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Service-Learning and Civic Engagement as the Basis for Engineering Design Education

Angela R. Bielefeldt and Marybeth Lima

Abstract

Service-learning (SL) is among the pedagogies that can be used to teach students the engineering design process. The similarities and differences of SL as implemented via engineering design are compared to community and civic engagement typical in disciplines such as social sciences. Although engineering design can be conceptualized via a number of paradigms, a human-centered design approach is particularly well-suited to SL projects. SL projects typically engage engineering students and instructors with stakeholders who do not have technical backgrounds. This approach is different than many industrially-sponsored projects that are more typical in capstone design projects and poses unique challenges and opportunities for engineering design education. Best practice recommendations for SL design projects have been distilled, with a particular emphasis on developing reciprocal partnerships and meaningful student reflection. SL design projects can lead to a rich array of knowledge, skills, and attitude outcomes among students, including ethical development, humility and empathy, and creativity and innovation. Enhanced recruiting and retention using this pedagogy has also been reported. Assessment of community partner satisfaction, learning, and outcomes are generally less well documented. SL design projects can be integrated into courses ranging from first-year to senior capstone, providing benefits to communities while enhancing students' skills.

Keywords: service-learning, community engagement, human-centered design, reflection, reciprocal partnerships, professional skills, attitudes, empathy, humility

1. Introduction

In the twenty-first century, “engineers are called to be change-makers, peace-makers, social entrepreneurs, and facilitators of sustainable human development” [1]. Preparing engineers to meet these challenges requires a rich educational experience. In particular, the way in which students are taught the design process is important. The products, processes, and infrastructure designed by engineers are critical to human quality of life, with an array of positive and negative impacts that should be carefully considered. More broadly, the designs of engineers are having global environmental effects. A rich design experience will reinforce to students the coupled socio-technical challenges they will face in practice, and prepare them to recognize and wrestle with the complex array of ethical issues that are inherent in all designs.

It is not sufficient that engineers have a great depth of technical knowledge, so-called I-Type education. Engineering education has been moving toward a T-shaped model that adds breadth skills that cross the boundaries of a single profession, such as teamwork, communication, and global understanding [2, 3]. Perhaps we need to move beyond T-shaped engineers to envision “cluster” type engineers [1], who will sit with a broad array of stakeholders (including members of the public and those in policy, social scientists, and natural scientists) to design appropriate and sustainable processes and products that better meet an array of environmental, social, and economic objectives.

It is our claim that service-learning can serve as an ideal basis for design education that strives to meet the aforementioned goals of educating global citizen engineers. In addition, the hard work invested by students and educators can yield tangible results that serve real people, as opposed to designs in AutoCAD or objects that are displayed at a design fair and then go to waste. Engaging with communities may also broaden the diversity of students interested in becoming engineers, both in terms of recruiting students into engineering majors in higher education as well as retaining students to graduate with engineering degrees and enter the engineering workforce [4].

This chapter begins by defining service-learning (SL) and community engagement and briefly describing their history in higher education and in engineering. Next, frameworks and theories of design that are particularly relevant to SL are presented, with a focus on human-centered design. This section is followed by a discussion of essential elements of SL-based design projects, as well as challenges and pitfalls of SL as a pedagogy for design education. The student knowledge, skills, attitudes, and identity that can result from SL-based design projects are presented next. Examples of SL-based design programs and courses are integrated throughout the chapter to illustrate concepts and best practices. This chapter is intended to provide the reader with an introduction to service-learning as a vehicle for design education, and to provide additional resources for readers who wish to delve into more detail with the theory and practice of this pedagogy.

2. Service-learning in engineering education

Service-learning is defined as “a credit-bearing, educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.” [5] Service-learning in higher education was pioneered by Ernest Boyer [6, 7] and other scholars in non-engineering professions [8–10] and was identified by George Kuh [11] as a high impact educational practice critical to the retention of early career college students. Service-learning, and more broadly civic engagement, which encompasses curricular and co-curricular efforts to ensure that the university is using its resources to partner with communities and other stakeholders to address complex societal issues, are a well-defined part of the higher education landscape in the USA. Campus Compact, the major professional society for civic engagement in higher education, has more than 1100 universities as members.

Models of service-learning were presented by Heffernan [12], and include (among others) a discipline or placement based model, in which students are situated within the community and perform community service to meet their learning objectives, as well as a problem-based or deliverable model, in which student create or co-create (with community) a product to fulfill course requirements. Service-learning in engineering has largely used the deliverable model, in which students deliver designs or designed and built artifacts.

Leah Jamieson pioneered service-learning in engineering through the Engineering Projects in Community Service (EPICS) program at Purdue University [13, 14]. This model features vertically integrated teams consisting of an approximately equal number of first-year, sophomore, junior, and senior engineering students who take a course repeating times for semester credit and who work together on addressing community issues using human-centered design. The teams are also multidisciplinary, including students studying an array of engineering and non-engineering disciplines. The community partnerships are often long-standing, with EPICS conducting a number of projects with partners over many years. Examples of projects conducted by EPICS in partnership with communities include hands-on exhibits for science museums, custom toys for children with disabilities, and software for elementary schools, non-profits, and public agencies. The EPICS model has expanded to include approximately 40 colleges of engineering nationally and internationally [15]. Edmund Tsang [16] is the editor of the engineering volume of the American Association of Higher Education's Service-Learning in the Disciplines. Numerous early models of service-learning in engineering are shared in this volume.

Though there is much work on service-learning in engineering, engineers serving the common good through co-curricular (outside the classroom) methods also play a large role in learning through service (LTS) activities [17, 18]. Many pre-professional and practicing engineers have participated in engineers without borders (EWB), whose mission is "To be the beating heart of the engineering movement for sustainable global development, building and evolving engineering capacity throughout the world." (<http://ewb-international.com/>). In this context, engineers partner with communities throughout the world that have a lack of access to resources in an effort to improve the quality of life for people in these communities. Common projects include improved sanitary conditions, enhancing water quality and availability, and access to energy.

There has been a proliferation of curricular and co-curricular opportunities for civic engagement in engineering since the turn of the century. SL design projects have been integrated into introductory courses for first-year students, technical core courses, and senior capstone design. Readers are encouraged to consult the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship* (IJSLE), especially two special issues published in 2014 and 2015, Opportunities and Barriers to Integrating Service-Learning into Engineering Education [19] and University Engineering Programs that Impact Communities: Critical Analyses and Reflection [20]. Additionally, the Community Engagement Division of the American Society for Engineering Education was created in 2012 and has a resource page for general knowledge in this area (<https://aseeced.libraries.psu.edu/resources>).

3. Design frameworks

The design process can be modeled in a number of ways, with specifics that vary somewhat depending on whether engineers are designing infrastructure at the community scale (e.g. a bridge, road, power system), physical products that are owned at a household or personal level (e.g. a car, computer), or processes (e.g. computer software). Some methodologies are more congruent than others with service-learning. The human-centered design process has often been used to frame service-learning (e.g. [21, 22]), and also aligns with numerous elements in the conceive-design-implement-operate (CDIO) process [23]. Human-centered design puts the people who are the users/community members at the heart of the process, engaging them throughout all phases. Optimally, service-learning embraces the notion of designing with

communities. **Figure 1** offers a visual representation of the human-centered design process. The hexagon in the center represents the team of people working together on a particular issue (inspired by [1]), which is embedded in the complex ecosystem of the technical, social, and environmental realms. The community members (C) are “at the table” working side-by-side with engineers (E) and other experts in policy (P) and natural and/or social scientists (S). There are opportunities to harness community expertise in all phases of the design process.

An individual or the community collectively should identify a problem or situation they believe engineers might be able to contribute to solving or improving. The community should be the driving force, with a vision of partnering with engineers. In other words, problem identification should not be externally imposed. An engineer might share data with the community that she/he believes indicates an issue, but should not presume that her/his external perceptions of a ‘problem’ are authentic to a specific individual or community. Otherwise, there is an implication that a particular community or individual is at a ‘deficit’, needing charity or help from an “expert” engineering student, versus being co-equal partners in working to improve a situation.

Once an issue has been identified by the community, the next step is to gain a thorough understanding of the issue. It is important to realize that a particular problem is situated within a larger framework of the planet and environment at large, the society and economy in which a community or individual resides, various cultural norms and legal constraints, and interactions among these complex systems. Engineers should

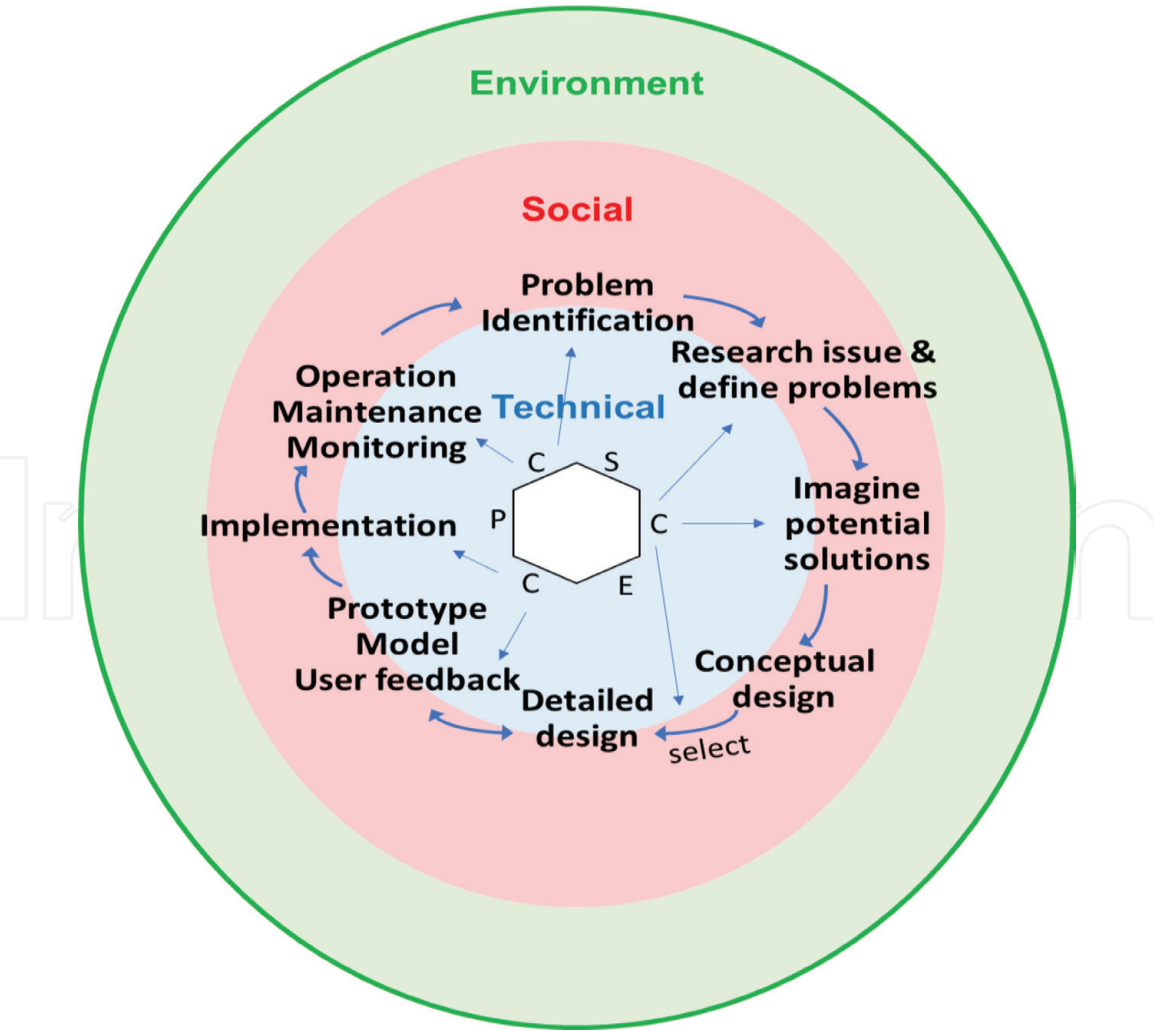


Figure 1. Conceptual model of the human-centered design process as a collaboration among engineers (E) and community members (C) with contributions by policy makers (P) and scientists (S), situated within larger environmental, social, and technical realms.

have a strong understanding of the technical issues that are relevant to a problem, as well as community issues that they can gain perspective on through research. Critically, they also need to partner with others “on the ground” to fully understand other conditions relevant to the problem. In this stage, students should talk with and listen to their community partners. Ideally, this process includes contextual or transformational listening, which is a skill that must be thoughtfully developed [24–26]. The public and community should not be viewed as a monolith; there are sure to be an array of individuals and groups with different perspectives. Engaging an array of stakeholders early in the process can yield important benefits. The more students in their role as novice engineers can immerse themselves in the communities and with the people their engineering is designed to serve, the more likely they are to better understand and appreciate the needs of the ultimate users of the co-created design. This approach aligns with the ideas of empathic design [21, 27]. Students may also need to recruit partners or work with other disciplines to gain a thorough understanding of relevant constraints and criteria.

The next phase in the process focuses on divergent thinking, where individuals imagine an array of potential solutions. Engineers often bring examples of solutions that have worked in similar situations. But each situation is unique, and engineers should not force fit technology to a problem. The analogy is often that engineers have a set of tools, and just because they have a “hammer” does not mean that is the right tool for the job. Students should not position themselves in roles as experts, but as learners, collaborators, and facilitators, bringing their ideas and inviting ideas from others. Interactive discussions with a broad array of stakeholders are likely to yield a diverse array of creative ideas. This step is critical to the process, in order for the best solutions to be among the array of options being considered.

Next, there should be a thoughtful process of evaluating the range of ideas under the set of local constraints and criteria, to narrow in on a sub-set of potentially feasible, appropriate, and optimal solutions. This process should be conducted by the community members and engineering students working together in a participatory design process. The evaluation process should consider the larger context of the issue, including the social and environmental spheres. Engineers then create conceptual designs, which allow rough evaluation of metrics such as cost, environmental emissions, etc. Typically a number of the important criteria that determine an optimal solution are subjective. Thus, community members must be engaged in contributing to the design and evaluating these issues. The community should select the ‘optimal’ solution from among the sub-set of options that went through the conceptual design phase. This is a convergent phase of the design cycle, and may be challenging given that different stakeholders may have different perspectives on ‘optimal.’

Engineers then typically handle the majority of the detailed design phase, which largely resides in the technical realm. Engineering students may complete this work if carefully supervised by instructors with appropriate expertise; some projects will require that licensed Professional Engineers review the designs. More forward-thinking SL programs are engaging in co-design among community members, students, and engineers. Where appropriate, prototypes of products are created, which can then go through testing by the community. In the case of infrastructure, computer models are built and subjected to expected human and natural conditions (e.g. hurricane); results are shared with stakeholders. Design changes can be made in response to the testing feedback cycle. This iterative process can often be viewed as a microcosm of the full design process (e.g. a problem might be identified in the prototype, alternative fixes are proposed and evaluated, etc.). The teams of engineering students and faculty should be completely transparent with stakeholders, explaining what they are doing and why. This approach provides an opportunity for co-equal learning among all of the

participants in the design process, and is inclusive of both community members and engineering students.

The implementation steps, such as manufacturing a designed product, are often thought of as ‘detached’ from users and communities. However, in service-learning projects there are often opportunities to engage communities in this phase. For example, community participation in constructing a school playground, building a Habitat for Humanity home, community participation in building a Bridges to Prosperity (B2P) bridge, and locals producing ceramic water filters for point-of-use household treatment of drinking water in a micro-enterprise [19, 20]. Community involvement in the implementation step can be particularly impactful and contributes to the community “taking ownership” of the constructed artifact that they co-designed and helped to construct. The same is true in the operation, maintenance, and monitoring phases of a project. Community understanding of the process and ultimately their sense of ownership is fostered by their intimate involvement in all phases. The greater the participation of the community in all phases of the project, the greater the overall sustainability of a project over the long term—and across the interconnected areas of societal, environmental, and economic issues.

Done well, service-learning enacted through a model of human-centered design requires frequent engagement with the community across all stages of the design process. The more engaged community members are in the entirety of the design process, the better the outcome will fulfill project goals. Community members may not be immediately available at the discretion of a student design team, and communication processes and timelines need to be respectful of these preferences and needs. The feedback cycle among members of a design team that stretches across disciplines requires thoughtful consideration at each step. Catalano [28] advocates for a contemplative paradigm, which he combined with service-learning in a senior capstone design course. The various elements in the human-centered design process imply that a majority of significant service-learning design projects will have timelines that stretch beyond the confines of a single academic term. This “feature of the landscape” requires creative thinking to integrate community-scale design problems into higher education, adapting traditional course structures (e.g. [29] ‘tyranny of the semester’). A thoughtful process to design the SL experience is encouraged. The Learning Through Service Program Model Blueprint is a tool that can facilitate this process, considering the perspectives of a wide range of stakeholders (e.g. students, community members, instructors, the university, intermediaries such as non-governmental organizations, practitioners) with respect to value propositions, relationships, and resources [30].

A sub-set of engineering service-learning design focuses on poverty alleviation, in programs such as Humanitarian Engineering and Engineering for Developing Communities. Nelson [31] described four different mental models that are commonly used to frame design processes associated with poverty alleviation: income first, needs first, rights first (including human-centered design), and local first. A well-being framework brings these four mental models together. The framework supports the importance of deeply engaging with communities and recognizing their unique expertise in their local context. Because poverty is framed as “the systematic failure to achieve wellbeing objectives”, the framework lends itself to a series of metrics that can form the basis of design objectives, constraints, and criteria; for example, “material sufficiency, bodily health, social connectedness, security, and freedom to make choices around action” (p. 2). A service-learning design program at Ohio Northern University is a case example of the well-being framework [31].

Entering into service-learning design projects, instructors may want to consider servant-leadership as a framework for their teaching and as a model for students to consider when they engage with communities [32]. Design instructors will have a role as a “guide on the side”, with a mindset of mentoring or serving both their

students and the community partner, and being mentored and served by these constituents. A case study of this approach was a service-learning project in a senior thermodynamics course at the Milwaukee School of Engineering [32]. The LSU Community Playground Project, which is affiliated with a first-year engineering design course, required the service-learning instructor to develop a servant leadership approach to be successful; the evolution from becoming a “traditional” engineering educator to a servant leader engineering educator is described in [33]. Stoecker [34] takes this concept further, suggesting that engaged faculty frame their work as community organizing.

4. Essential elements and challenges of SL-based design projects

There are several essential elements of successful service-learning-based projects. The authors strongly suggest that faculty who wish to use this pedagogy work with their university’s office of civic engagement and/or service-learning to help identify community partners and to assist with planning and executing their projects within a reciprocal framework. Other groups, such as non-governmental organizations (NGOs), may be key stakeholders, particularly in international service-learning projects.

In terms of reciprocal partnerships, an asset based model of collaboration is ideal because it acknowledges the resources and assets that the university and community “bring to the table,” as well as identifies the needs that each constituent seeks to meet through partnership. For example, universities might have assets with respect to discipline-specific knowledge and monetary resources, while communities might have assets with respect to community-specific knowledge and capacity resources. Partnerships are more successful when constituents combine their strengths to address a community issue together rather than a charity model in which one constituent helps the other. Another way to frame this asset based philosophy is that each constituent will both learn something from and teach something to the other.

The 2006 Community Partner Summit [35], p. 13 and Portland State University’s 2008 Partnership Forum [36], p. 3 identified the following essential components for successful community-university partnerships:

1. Quality processes (open, honest, respectful; relationship-focused, characterized by integrity; trust-building; acknowledgement of history, commitment to learning and sharing credit)
2. Meaningful outcomes (specific and significant to all partners)
3. Transformation (at individual, institutional, organizational, and societal levels)

These essential components are achieved by practicing the following processes ([36], pp. 3–4):

- Asset (resources, strengths, and interests) identification and recognition for all partners
- Dialog within partners and between partners
- Creation of common language

- Relationship-building strategies
- Describing and understanding each other's culture
- Learning together
- Collaborative problem posing and solving
- Collaborative agenda setting
- Identification and recognition of each partner's needs, issues and challenges
- Self-assessment and reflection within each partner group and between partners
- Constant negotiation and modification
- Supporting infrastructure in each partner's organization

Another important component of a successful service-learning partnership is reflection, or metacognition. Professionals constantly reflect on what they are doing, why they are doing it, and next steps; students need to develop this skill that professionals may forget that they practice, because this practice is so embedded in their daily work. There are many models of reflection ranging from the simplest (what, so what, now what) to those that are more complex [37, 38]. Lima and Oakes [39] have a list of reflection questions in Chapter 2 of their textbook on service-learning in engineering. Reflection can be used to catalyze and assess student learning.

A thoughtful assessment plan should be developed, to help ensure that the outcomes desired for both communities and students are achieved. This plan should include formative assessment to enable during-course adjustments, as well as summative assessment to provide 'lessons learned' for the future. Assessment methods for student outcomes are well documented (see examples in [40]). Community outcomes have been rigorously studied in fewer instances, and are an area where additional scholarship is needed.

Even when adhering to all essential components and processes for successful partnerships, there can still be challenges and pitfalls. For example, as mentioned previously, it can be difficult to manage partnerships within the time constraints of a semester: most community issues involve people working on them throughout the year, not in 15-week blocks. This constraint may require some thought in terms of deploying a design and maintaining it once it is built. Repeating courses with the same community partner is one way to address this issue; others have created infrastructure to complete and maintain projects [39, 41]. Such considerations ensure that a design effectively serves the community, instead of being dumped on the community. Student resistance to participating in service-learning classes is also possible [32]; explicitly and repeatedly connecting the service activities to the learning objectives in class allays most student concerns. Finally, communication can be an issue, particularly where media is concerned. University media tend to focus on the students and faculty involved in a service-learning project and typically portray the community-university relationships as the university helping the community [42]. An explicit conversation among constituents about uniform talking points for media, and if at all possible, media interaction with all constituents present, is recommended. See [42], for more details.

5. Potential student outcomes of SL-based design

Across all disciplines, service-learning has been shown to be an impactful pedagogy. A recent meta-analysis of SL across 62 studies (all included a control group, elementary through postsecondary level students with 68% college undergraduates) determined that SL resulted in “significant gains in five outcome areas”: academic achievement (grades or test performance; highest mean effect size, ES, 0.43), social skills (leadership, cultural competence, social problem solving; ES 0.30), attitudes toward self (self-esteem, self-efficacy, personal abilities, feelings of control; ES 0.28), attitudes toward school and learning (academic engagement, enjoyment of course; ES 0.28), and civic engagement (civic responsibility, altruism; 0.27) [43]. It is unclear whether or not any of the studies included in the meta-analysis included engineering students, but the results are nevertheless compelling.

Within engineering, previous research has identified a number of knowledge, skills, attitudes, and identity (KSAI) outcomes that could result from engineering student engagement in project-based service-learning (PBSL); [40] presented a literature review from numerous published sources. While that study extended beyond SL in design settings, SL-based design should have the capacity to yield the same array of outcomes. SL-based engineering design education can achieve all of the core technical outcomes one would expect from engineering design in general (aligned with the academic achievement outcome in the meta study), while also realizing a number of additional outcomes. The potential outcomes of SL-based design education that map to the technical and professional knowledge and skills expected of engineers internationally and by U.S. accreditation are summarized in **Table 1** [44, 45].

A greater complexity and range of design constraints are typical in SL-based projects compared to other design experiences. Service-learning executed through human-centered design may be superior to standard design pedagogy in developing

IEA Washington Accord Program / Graduate [44]	ABET Engineering Accreditation Criteria [45]
Complex engineering problems: WP3 No obvious solution and require abstract thinking, originality in analysis.... WP5 Outside problems encompassed by standards and codes.... WP6 Involve diverse groups of stakeholders with widely varying needs	Complex engineering problems... no obvious solution, ...not encompassed by current standards and codes, involving diverse groups of stakeholders, ...
WK7 Comprehend the role of engineering in society ... ethics and the professional responsibility of an engineer... impacts of engineering activity...	
WA3 Design solutions... that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations	2. Apply engineering design... with consideration of public health, safety, and welfare, ... global, cultural, social, environmental, and economic factors
WA6 Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice...	4. Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider... global, economic, environmental, and societal contexts
WA7 Understand and evaluate the sustainability and impact of professional engineering work...	
WA8 Apply ethical principles...	
WA9 Function effectively...as a member or leader in diverse teams in multi-disciplinary settings	5. Ability to function effectively on a team ... provide leadership ...
WA10 Communicate effectively on complex engineering activities with the engineering community and with society at large....	3. Ability to communicate effectively with a range of audiences
WA12 ...have the preparation and ability to engage in independent and life-long learning ...	7. Ability to acquire and apply new knowledge as needed...

Table 1.
Knowledge and skill outcomes achievable via SL-based design and PBSL.

communication skills with diverse audiences and teamwork/leadership skills in interdisciplinary settings. In addition, PBSL in engineering has been shown to yield enhanced creative design; cultural competency and leadership (social skills); self-confidence; attitudes toward community service; and engineering identity. The compiled data in [40] indicated outcomes for which the projects with a SL context yielded enhanced outcomes in comparison to non-SL projects.

SL-based design embeds an array of ethical issues, both microethics and macroethics, and may be particularly impactful in building students' ethical reasoning skills. In a faculty survey on ethics and societal impacts instruction, 212 respondents who described their capstone design course as including ethics and/or societal impact topics indicated that these topics were taught via service-learning [46]. Zoltowski and her collaborators [47] have been developing instruments and methods to measure ethical gains as a result of SL-based design experiences (e.g. [48]).

In addition to knowledge and skills, attitudes are important to the professional success of engineers and are explicitly recognized in CDIO [23] and the American Society of Civil Engineers (ASCE) *Civil Engineering Body of Knowledge for the 21st Century* (CEBOK). The third edition of the CEBOK [49] explicitly includes affective domain goals and rubrics associated with seven outcomes. Attitudes supportive of professional practice that may be specifically developed via a SL design experience, such as "value effective and persuasive communication to technical and non-technical audiences" which requires "empathy... with diverse clients and stakeholders" ([49], pp. 2–42–43). The professional attitudes listed in the CEBOK3 (pp. 2–53) and developed specifically via SL may include creativity, flexibility, consideration of others, empathy, honesty, integrity, respect, sensitivity, thoughtfulness and tolerance. Humility [50] and empathy [51] have been proposed as important mindsets in working with communities.

Of additional interest is the extent to which SL-based design is effective at developing students' creativity and innovation skills. This has not yet been rigorously studied using established instruments (such as the Creative Engineering Design Assessment Purdue Creativity Test or Purdue Creativity Test [52]); rather, the data reflects student self-assessments in surveys or anecdotal statements by instructors. One of the more rigorous assessments was associated with a first-year mechanical engineering design course [53]. A sub-set of the design projects were SL-based and included leadership training. Students engaged in SL projects had a statistically significant gain in the self-assessed extent to which they possessed creativity/ingenuity on the post- versus pre-assessment using a five-point scale; gains were not statistically significant among students working on non-SL design projects. In a senior product design course with service-based projects, students rated their creativity at a higher level on the post-survey than the pre-survey (average ~6.55 increased to ~6.95 on nine-point scale; $p < 0.05$); this compared to a gain of about one-point in their self-rated product design skills [54]. Fully anecdotal statements regarding growth in students' creativity and/or innovation skills in association with service-based design projects were made in a number of other papers [55–61].

Another set of proposed outcomes from SL-based design is that it may help attract students to engineering majors and/or retain students in engineering, particularly women and underrepresented minorities. Many students are drawn to engineering due to a desire to make a difference, help others, and improve society. SL projects offer tangible examples of these outcomes, inspiring students and providing rewarding experiences. Three large service-learning programs in engineering have data related to the impacts of their program in recruiting/retaining female students: the Service Learning Integrated Throughout a College of Engineering (SLICE) program at the University of Massachusetts Lowell [62], EPICS at Purdue University [63], and the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Pennsylvania State University [64]. Other SL programs have

reported on the large percentage of women among the participants, such as the Humanitarian Engineering Center at Ohio State University [65] and engineers without borders [66, 67] provided data from a variety of developing community programs. The real-world tangible nature of SL design projects is a significant motivator, in addition to making a positive difference.

6. Assessing community impacts of SL design projects

Service-learning has co-equal goals of benefits to community partners and student learning. Assessment is needed to demonstrate whether SL design projects have met these goals. SL projects may have impacts at the individual, organizational, community, or system scales [68]. Jiusto and Vaz [68] present a model that considers these impacts to both communities and academics, which can inspire instructors considering the use of SL as a design pedagogy to think beyond immediate impacts. This broader systems-level perspective can include potential project outcomes such as improvements in the health and well-being of community partners, while recognizing how these outcomes might contribute to enhancing community sustainability or social cohesion. Identifying impacts of interest in partnership with all stakeholders is the first step in developing a plan to assess these impacts.

In practice, SL has often focused its assessment efforts on student learning and less on evaluating the impacts on community partners and communities; this imbalance is evident both for SL in the context of engineering design and SL more broadly [69–71]. Reynolds [72] provides a critical review of literature on community perspectives on service-learning, and conducted research on the perspectives of the international partner community in Nicaragua on their partnership with the College of Engineering at Villanova University. Although this was a research project, assessment lessons can be learned. Observations, interviews with community organization representatives, interviews with community residents, and document reviews were conducted. Community partners confirmed the tangible results of improved access to clean water and healthcare which saved lives, but also described trust, a sense of pride, and connections/awareness as important outcomes. The community also had less positive perceptions that included feeling like their community was a laboratory for students. The community also had goals toward student learning, including shifting students' perspectives from helping to learning and having a responsibility to others.

These findings represent the particular ways in which SL projects were conducted in this instance and their specific community partners, and should not be generalized. However, these important insights provide an example of the types of outcomes that assessment can illuminate. Others have also used interviews [73, 74] and surveys [14, 74, 75] to assess community partner satisfaction and other perspectives on SL engagement. Readers are encouraged to consult participatory action research models [76] to learn more about the process of planning, executing, and evaluating projects together; communication, transparency, and shared power in decision-making are hallmarks of these approaches.

Design projects and their products should be monitored over time to evaluate sustainability and long-term impacts. This process is easier for projects in local communities and more challenging for international projects, but is critical in all cases. SL projects could model practices and processes used in international development work for monitoring and evaluation (M&E), which typically include mixed-methods [77]. The community and/or students can be involved in monitoring the designed systems, and can work together to resolve any issues that are identified. On-going collaboration with groups charged with monitoring and evaluation is

also a strategy. For example, with the LSU Community Playground Project [33, 41], once community-designed playgrounds are built at public schools, a company that subcontracts with the school system to provide grounds and maintenance services to the schools takes over the maintenance of the playgrounds. On-going communication among the playground project, the school system, and the company ensures that playgrounds are re-designed, built, and maintained based on need.

7. Conclusions

Done well, service-learning based engineering design can yield a rich array of benefits for engineering students and communities. However, faculty must carefully plan their course and partnership in order to achieve the full potential of SL-based design. Engineering faculty and students should enter into the design process from a mindset of humility and listening, being respectful, and embracing the expertise of the community. This positioning is often different from the techno-centric, “expert” perspective that pervades engineering. To instill this human-centered or empathic design perspective in students, their first formal education on the engineering design process should promote these views. This approach can perhaps grow into participatory design in the senior year. One challenge is the fact that many engineering faculty members have not previously experienced such approaches, either during their education and training, or in practice. Fortunately, the literature provides rich examples for faculty to draw from to implement this methodology in their own courses. We believe that best practices in service-learning in engineering design make our students better engineers and enables our profession to fulfill its highest purposes.

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Conflict of interest

The authors declare that they have no conflict of interest related to this work.

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