table 1. Several interesting aspects of these dimensions came to light during the discussions. First, it became clear that some of these dimensions represent "threshold" requirements for an effective LTS program. For example, a program that has no learning outcomes cannot be characterized as LTS. So there is a minimum threshold necessary in this dimension, and moving towards clear, rigorous outcomes should be a goal in the design of any educational program including LTS programs. Learning outcomes should be articulated for sound program design. A statement of the intended learning outcomes is needed to support other academic elements of the program such as assessment. Learning

objectives may include both technical and non-technical components, as discussed below. Dimension 2, deliverables, is an important aspect of assessment. There should be some form of deliverable that can be used for outcomes assessment and provide a meaningful outcome for the target community. The deliverables might include but are not limited to things such as diaries or blogs, research reports, engineering reports, prototypes, presentations, and/or fully functional devices. The deliverables should have a clear connection to the academic and civic goals of the program. The deliverables dimension obviously is one in which the goal is somewhere in the middle of the scale; not too many, not too few. The third dimension, assessment, should include both technical and non-technical aspects that are well-aligned with the learning objectives. Civic outcomes, the fourth dimension, should complement the academic learning outcomes and provide a meaningful contribution to society and/or personal development of the student. Evidence of civic engagement and self-awareness are key elements in assessing the civic outcomes.

Several of these dimensions obviously relate to Jarvis's model and Butin's models.[5,6] Producing deliverables (i.e. action) and reflecting on one's experience are aspects of learning in Jarvis's model. Reflection and action allow the student to move beyond their "first impression" of the experience. That is, move beyond the first meaning they assign to the experience. They must explore and deepen their understanding through negotiation of meaning, combining this experience with other experiences (studying a textbook, hearing a lecture, engaging in discussion, etc.), and reflecting on themselves and society (i.e. achieve civic outcomes). Having substantial, well-defined outcomes helps an instructor define their objectives in terms of Butin's models. This is explored in more depth in dimensions 11 and 12.

Table 2. Program Design Characteristics

⟸ 5. Curricular positioning ⟹			
Extra-curricular	Co-curricular	Elective	Required for graduation
⟸ 6. Student group characteristics ⟹			
1 person	6.a) Size		Large teams
Single discipline	6.b) Disciplines		Multi-disciplinary, including non-engineers
⟺			
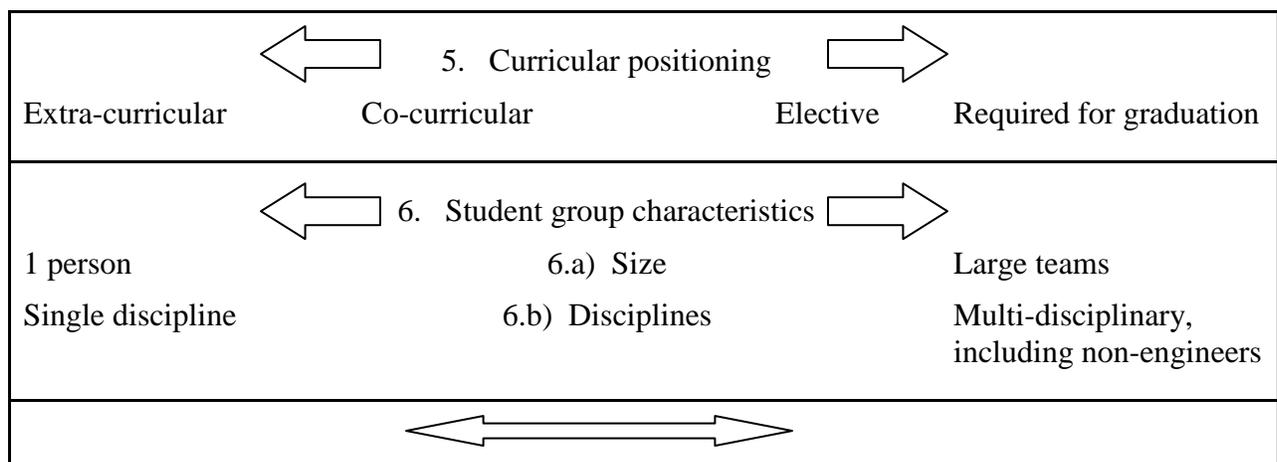
Meaningful LTS experiences can fit into a broad range of academic and non-academic settings. Some institutions may require LTS activities as a degree requirement, through formal course offerings or other requirements. Others may choose to work with student groups through extra-curricular or co-curricular opportunities such as Engineers Without Borders (EWB) or Habitat

for Humanity (HFH). Dimension 5, shown in Table 2, represents this variability as the curricular positioning of the program.

Group size and composition also vary from a single student to large, multi-disciplinary teams including both technical and non-technical majors (dimension 6). There is no minimum threshold on the size or scope of projects that may be considered as valuable LTS experiences. As such dimensions 5 and 6 have no optimal threshold or goal (in contrast to dimensions 1 through 4). The dimensions in table 2 simply describe the characteristics of a program. Faculty or schools who are starting LTS programs may find it easier to begin at the left side of these dimensions and evolve to the right. These dimensions also serve as a point of discussion for faculty teams involved in, or planning to get involved in LTS. There may be strong feelings amongst some team members that LTS should be a required curricular element, or involve multi-disciplinary teams. In our experience working through these discussions, the development of shared values by the teaching team on issues such as these during the program design process can make the implementation phase run more smoothly.

The dimensions in Tables 2 and 3 pertain to concrete implementation issues for a LTS program, which sets this model apart from the more theoretical models in the literature. However, disagreement over these concrete issues can pose significant difficulty for a teaching team that is developing an LTS program. Coming to terms with these issues are important steps in the implementation of an LTS program.

Table 3. Management/Administration Characteristics

From the university perspective		
Few students Few faculty ⇐ 7. Size of program ⇒ Many faculty Few staff Few community partners		Many students Many staff Many community partners
Local ⇐ 8. Geographic Context ⇒ International		
From the community partner perspective		
Short ⇐ 9. Duration ⇒ Long, possibly years		
Minimal/indirect ⇐ 10. Interaction ⇒ Immersive		
⇐⇒		

Table 3. shows dimensions related to the size and scope of the program which impacts on program management, resources and logistics. Program size encompasses many individual parameters such as the numbers of participants and support needed. Smaller programs require less staff support and may be implemented by individual faculty. However, larger programs may require funding and administrative support at the department or university level. Program design and planning should strive to ensure that sufficient administrative support is provided for larger programs. Dimension 8 is Geographic Context and describes the global coverage of service learning projects and stakeholder involvement. Local projects are logistically easier to implement and typically less expensive than international projects, and can be structured to provide many of the benefits of LTS. The left end of the spectrum in these dimensions may represent an easier entry path for practitioners interested in starting a new LTS program.

The engagement of community partners is a vital component of a successful LTS program. Programs may involve a community partner only for the duration of a single project and still enable a meaningful experience for the students. Longer term community partners can provide a reliable and ongoing source of projects as well as financial support, and these partners also tend to develop a deeper understanding of the program's desired outcomes. Students may interact with clients at various levels, from liaising through the faculty with limited or no direct student-client engagement, to fully immersive experiences. From a community partner perspective minimal, indirect, or very short term interaction may not yield the results hoped for. However, long term, immersive programs require a substantial community engagement and commitment and on-going stewardship on the part of the institution. Therefore it is important to carefully plan the size and scope of the projects and engage the community partner appropriately so they are fully aware of what is expected from them and what they can expect in return and to take into account the time and effort required for faculty to maintain a community relationship effectively.

Table 4. Technical/social balance

None	⟵	11. Technical content	⟶	Deep, complex
None	⟵	12. Social/cultural content	⟶	Deep, complex
		⟷		
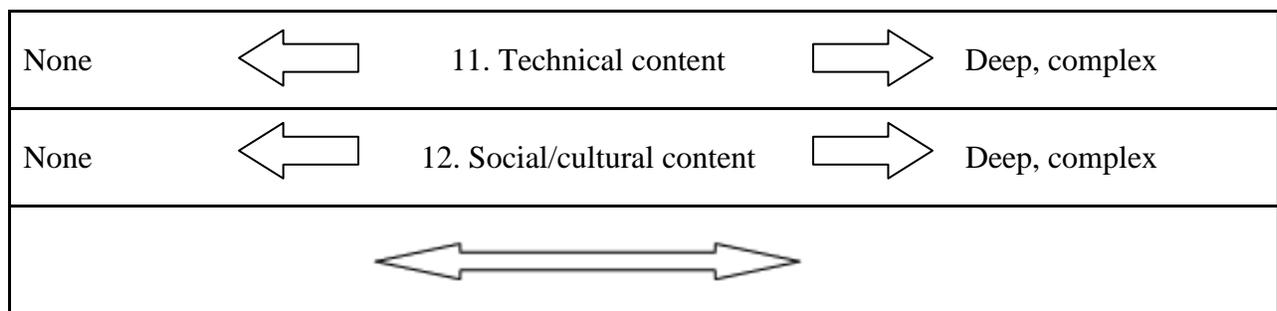
The group that developed this model explored the balance between technical content and social/cultural content in more depth and a definition of what kind of content makes LTS an engineering-specific or engineering-inclusive experience as opposed to non-engineering LTS. This led to a realization that program objectives often drive the design of LTS in these dimensions. One obvious observation is that a program which is purely technical with no substantial social or cultural context is not learning through service. This limit perhaps best

describes a traditional technical engineering course. Similarly a program which is purely social and cultural with little technical content could perhaps best be described as a social science or humanities LTS experience for the students. Most engineering LTS programs try to achieve some balance between these two dimensions. At the freshman level faculty often try to find projects that have relatively basic technical content and tend to emphasize the importance of social/cultural context. At the upper year level there is the opportunity to have the students working on more complex technical projects that also require them to address the social/cultural context. Ideally at this level the student is bringing to bear both their technical expertise as well as a deeper understanding of the social and cultural issues.

In this sense, it helps to also consider the balance of technical versus social/cultural learning goals in a two dimensional system, as shown in Figure 1. Quadrant 1 has low technical and low social/cultural learning goals. Basically, little planned learning is actually occurring. The students may be participating in an experience but without more clearly defined learning outcomes (see dimensions 1 and 4) the experience is simply a volunteer opportunity or service without learning goals. Programs that fall in quadrant 2 could best be described as a humanities or social science service learning programs. There are few or no technical learning goals. Courses or experiences in quadrant 3 could best be described as traditional technical engineering courses. There are few or no social or cultural learning goals. The service may provide some context for the technical learning, but there are no planned learning outcomes in the social/cultural domain.

Most engineering service learning programs would then be situated in quadrant 4. At a freshman level the learning goals on both axes may be modest. However, in a capstone type project or a multi-year project we would expect substantial learning to take place in both dimensions. Ideally the program would be planned to have deliverables, learning outcomes, reflection and community engagement that supports substantial learning in dimensions 11 and 12. The difference between points 4 and 5 represents the sophistication and depth of a project. While 4 may represent a freshman LTS experience, 5 would be a capstone LTS experience, building upon previous technical and social learning in programs such as EPICS, which provides graduated project experiences for freshmen through seniors and graduate students that can become more complex as the project progresses and as more senior-level students become involved.

This balance can be viewed in terms of Butin's models.[6] Basically, we have collapsed Butin's Cultural, Political, and Anti-foundational models onto one axis. In our experience few engineering LTS program have a very strong anti-foundational goal set. The goals tend to be more often technical, cultural, and political. We could separate the cultural and political goals to better articulate the differences between programs. However, many engineering faculty do not draw a clear distinction between learning goals focused on "expanded understanding of self" and goals focused on "fostering a more equitable and socially just environment" that Butin describes.[6] It is probably sufficient to say that a well-designed engineering LTS program should strive for a balance between technical and social/cultural outcomes and that both are important aspects of LTS in engineering.
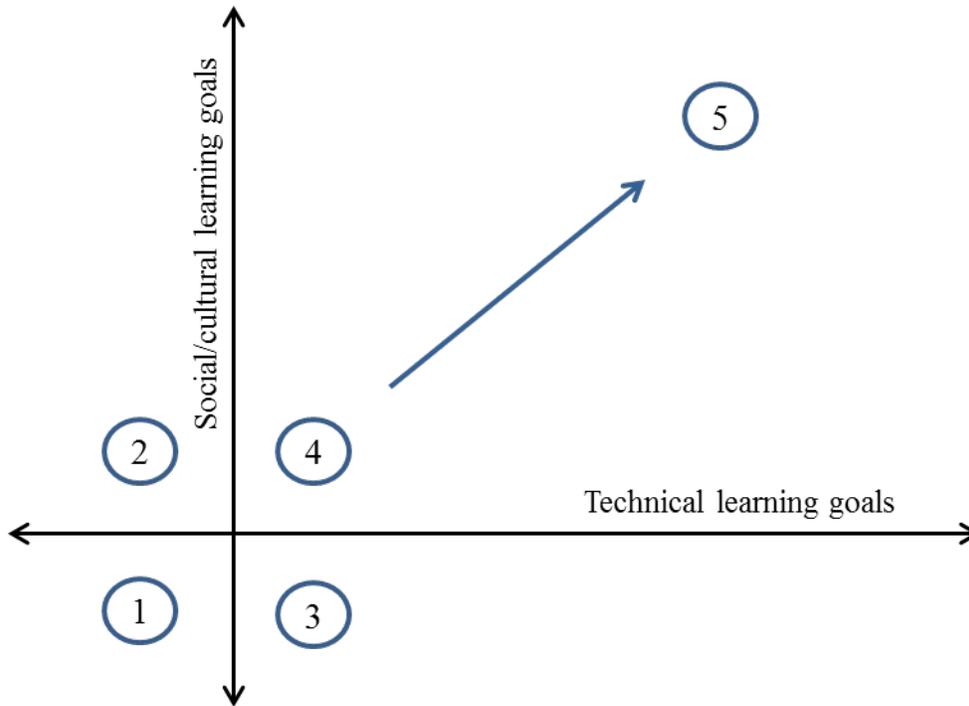
Figure 1. The relationship between technical and social/cultural learning goals in engineering LTS programs.

4. Exemplars of Current Programs

In this section we compare several examples of LTS programs at very different institutions. We use proposed model as a framework to compare and contrast these programs.

Example 1. The WPI *Global Perspective Program*[7,8]

WPI implemented a unique project-based curriculum over 40 years ago. The "WPI Plan" requires students to complete not only a senior capstone project in the major, but also a junior-level "interactive" project (IQP) that "relates technology and science to society or human needs".[7] This project is a degree requirement equivalent to 9 credit-hours of student effort, usually conducted by multi-disciplinary teams of 2-4 students, under direct faculty supervision. Currently, over half of all WPI students fulfill the IQP requirement at one of sixteen international and domestic project centers through participation in the Global Perspective Program.[8]

WPI has articulated a clearly defined list of learning outcomes for the IQP. These objectives include developing research, communication, teamwork and problem solving skills as well as increasing awareness of social context and ethics, so this program would be placed high on the Learning Outcomes scale. The high level of Deliverables typically consists of an extensive written report as well as numerous oral presentations throughout the duration of the project. The reports and student performance throughout the project are assessed by faculty in accordance

with the stated learning outcomes. While reflective assignments are not specifically required by most faculty supervisors, due to the immersive nature of the projects, civic outcomes are substantial. Program evaluation through re-entry programs, surveys and focus groups of program participants has demonstrated the substantial civic and cultural impacts of these projects.

The WPI GPP program ranks as a very large program, with over 400 students, 50 faculty, and 100 community partners annually. The program is supported by a full-time dean and five administrative staff. The program encompasses a wide range of project center locations, from local sponsors in Worcester to international sites on five continents. Students work full time for seven weeks on-site with their project sponsors, a fully immersive experience. While new sponsors are recruited on an ongoing basis, many long-term relationships have developed throughout the years, and a majority of sponsors will host multiple project teams over the course of several years. These projects focus on social impacts of technology and therefore strike a balance between technical and social content, with some variation from project to project.

While WPI's GPP ranks on the high end of the spectrum for most of the elements in the LTS model, it is worth noting that this program has grown and evolved over several decades, with full support from the faculty, students and administration, and has become embedded within the WPI culture.

Example 2. *Engineering Strategies and Practice* at the University of Toronto[9]

In contrast *Engineering Strategies and Practice* (ESP) at the University of Toronto uses a one semester (13 week) service learning project at the freshman level. The course carries equal weight to the other 4 courses the student takes in the spring term of their first year. The course is mandatory for most first year students, and has an enrolment of about 850 to 950 each year. Multi-disciplinary teams of 4 to 6 students work through a design project during the semester culminating in a final report to their client organization and a presentation. The client also receives two interim reports, and there are a number of other deliverables that are submitted to the course instructors.

The learning outcomes are substantial and well defined. The outcomes include demonstration of design ability, team skills and communication, as well as systems thinking, independent learning, and problem solving. The course emphasizes the importance of considering social, environmental, human factor, and economic considerations in the design process. One deliverable in particular, the final individual portfolio, is used to assess the student's contribution to the team and development of their professional identity.   The design reports also include sections related to the impact of the design with respect to the organization and its goals, which are typically social, cultural, and/or political in nature.

The course requires substantial resources. There are over 30 teaching assistants involved, who have been trained in facilitative teaching and advising on teamwork and communication skills. There is a group of professional communication instructors, and a communication coordinator for the course who specialize in engineering communication teaching. There are approximately 15 faculty members involved as project managers for the 180 different projects that happen each spring. The community partner contributes 4 hours of their time for meetings with their team, typically on site at their organization offices, and attendance at the final presentation. Many of

the teams spend additional time at the organization's site collecting data, volunteering, or observing the operation of a facility to get a better understanding of the design problem. The interaction with the client, on average, could be described as short term, and low (i.e. not immersive). While the resources committed are substantial, in fact an analysis has shown that the cost of this course is approximately equivalent to a laboratory course for the same number of students. It was designed to be cost neutral, and has successfully been run this way for several years now.

Using the model, we can compare and contrast the WPI program and the UofT program. WPI is clearly a more immersive program that stretches across multiple years and involves several LTS experiences. It is a core aspect of the curriculum. The UofT program is a single course program, which is a core part of the curriculum but LTS is not a central aspect of the engineering curriculum at UofT. The UofT program explicitly requires a deliverable (an individual portfolio) that asks the student to reflect on their learning and development of professional identity. However, at the first year level, students often focus more on the development of their writing ability and general contributions to the team, rather than professional identity per se. Both programs include social/cultural outcomes explicitly. Because of its scope the WPI program provides an opportunity for deeper social/cultural outcomes to be achieved and by the senior year students are able to engage in complex technical and social problems effectively. At the first year level at UofT, the design problems are not as technically challenging and the social/cultural outcomes are much more modest. The emphasis is on the quality of the design process followed by the team, and the steps they took to include the community partner's context and needs in that process.

Overall, the model allows us to make this comparison between these programs effectively. The dimensions help us to discuss the similarities and differences and identify how differences in goals have driven the differences in the designs of these programs. As educators who are experienced in this pedagogy, having a framework to discuss our programs is highly valuable. It allows us to make generalizations about our programs and identify the strengths and weakness that they possess.

Example 3: *GlobalResolve* at Arizona State University[10,11]

GlobalResolve is a curriculum at ASU leading to a concentration in Social Entrepreneurship in the College of Technology and Innovation (CTI). The goal of the program is to help students develop technologies to address issues of poverty both abroad and in the US, and prepare entrepreneurs to create community-embedded sustainable enterprise around the technology. The curriculum consists of 5 project-based courses: Design for Impact, Global Impact Entrepreneurship, Systems Innovation, Village Energy Systems and Community Appraisal, the last course involving immersive travel to the community to assess needs and resources and develop partnerships. A diverse set of student majors is recruited from the university to work on the projects, primarily because every project is part a system of science, technology, culture, politics, economics, geography and sociology – in fact, nearly all of a university's offered disciplines. There are no specific pre-requisites for the courses other than Community Appraisal must follow completion of at least on of the other courses.

In addition, GlobalResolve supports Social Innovation projects in the sophomore year of the engineering curriculum. The Engineering program in CTI is project-based, in which students are required to take project courses every one of their undergraduate semesters, with one of the sophomore project courses devoted to GlobalResolve-type projects. This is not as resource-intensive as the programs described from University of Toronto or Worcester Polytech, but does involve team teaching in nearly every course by a range of disciplinary faculty from engineering, design, entrepreneurship, technology and sustainability. There are typically 50 students per semester enrolled in the various courses working on 15-20 projects. Most of the projects are one semester in duration, but some of the most promising are continued for multiple semesters through technology development and further, to entrepreneurship and business planning.

GlobalResolve, in terms of metrics is somewhere between WPI and UofT in terms of immersion in that it is an elective program, but involves a student for 5 courses, usually being 5 separate semesters. Deliverables are expected in terms of technology proof-of-concept prototypes, business plans and trip reports. Because of its multi-disciplinarity, it involves both socio-cultural and technology components about equally where some team members work specifically in either one of these domains for the complete course. The final course is a senior project that has much the same requirements as a capstone course, except is more balanced between technical and socio-cultural topics whereas a pure engineering capstone if much more technical with essentially no socio-cultural content. The GlobalResolve experience would be somewhere between 4 and 5 on Figure 1. As at UofT, a design process, specifically human-centered design, is emphasized and followed in each project.

Example 4: *Introduction to Engineering Design* at Western Michigan University

At Western Michigan University, ENGR 1001, "Introduction to Engineering Design," has served as a standalone course for one of the authors of this paper (ET) to include service learning as the focus of the design project since 2005. ENGR 1001 carries one credit hour and meets once per week for 150 minutes, and it has a typical enrollment of 40-50 students per course offering. The community partners for ENGR 1001 are K-12 schools. In ENGR 1001, students research the need of the K-12 partners, learn the scientific principles governing the design projects, identify the design specifications in collaboration with the K-12 partners, brainstorm and evaluate solutions against the design specifications, and build and test prototypes. Some of the deliverables include an instructional device that simulates x-ray diffraction of single crystal to meet the desire of a high-school physics teacher to teach x-ray diffraction and rotation symmetry of cubic systems. Another example is an instruction device that allows the teacher to demonstrate that light reflection, refraction, absorption and transmission occur concurrently, not discretely. The device also allows students to investigate effect of a medium's thickness and refractive index as well as the angle of incidence on the optics phenomena.

In 2010, at the request of the Chair of the Department of Civil and Construction Engineering (CCE), Safe Routes to School (SRTS) became the focus of the ENGR 1001 design project to align with the CCE program educational objectives of "use your profession to contribute to society through service to the community." SRTS is a federal program that seeks to enhance physical wellness of school children by encouraging them to walk or bike to school. The deliverable is an Action Plan which is submitted to an SRTS Action Team consisting of school and city officials.

Since this standalone course is taught by one instructor and one student assistant and involves ~40 students lasting one semester, it is much less resource intensive than the other projects described in this paper. All students work on the same design project but students are divided into teams, with each team working in a different neighborhood zone around the school. From the geographic context, it is 100% local. In the second iteration of SRTS in 2011, a guest presenter and reading materials on poverty as well as design standards of the Michigan Department of Transportation (MDOT) were added to the design assignments. Furthermore, a follow-up course, ENGR 1001, "Introduction to Engineering Analysis," has been revised to include proposal writing to seek SRTS funding. Therefore, in terms of the technical versus social/cultural learning goals of Figure 1, ENGR 1001 would be located above point 4 and perhaps would best be described by point 5.

5. Discussion and Conclusions

We have developed metrics that can be used in a model to characterize and compare LTS programs. In addition, this model can be used to design a new program, or assess an existing LTS program.

A well-designed LTS program should take into account all 12 dimensions. There are, of course, other aspects of the logistical planning and implementation that will need to occur. However, the dimensions described are an excellent starting point for the development process. In particular, they encourage an instructor to think critically about the learning experience they want their students to have, and the learning outcomes they want to achieve. They effectively require an instructor to articulate their goals with respect to the models identified by Butin[6], and design important components, such as reflection, into their program. If the program is being designed by a team of instructors, then this model encourages discussion of key issues. It is important in team teaching that the team share a commitment to a core set of values, and working through the dimensions can help the team articulate these values. The net effect is a thoughtfully designed program that is aligned with the current literature on learning and LTS.

Similarly, the model could be used to assess the quality of an existing LTS program. Reflecting on the design of an LTS program from the multiple dimensions of the model helps us identify strengths and weakness in a program. For example, we can identify that the WPI program currently does not specifically include reflection per se, but generally results in a high degree of civic learning outcomes. This may be an area for improvement. Or the University of Toronto program has opportunities for students to achieve some degree of cultural or political outcomes, but these outcomes are limited by the lower duration of interaction with the client and limited follow-up in the classroom. This suggests that pairing deeper client interaction with readings on social issues and/or class discussions could potentially expand the learning outcomes achieved in this area.

However, expanding LTS program goals can have resource implications and this is obviously a key concern for engineering schools. In the LTS programs we are familiar with there are always trade-offs and compromises that must be made. The dimensions in the model are meant to identify the major causes of the resource implications (i.e. number of students involved, location

of the projects, etc.) so that a discussion can take place around balancing of resources with educational learning outcomes and student experience in mind. The model can be used to prioritize the goals of the program and scope appropriate resources.

Overall, the model is an addition to a growing body of literature aimed at supporting faculty and administrative leaders who are interested in engaging in LTS pedagogy. This aligns with and supports the goals of the Engineering Faculty Engagement in Learning Through Service (EFELTS) project.   The model was developed by a team of instructors experienced in this pedagogy who incorporated their practical expertise into the development of the 12 dimensions. The result is a model which describes both the essential practical and essential philosophical components that characterize a Learning through Service program in engineering. We invite participants in university LTS programs to contact the authors if you would like to participate in a continuation of this study to compare LTS programs using this model. Populating the model with many LTS programs will help similarly focused programs to network with each other for support and growth and will help growing programs establish aspirational targets.

References

1. American Society for Engineering Education, 1994. Engineering Education for a Changing World: A Joint Report of the Engineering Deans Council and the Corporate Roundtable of the American Society for Engineering Education.

2. The Engineer of 2020: Visions of Engineering in the New Century, 2004. National Academy of Engineering, The National Academies Press.

3. ABET, Baltimore MD, Criteria for Accrediting Engineering Programs 2012-2013. http://www.abet.org/engineering-criteria-2012-2013/ Accessed: January 2012.

4. National Science Foundation, Arlington VA, NSF Awards page: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=1022927 Accessed: January 2012

5. Jarvis, P., Adult education and lifelong learning: theory and practice, London ; New York: Routledge, 2010. 4th ed.   (also described in his book Towards a Comprehensive Theory of Human Learning).

6. Butin, D.W. "Focusing our Aim; Strengthening Faculty Commitment to Community Engagement", Change, November/December 2007, p. 34.

7. Worchester Polytechnic Institute, Projects Program, http://www.wpi.edu/Academics/Projects/ , 2012a

8. Worchester Polytechnic Institute, Global Perspective Program, http://www.wpi.edu/Academics/GPP/ , 2012b

9. S. McCahan, P.E. Weiss, K. Woodhouse, R. Andrews, P. Anderson, M. Kortschot, S. Romas, "Engineering Strategies and Practice: Team Teaching a Service Learning Course for a Large Class" Alan Blizzard Award paper, McGraw-Hill Ryerson, 2007. Published as a special booklet by McGraw-Hill Ryerson. Available on-line at: http://www.stlhe.ca/wp-content/uploads/2011/06/2007-Blizzard-Paper.pdf

10. Rogers, B., Pugliese, M., Henderson, M., The Twig Light: Ultra Low-Cost Lighting in Ghana, NCIIA Conference, San Francisco, March 25-27, 2010.

11. Rogers, B., Henderson, M., Gintz, J., Danielson, S., The Development Of A Gel Fuel Processing System For Use In Rural Ghana, Proceedings of the ASEE Annual Conference, June 2008, Pittsburgh, PA.