

A Framework to Guide the Implementation of Pre-College Service-Learning Engineering Curricula

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Introduction

Nearly any national or state document concerning STEM education reform within the past five years highlights the urgent need to increase and diversify the STEM workforce. In explaining the problem and the need to improve the public's perception and understanding of engineering, the National Academy of Engineering (NAE)²² discusses the disparities in gender and ethnic diversity in the engineering community in their *Changing the Conversation* campaign. These efforts to improve access to engineering education for women and underrepresented groups and to vitalize the profession with greater diversity is nonetheless, often framed within the utilitarian context of strengthening U.S. economic competitiveness and workforce preparation^{12, 36}. Such narratives pervade STEM Education reform movements, as exemplified in landmark initiatives like the Next Generation Science Standards²⁵, the development of which is predicated upon promoting America's ability to compete in the global market and lead in technological innovation. However, confounding equity issues with economic utility not only narrowly frames equity efforts and the many purposes of education, but as Gutstein¹² aptly comments, "But to discuss equity from the perspective of U.S. economic competition is to diminish its moral imperative and urgency" (p. 38).

To what ends then, should this "moral imperative and urgency" for equity, and even more fundamentally, the purpose of education be oriented, particularly as it pertains to engineering education? In endeavoring to answer this question, it is perhaps here that it is fitting to remind ourselves of the reality of inequity in society and the potential a quality engineering education can possess in remedying these ills. One such notable example is the 2015 lead-water crisis in Flint, MI--a city where over 56% of the population identifies as Black or African American³⁵. Despite the governmental and corporate beguilement responsible for this calamity¹⁶, backgrounding this crisis are those honorable aid and relief efforts, particularly those organized by the engineering community. Chief among them is the independent team of engineers and scientists from Virginia Tech who took it upon themselves to organize and study several water samples on behalf of the Flint residents in an effort "to support *citizen scientists* concerned about public health, by empowering Flint residents and stakeholders with independent information about their tap water"⁹. Similarly, the National Society of Black Engineers²⁴ organized a GoFundMe relief campaign to supply the residents of Flint, Michigan with: bottled water; water filters; water test kits; education about water filtration system; and sustainable engineering solutions to pipe corruptions to address the root cause of the problem²⁴. Of note in both these aid efforts from Virginia Tech and the NSBE is the language of empowerment and democratic citizenship which motivate them. It is a language of agency that hinges on service and community engagement. It is a language which inherently urges a deeper sense of integrity to the reform efforts in STEM Education, where improvement and equity efforts are pursued to promote a sense self-actualization and self-transcendence for the students they seek to serve.

How, then, can pre-college educational reform efforts cultivate such learning environments? Social cognitive theories posit that a sense of altruism is a “meta-amplifier” of motivation¹⁰, which itself is consistently identified to be the greatest predictor of learning and achievement²⁸. That is, a sense of personal relevancy, meaningfulness, and higher purpose among youth not only foster their optimal learning and higher academic achievement¹⁰, but these feelings are also correlated with better retention rates and a greater sense of self-efficacy⁴. As it pertains to the service-learning philosophy, studies on the impacts of past service-learning programs corroborate the benefits of an altruistically-oriented model of education. For example, three studies evaluating three national service-learning initiatives, *Serve-America*, *Learn and Serve*, and *Active Citizenship Today (ACT)* showed that overall, pre-teen and teen participation in service-learning experiences had statistically significant (with confidence levels of at least the .10 level) positive associations with: attitudes to civic/social responsibility and concern; school engagement; decreased absenteeism; increased hours spent on homework; science and math grades; and, core grade point average¹¹. Findings such as these are what makes pedagogies that promote social responsibility, like the service-learning philosophy, so compelling in the efforts to create richer, more equitable educational experiences for our youth.

Historical Foundations of Service-Learning and Current Need

The service-learning framework is founded upon constructivist philosophy. Past literature has abundantly expounded upon the pedagogy’s deep roots to the seminal experiential and sociocultural learning theories of prominent modern education psychologists and theorists like John Dewey, Jean Piaget, and Lev Vygotsky^{27, 29}. Pritchard and Whitehead²⁹, elaborate:

“The connections between these propositions from constructivist learning theory and service-learning are readily apparent. Service-learning engages students in interacting with the world and thus helps them build new cognitive structures in accord with Piaget’s general view of intellectual development. It involves students in collaborative work with teachers, peers and community members and thus engages them in the dialogic social interaction identified by Vygotsky as crucial to intellectual maturation.” (p. 7)

Thus, the service-learning pedagogy not only highlights the agentic nature of learning but also intimately integrates students’ sociocultural context by situating the learning experience within the community by its very nature.

This notion of learning through participation in local community has also historically resonated with the democratic principles on which American society is premised. The service-learning pedagogy would argue that at least one of the purposes of education is to promote citizenship and civic responsibility^{29, 31}. With initiatives like the *National and Community Service Act of 1990* and *National and Community Service Trust Act of 1993*, as well as national, state, and private sector programs and organizations such as the *Serve America Program* (national), *Learn and Serve America Program* (national), and *Learning in Deed* (private sector)¹¹, it is clear that the commitment to cultivating civic responsibility among American youth was not reserved to those socially conscious teachers of local classrooms, but rather, it has long been a national ideal that was meant to be passed onto younger generations of Americans.

Yet, despite its decades-old practice and the burgeoning body of literature on best practices for it, research detailing just how common the service-learning pedagogy is in the K-12

landscape is scarce. Furthermore, a literature search reveals that the contexts in which service-learning curricula are integrated are few and typically a component of staple subjects like English Language Arts, history/social studies, and science. However, recent efforts to improve K-12 STEM (science, technology, engineering, and math) curriculum, like the NGSS's three-dimensional philosophy of core ideas, cross-cutting concepts, and science and engineering practices, signifies a new canopy of reform in American education. And, it is here wherein the service-learning pedagogy may find fruit ripe for harvesting.

Engineering, by its very nature, is oriented toward problem solving. Indeed, the NAE²¹ has identified some core messages it wishes to promote among the public. Among these are “Engineers make a world of difference; Engineers are creative problem-solvers; and, Engineering is essential to our health, happiness, and safety”²¹. While it may not always be perceived as such, engineering is thus often an endeavor oriented toward finding solutions to society's problems. By this virtue, engineering curricula could arguably lend itself easily to service-learning. Nevertheless, with the few exceptions of Purdue's EPICS (Engineering Projects In Community Service) High²³ and Hofstra University's Engineering for All (EfA)¹³, there otherwise exists a dire lack for such formalized precollege service-learning engineering curricula. In light of this void, the purpose of this paper is to synthesize the service-learning literature and precollege engineering education research to develop a working framework for the integration of the service-learning pedagogy into precollege engineering education. To this aim, the ensuing pages will briefly examine the various spectra of considerations emergent in the literature that should inform curriculum development efforts in precollege service-learning engineering education.

Defining Service- Learning: What is it?

While the earliest underpinnings of service learning date back to the 19th century, and in the 1960s as a pedagogical strategy^{1, 32}, the vast literature on this subject does not provide a singular definition for service learning; rather, quite the contrary is true³². Indeed, service-learning is often framed within larger umbrella philosophies such as “learning through service (LTS)” or “community engagement (CE)”^{1,32} in which some form of a community partnership is forged. As such, learning experiences immersed in community are better understood in the context of a continuum. Swanson et al.³² offer a two-dimensional portrayal of this continuum (see figure 1 on the following page), in which the focus of the program (service vs. learning) and the beneficiaries (provider vs. recipient) intersect.

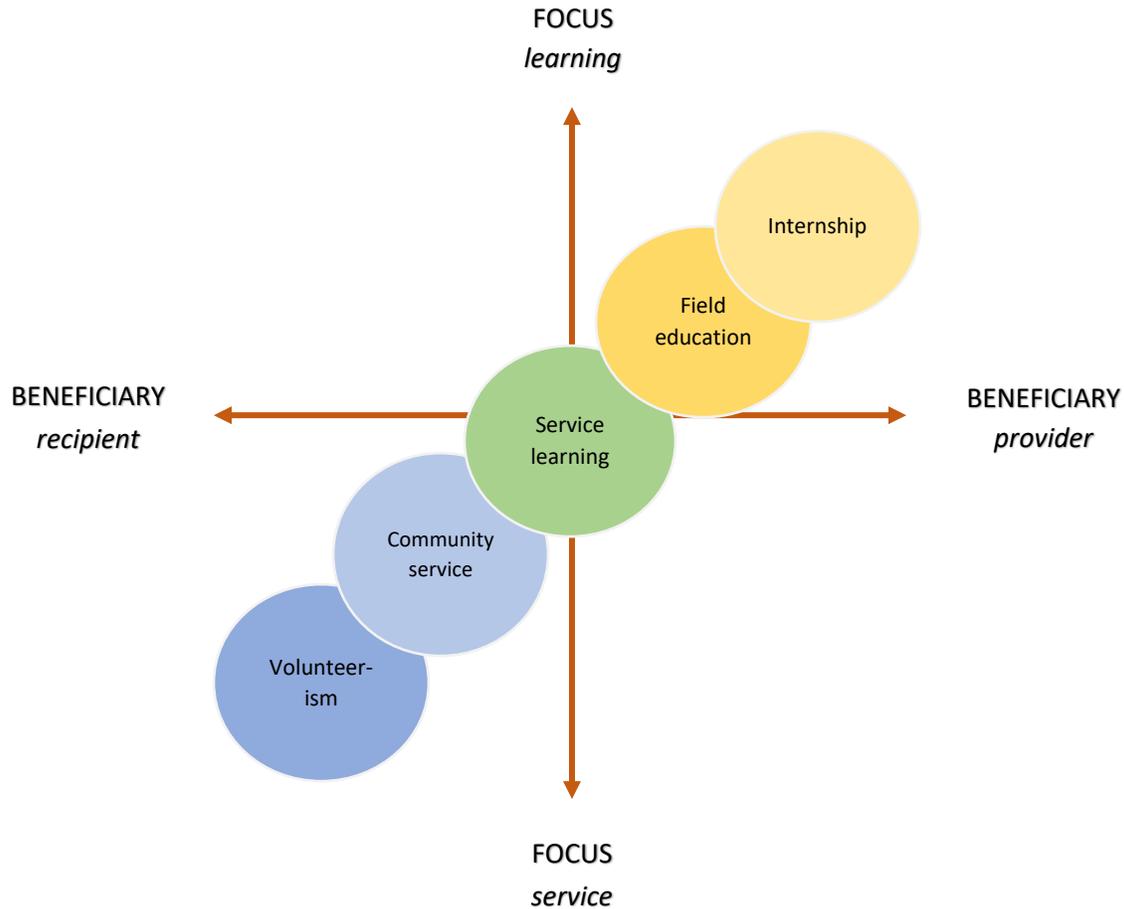


Figure 1. Continuum of service and learning. Adapted from Swanson et al. (2014).

Although there does exist a broad range to the definitions and types of community-oriented curricula, consistent themes do emerge in the service learning literature. These themes suggest that a true service-learning experience is at its essence a rich, authentic academic experience entwined with a *reflective* experience of serving community needs. Indeed, ongoing reflection on the service experience and its pertinence to the academic objectives of the curriculum is an essential facet to the service-learning experience^{1, 2, 6, 19}. In doing so, this reflection should promote a greater sense of civic duty and applied learning². Perhaps the most integral characteristic of service-learning is the bidirectional advantages that should result from a service-learning experience. Not only should the learners partaking in the service-learning curriculum acquire a rich educational experience, but the community partners involved must also benefit from the service provided by the learners³². In synthesizing these principles, Pritchard and Whitehead²⁹ outline the essential characteristics of service learning:

Taken together, these two definitions identify four fundamentals of service learning:

- Students provide service to meet authentic needs.
- Service links through deliberate planning to the subject matter students are studying and the skills and knowledge they are developing in school.
- Students reflect on the service they provide.

- Service-learning is coordinated in collaboration with the community. (p. 3).

To further understand what service learning is, it is also useful to define what it is not. The literature appears to consistently distinguish service learning from community service, in that academic learning is a fundamental feature of the service learning experience, while it is not an essential component to community service^{2, 29, 32}. Similarly, as noted above, structured time for reflection also sets apart service-learning from community service in which reflection may occur more passively. Furco and Billig¹¹ elaborate:

Beyond this criterion, which is shared by everyone, service-learning advocates often distinguish service-learning from community service by calling for some or all of the following:

- Clearly identified learning objectives
- Student involvement in selecting or designing the service activity
- A theoretical base;
- Integration of the service experience with the academic curriculum and
- Opportunities for student reflection. (p.7)

In brief then, service-learning is the contextualized learning of academic content, characterized by ongoing reflection, within the authentic, real experience of serving a community need. However, it is not sufficient to merely define service-learning as a school of pedagogical thought. It is equally important to elucidate the various facets of integration if ever the pedagogy is to be adopted in precollege engineering education. As the following paragraphs will reveal though, these decisions of implementation are not based on rigid, formulaic parameters. Instead, they appear to resemble a series of fluid spectra that address the following considerations associated with the implementation of service-learning projects: context of service; project selection; and assessment.

Context for Service-Learning

Type of Service x Level of Curricular Integration x Time Investment

While any *service-learning* curriculum suggests the incorporation of altruistically-oriented activity, the opportunities for the *scope* or the *type* of service students will be providing community partners are open for definition. When defining the contexts for the service-learning experience then, these two facets become of critical importance. To that aim, teachers or facilitators must consider these essential questions:

- *Who will the community partners be?*
- *What is the exact nature of the service students will be providing the community partner and to what degree of depth?*
- *Where will the service take place?*

Payne²⁷ recommends that to answer the first of these, teachers and students should conduct a formal needs assessment of the community. The community identified to be served can be broadly defined, including anywhere from the students' own school to community organizations, or the general public²⁷.

As it pertains to the latter two questions, Pritchard and Whitehead²⁹ offer a comprehensive framework of the variety of contexts in which service-learning pedagogy can take shape. In composing this framework, Pritchard & Whitehead also consider teacher experience level, student maturity level, implementation time, resources support level, and service possible (see Table 1 below)

Design	Teacher Experience Level	Student Maturity Level	Planning Time	Implementation Time	Resource Support Level	Service Possible	Special Consideration
In-class approach	Pre-professional Beginning	Well suited to young students or students with relatively high structure needs	2-3 planning periods	2-3 class periods	Low. System aware of S-L, but not using the method	Indirect Advocacy	Centers on teacher control as it introduces S-L elements in the classroom with cooperation from community partners.
One-day event	Beginning	Useful with students of any age who have moderate to low structure needs	5-8 planning periods spaced over 2-3 weeks	1 week of regular class periods plus 1 full day on site	Low. System aware of S-L but not using the method.	Indirect Advocacy	Helps students and community partners use school system structures to implement S-L elements in class and on site
Prototype Project	Experienced, Master	Most useful with older students who can function autonomously	Once-weekly planning periods over 6 months-1 year	Double or triple periods, once or twice weekly for 3-6 weeks	Moderate. System plans eventual use of S-L.	Direct Indirect Advocacy	Uses S-L elements in class and on site. Usually involves adjustment of student schedules and formal evaluator.
Continuing (Recurring) Curriculum Component	Experienced, Master	Provides opportunities for students of varying needs for structure	Once-weekly planning periods spaced over 6 months-1 year	Double or triple periods, once or twice weekly for 4-9 weeks	High. S-L institutionalized in system via continuing initiatives, structures and resources	Direct Indirect Advocacy	Joins school advisory committee, grade-level/subject-area teachers, students and community partners in annual S-L projects. Involves adjustment of student schedules, formal evaluator.
Cross-disciplinary program	All levels	Provides opportunities for students of varying ages with varying needs for structure	Once-weekly planning periods spaced over 1 year	Double or triple periods, once or twice weekly for 9 weeks	High. S-L Institutionalized in system via continuing initiatives, structures and resources	Direct Indirect Advocacy	Joins coordinating council grade level/subject area teams, students and community partners in school-wide S-L projects. Involves adjustment of student schedules, formal evaluator.

Table 1. Characteristics of Five Designs for Implementing Service-Learning (S-L) in Middle and High Schools (Pritchard & Whitehead 2004)

As shown in the table above, Pritchard and Whitehead²⁹ propose the following five designs: *in-class approach*; *service-learning as a one-day event*; *service-learning as prototype project*; *service-learning as a recurring curriculum component*; *service-learning as a cross-disciplinary program*. These designs increase in scope and community-immersion in the order listed, as well as in status as a mainstay of the school culture. With the *in-class approach*, the service activity happens almost exclusively within the classroom. Community partners may visit the classroom but students participate remotely, often producing a tangible that is later relayed to the

community. The duration of these type of service-learning projects is often comparatively small in magnitude, and are therefore attractive to intern or beginning teachers²⁹. Although *service-learning as a one-day* event may, at first glance, imply less of a time investment, the name refers to the duration of on-site participation by students. In this model, while students may spend several days in the classroom learning, organizing, and preparing for the service-event, the service component occurring on-site may only last one day²⁹. The *prototype project* model of service-learning is the implementation of a full scale service-learning project as a reformulation of traditional classroom-based approaches. This design seeks to "...visibly incorporate[e] 1) strategies for obtaining commitment from all service-learning constituents, 2) cooperative outcomes planning 3) reflective learning sequences that link service and classroom study and 4) evaluation of outcomes and celebration of growth"²⁹ (p. 23). Thus, the prototype project design demands a substantial amount of time to plan and coordinate its implementation. This temporal investment, however, is amplified in the *service learning as a recurring curriculum component* wherein full-scale service learning projects are not just a singular, trial occurrence within a course, but a recursive component of the course expectations and structure. In this model, service learning is a feature of the course curriculum from term to term²⁹. Finally, *service-learning as a cross-disciplinary program* would be the embodiment of a schoolwide commitment to service-learning. Here, service-learning projects span multiple subject-areas in which students explore different dimensions of the community/service needs while also learning the relevant academic content of the various disciplines in which the project is integrated. As one might predict, this context for service-learning integration requires much forethought and planning²⁹. As these five models illustrate, there are varying degrees in the scope and time in which service-learning can be integrated.

Although, Pritchard and Whitehead identify six characteristics (as seen in Table 1 above) that might inform these designs, perhaps these designs are better reimagined as the interaction of three meta factors which inform all other decisions regarding the service-learning context: the *type of service*, the *time investment* involved (for both planning and implementation, as they appear to be proportional), and the *level of integration* into the academic curriculum or school culture. Each of these factors then could be viewed as a continuum of bifurcations: time investment as *short vs. long*; type of service as *indirect/remote vs. direct/immersed*; and level of integration as *supplemental vs. fully-integrated*. Figure 1 below provides a visual representation of the intersection of these three dimensions. Although, this conceptualization may only represent idealized versions of the five designs proposed by Pritchard and Whitehead²⁹, the three dimensional space of the visualization presented here allows room for other variations or possible incorporations of service-learning pedagogy into an academic program. As discussed in the subsequent section, this fluidity becomes especially relevant and important when considering the potential contexts for service-learning in precollege engineering curricula.

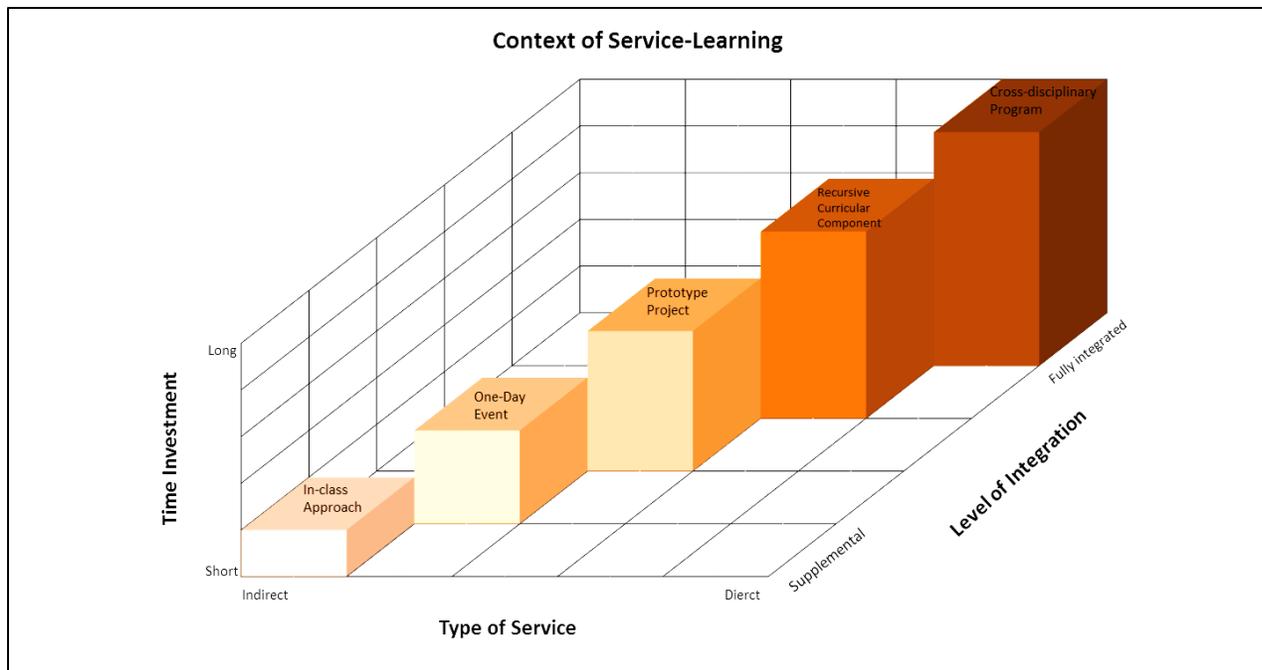


Figure 1. Dimensions of the context for service-learning based on the Pritchard & Whitehead (2004) Designs for Implementing Service-Learning Framework.

Contexts for Pre-College Service-Learning Engineering Curricula

In considering the context of service-learning in precollege engineering education, the same three essential questions as well as the same three dimensions described in the preceding section apply. However, there are additional considerations nested within this contextual framework that are specific to engineering in the K-12 classroom. The first pertains to the level of integration for engineering curriculum, while the other concerns the type of service.

Due to its relatively nascent emergence, a foremost challenge to the integration of engineering curricula into the precollege educational experience is determining where in the academic landscape it belongs. Here lies an important dilemma facing education reformers: should precollege engineering education exist for the sake of engineering and technology literacy or should it exist as a backdrop and a means to promote science and math content learning? By its nature, engineering requires the synthesis and practical application of diverse content knowledge in an endeavor toward innovation and problem-solving⁵. Brophy and his colleagues⁵ explain how design challenges “motivate a ‘need to know by satisfying a ‘need to do’ as an intrinsic desire of all young learners” (p. 376). Thus, authentic engineering experiences serve the potential of elucidating inherent scientific and mathematical principles which underlie a design challenge or engineering solution and therefore provide a rich, rigorous setting for STEM inquiry.

However, contenders of this approach in which engineering serves a backdrop to and facilitator of science and mathematics education argue that such a philosophy potentially undermines engineering as a discipline and profession in its own right. In discussing one of the flagship movements in precollege engineering education, the UTeachEngineering program, instituted by the University of Texas at Austin, Marshall and Berland²⁰ explain that one of the

chief commitments of the UTeach*Engineering* program is that of a commitment to *engineering practice* for its own sake. They offer this rationale for this philosophy:

For example, this work posits that that [sic] a primary goal of pre-college engineering education is for students to develop a command of the engineering design process and engineering habits of mind and that traditional math and science content goals are secondary to this in an engineering class. This is an important commitment. [...] Our contention is that they cannot be a side-note in traditional math and science classes. (p. 49).

In this approach, the emphasis is placed on the engineering design process and engineering habits of mind. However, it does not altogether ignore the importance of STEM content understanding to engineering design and recognizes that science and mathematics understanding is a natural and fundamental virtue of engineering design²⁰. Neither are these two viewpoints necessarily dichotomously opposed. Indeed, the National Academy of Engineering's (NAE) offers perhaps a more harmonized concatenation of these two stances in their proposed vision for K-12 engineering education:

- Principle 1. K–12 engineering education should emphasize engineering design.
- Principle 2. K–12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills.
- Principle 3. K–12 engineering education should promote engineering “habits of mind.”¹⁵

As it concerns the service-learning strategy then, these varying approaches to precollege engineering education pose interesting implications for the service-learning context. It suggests an additional spectrum which represents some of the underlying tensions, as well as overlap between the *service-learning as a prototype project*, *service-learning as a recurring curricula component*, and *service-learning as a cross-disciplinary program* models at the “level of integration” axis. That is, if an engineering service-learning project were to be implemented, the content-area setting of the project will not only reveal how integrated the engineering curriculum is within the wider curriculum, but also by association, how embedded the service-learning pedagogy is in the program's STEM education efforts, and possibly even, within the wider school culture. In another report commissioned by the National Academy of Sciences and the National Academy of Engineering exploring the research on STEM integration in the K-12 setting, the authors allude to this relationship in their analysis of integrated STEM (iSTEM) curricula:

In integrated STEM education it is frequently the case that one STEM subject has a dominant role—the explicit or implicit focus of a project, program, or school is to develop students' knowledge or skill mainly in one content area, such as mathematics. [...] In terms of scope, integrated STEM education initiatives exhibit a variety of relevant parameters, such as duration, setting, size, and complexity. Initiatives may occur as a single hour-long project or over one or several class periods, or they may be reflected in the organization of a single course, a multicourse curriculum, or an entire school. [...] Complexity varies, too, from efforts that are designed to be plugged into an established curriculum (with no other changes to the status quo) to those that ambitiously strive to

design a new integrated learning experience in concert with professional development for the teachers who will deliver it, sometimes in the context of a whole-school design. [...] The scope and nature of integration have a direct bearing on the time and resources needed for implementation; on the level of acceptance or resistance such initiatives receive from students, educators, and administrators; and on the types of outcomes that may be expected and the challenge of measuring them¹⁴ (pp. 42-43).

It could be hypothesized then, that iSTEM approaches would perhaps lend themselves more easily to the *recurring curricula component and cross-disciplinary* models of service-learning. Thus, in the context of pre-college service learning, the place of engineering curriculum can potentially be conceptualized as an embedded interaction within the meta-axis of integration. A graphical representation of this space is depicted in figure 2 below.

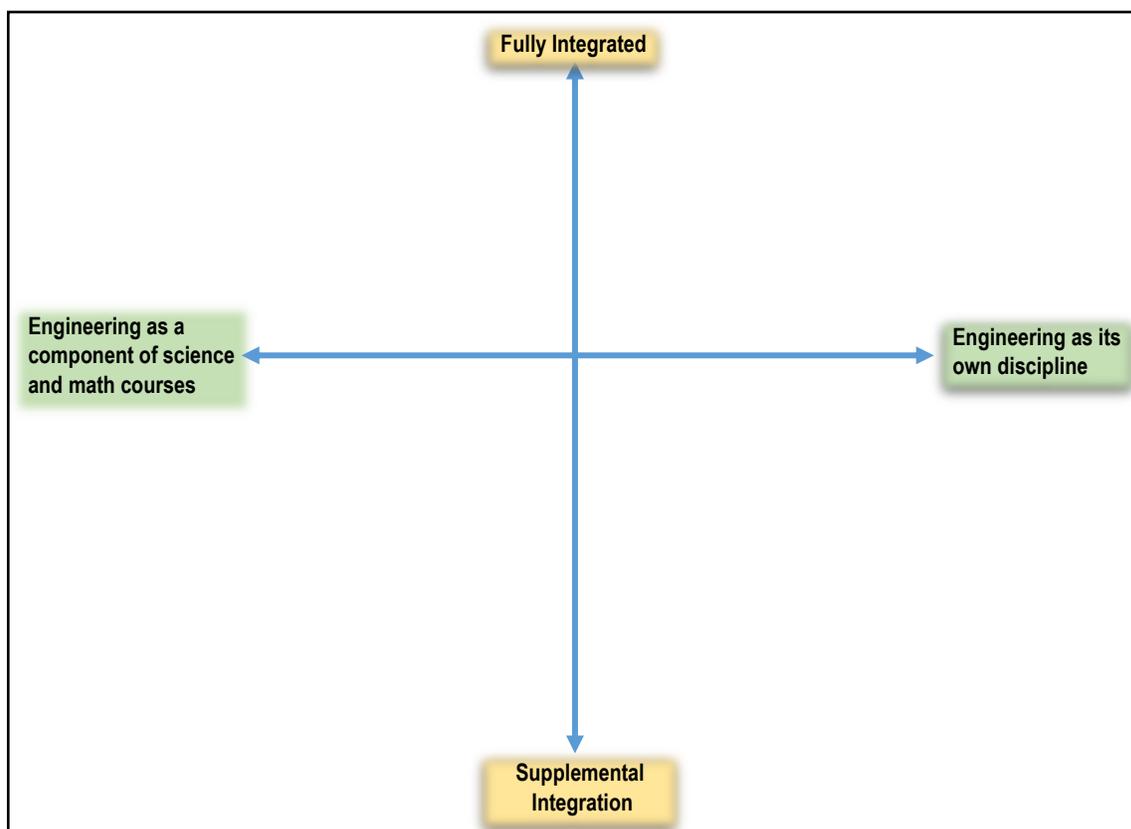


Figure 2. Engineering's Place in the School Academic Landscape

Relationship of Service with the Engineering Design Process

Regardless of its place in the typical American school, the engineering design process is repeatedly identified in the literature as fundamental to any engineering curriculum. While many versions and purposes of the engineering design process (EDP) is proposed in the literature (the reader is strongly encouraged to refer to the Tate et al.³³ for a more thorough, comprehensive discussion on this topic), the inherent challenge as it relates to service-learning reduces to the type of service that will be possible contingent upon the level of completion through the EDP that is undertaken. In other words, how far into the engineering design process will the service

provided by students go? The literature indicates that there are several factors which can contribute to the level of completion and cycles students will undergo with the EDP. Among these factors are: the nature of the design problem and the resources required to solve the design problem; student maturity and knowledge level; the type of the design process or model used and its purpose; and most importantly, the time available for students to meaningfully engage in and progress through the design process^{7, 30, 33}. Thus, with regard to the type of service students are to provide, some of the logistical questions to be considered during the planning phase of the service-learning project could include:

- *What is the purpose of the service to be performed? (ex: To raise awareness? To brainstorm ideas for solutions? To provide a functional solution to the problem?)*
- *How far into the engineering design process can and will students be expected to go in addressing the engineering design challenge? Will they only engage in a partial design process or complete the entire design cycle and multiple iterations of it?*
- *What type of service, specifically what level of an engineering solution, will students be able to reasonably and logistically provide the community partner considering the resources and student maturity/comprehension level? (Are students expected to provide ideas for a solution, a prototype of a proposed, viable solution, or a fully functional product or solution ready to be used by the community partners?)*
- *How often will students interact directly with the community partners?*
- *How much time will students need to accomplish their service task goals?*

It should be noted that these questions are dynamically interrelated: as one moves down the list, the answer to that question is at least somewhat predicated on answers to the questions preceding it. Furthermore, these may not be the only relevant questions, but they are nevertheless, of crucial importance. Fundamentally though, these considerations of service learning activity in an engineering education paradigm can be viewed as the intersection of at least two axes: *type of service* (a meta axis of context, as identified above) with *engagement with the engineering design process* (EDP). Figure 3 below depicts this interaction.

As is shown in figure 3, I have proposed here a theoretical “zone of ideal engineering service-learning activity” which is characterized by a greater fidelity to the complete engineering

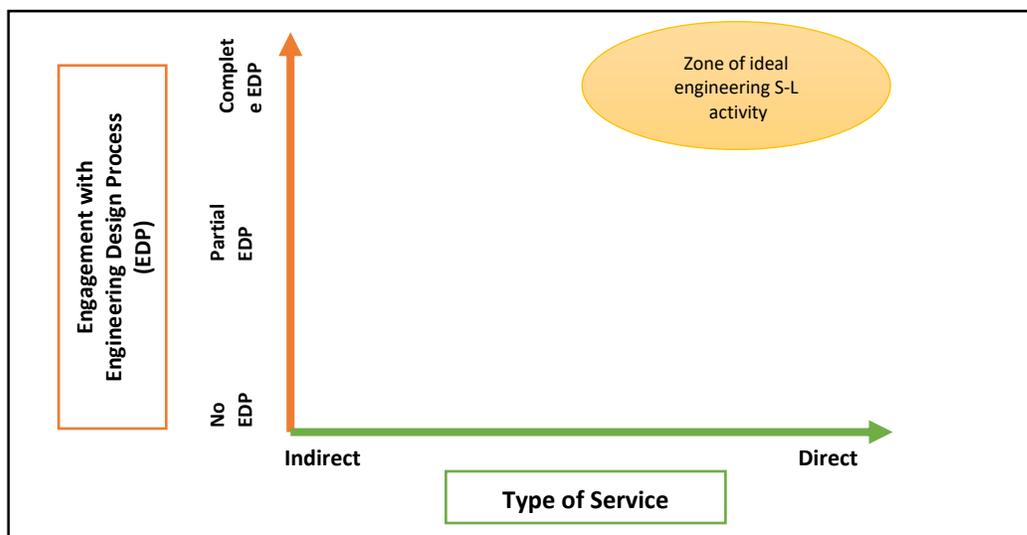


Figure 3. Continuum of Precollege Engineering Service-Learning Activity

design process and more direct, or immersed, student interaction with the community partners. This zone is proposed as an ideal because such an interaction would likely produce the greatest benefit to both constituents involved (students and the community receiving the service activity). As discussed previously, this quality of mutual beneficence is an important component of the service-learning paradigm^{26,32}. It would follow that by engaging in a complete engineering design process while also having ample opportunity to directly interact with the community they are serving through an engineering design process, not only will students have the opportunity to experience a complete design cycle integral to engineering, but they are also likely to experience the benefits of learning posited by experiential learning and social-process learning theories^{27,29}. Similarly, if the participating students complete a full engineering design cycle, regardless of the EDP model chosen, the assumed natural end product of that process would be a refined and functional product or engineering solution^{26,33} that can be used by the community partners.

However, while this zone does represent an optimal manifestation of the service-learning pedagogy in K-12 engineering education, the achievement of this ideal is highly dependent on the project selection. The subsequent section briefly explores the key dimensions of project selection.

Project Selection

Before examining the decision parameters which inform project selection, it is worth noting here again that the contextual elements addressed above are meta factors which underlie those more specific ones that influence project selection. That said, taken together, the principles in the literature suggest that these are the essential questions on which project selection is premised:

- *What are the needs of the community?*
- *What are the academic goals and objectives of the project?*
- *What are the service goals and objectives of the project?*
- *What are the resources and student capacities available?*
- *Who will be driving the project selection?*

Arguably, the most fundamental step in planning a project for a service-learning curriculum is identifying the areas of need in the community^{27, 29}. The needs assessment can occur prior to answering the other questions or simultaneously²⁹. The academic goals of the service-learning project, are informed by state and national curriculum content standards²⁹. In a precollege engineering context, these content standards will depend on the manner in which engineering is delivered. This again is directed by whether engineering is taught via an integrated STEM approach or as a course on its own. Irrespective of the approach and whatever the academic standards, they should ultimately be linked with the community needs assessments.

Much like the academic standards, the service goals of the project need to be outlined^{27,29}. These service goals can be multifaceted in nature. While the service objectives should always delineate the tangible form in which the service will take shape, they may also refer to the more subtle intrapersonal, interpersonal and socio-cultural service competencies students are to grow in as a result of their participation in the service program²⁹. Although national or state adopted standards do not necessarily exist, several experts in the field as well as private organizations

have proposed at least broad categories for these competencies. For example, as outlined in Furco and Billig's *Service-Learning: The Essence of Pedagogy*¹¹, some learning non-academic outcomes that are intrinsic to the service-learning philosophy fall within these domains: vocational (career); personal; civic and cultural; ethical; and, social. For a more thorough elaboration of these domains, the reader is directed toward the original source.

Other key components driving the decisions behind the project selection in a service-learning context are the resources available and student capacities to meaningfully engage in the proposed projects. Resources refer to the institutional, community, financial, and material resources and support available to a service-learning initiative^{11, 27, 29}. In considering student capacities, the teacher must consider all the developmental characteristics that will inform a student's learning experience. Although it is well beyond the scope of the present paper to expound upon all such factors (as indeed, the research on this topic comprises an entire sub-discipline of psychology), briefly, these factors may be extrinsic (ex: family, society & culture, religion, etc.) or intrinsic (ex: biological, maturity level, intellectual functioning, self-esteem, etc.)¹¹. Together these comprise the developmental-contextual framework of student learning, a comprehensive lens through which student capacities can be assessed¹¹. When selecting an appropriate engineering design challenge, be it for a service-learning project or not, these parameters are no less important. Whatever the identified community need, the associated design challenge should be framed in such a way that it is not beyond the scope of possibility both in terms of resource gathering or students' ability to manage the academic and the service demands of the project^{7, 30}. However, as obvious as this may seem, authentic engineering design problems are often very complex and thus scaling the problem so that it is accessible to students and easily supported by the institution and available resources, without oversimplifying it, may often be more challenging than one may assume³⁰.

While all of these considerations are vital to the project selection process in service-learning, perhaps the issue of student choice in project selection is most crucial to the present discussion. Although the literature on precollege engineering service-learning is limited, in examining the artifacts from Purdue University's EPICS High curriculum as well as Hofstra University's Engineering for All program¹³, it appears there lies a spectrum of who among the constituents are driving the service learning projects. The EPICS K-12 program offers multiple curricula modules corresponding to various levels of institutional integration of engineering service-learning: the EPICS High year-long module; the EPICS High extra-curricular module; the EPICS Middle School year-long module; and the EPICS after-school module. In all of the EPICS K-12 modules, there is included a project-identification phase in which students systematically identify compelling needs in the community to be addressed by an EPICS project⁸. On the other hand, from what can be ascertained from the web resources, Hofstra University's Engineering for All program appears to be somewhat more semi-structured, or pre-deterministic, in the project selection process. The program's mission goals identifies two thematic project contexts to be developed for its two curriculum modules: one in a food context and the other in a water context¹³. While perhaps there may be room for student input in deciding which specific need within these themes will be addressed by the service-learning project, there still exists some level of teacher/facilitator control or direction.

In light of these examples, it could be said then, a spectrum of constituent choice exists in the project selection decision for an engineering service-learning program. These constituents may be distinguished in the following way: student, teacher/school program facilitators, and community partners. It is important to note that these constituent desires need not necessarily be in conflict with each other; indeed, quite the contrary should be true for the successful implementation of a service-learning project. Nevertheless, the service-learning literature does seem to regard higher levels of student choice as ideal and favorable to the project selection process. Furco and Billig¹¹ explain:

Projects that are consistent with the interests and values of participating students are most likely to show positive student outcomes of service involvement [...] Program elements, including student autonomy and the matching of student goals and interests, have been identified as central components of successful service-learning programs. This suggests that service-learning programs will be more successful if they allow students to work independently, to take responsibility for their involvement in service projects, and to determine their own goals and means of participation in service-learning. (p. 86)

Payne²⁷ and Pritchard and Whitehead²⁹ also sympathize with this view, arguing that student choice promotes greater ownership of learning.

Regardless the level of input from each constituent, as discussed above, the project selected must also align with the identified academic and service goals, as well as, the resources available and student capacities for participation in the project. Thus, here too lies important interactions between these various factors. However, since the academic goals are assumedly, largely driven by state and national standards, the project selection factors can be conceptualized as an interaction of constituent choice, resource availability, and student capacity. Figure 4 on the following page illustrates this notion as the intersection of three axes. In the visual representation of the project-selection factors, the reader may notice that the service goals are omitted. This is because the service objectives have a bidirectional dynamic with the project selection process. That is, while the service objectives inform the selection process of the service project, it is also in turn, informed by the project selection. The service goals both beget and is begotten by the project selection.

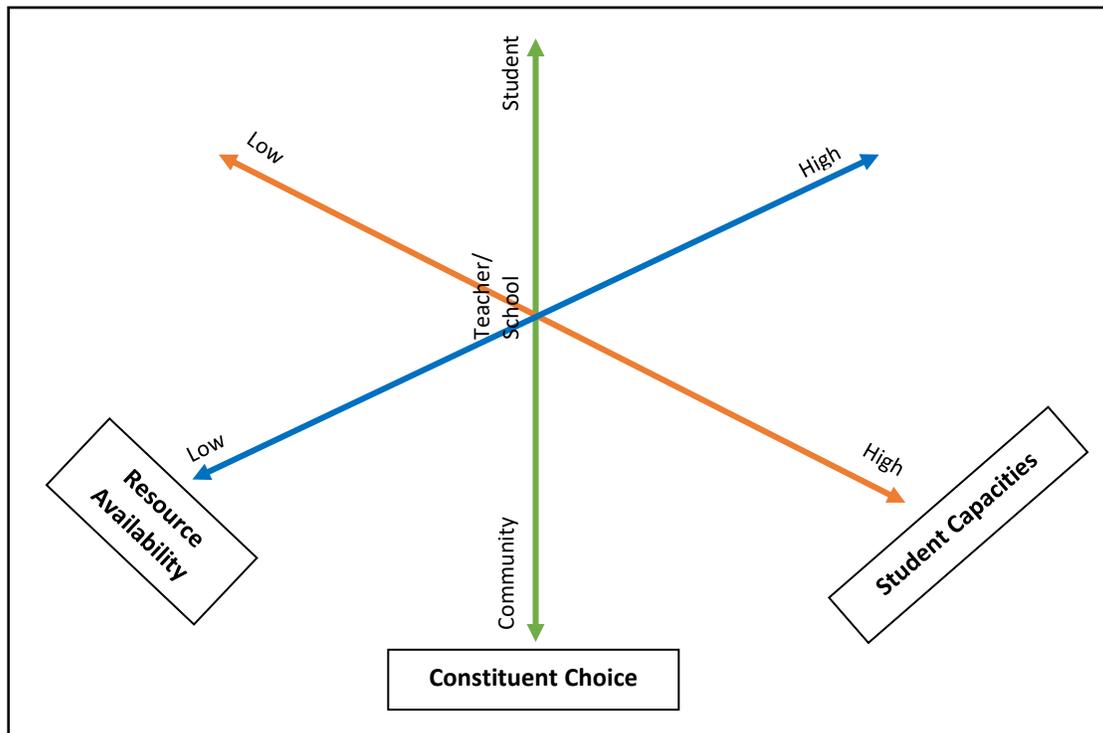


Figure 4. Interaction of factors influencing engineering project-selection in service-learning.

Assessment of Student Academic Outcomes

In addressing the assessment paradigms of engineering service-learning curricula, it must be stated from the outset that this discussion will contain, at best, only a cursory review of the decision parameters which may influence the assessment of student outcomes that will stem from precollege engineering service curricula. This is largely because the research and theories surrounding assessment in education literature, service-learning literature, as well as precollege engineering literature are each so vast, it would be a gross injustice to attempt to synthesize these bodies of scholarship within the scope of this paper. That said, this discussion will only merely address two major forms of assessment as it pertains to assessing the academic outcomes of student learning within the service-learning paradigm.

Since throughout this paper, service-learning has been discussed as a pedagogy for academic learning, among the most important outcomes to be measured, as a result of its use, is student academic achievement. Foremost to any decisions made regarding assessment is alignment with academic goals and objectives^{27, 29}. In determining how this assessment will take form, two broader categories of assessment are considered here: performance/nontraditional assessment and standardized/traditional assessments.

Performance/nontraditional assessments may include portfolio assessments, observational data, surveys and a collection of other artifacts from which qualitative conclusions about student learning can be made^{27, 29}. Payne²⁷ characterizes performance assessments as consisting of some or all of the following elements: value beyond the assessment itself; student-constructed responses; realistic focus; application of knowledge; multiple data sources; objectives-based and

criterion-referenced; reliability; multiple approaches; multidimensional in structure; multidimensional scores. Standardized/traditional assessments is a category which includes teacher-created tests/examinations or high-stakes standardized tests. Generally, these assessments often fall within the category of criterion-reference tests²⁹, and "...determine the degree to which people can accomplish tasks that indicate they possess particular skills and abilities... The level of student' learning is judged by the number of the criterion steps which they can absolutely demonstrate."²⁹.

These two categories of assessment pose important implications for assessing academic outcomes within an engineering service-learning curriculum. By virtue of it being an engineering curriculum, a requisite component would be student engagement in an engineering design process. The question remains then: how is student learning to be assessed in a design context? The nature of design and innovation inherent to engineering would suggest that performance-based assessments are perhaps most appropriate to assessing engineering design thinking. Indeed, in examining the assessment features of the EPICS K-12⁸ and Engineering for All¹³ programs, both curricula are characterized as a series of diverse performance-based or qualitative assessments throughout the entire engineering design process. This is especially true at the end of the design process in which student design solutions are assessed by rubrics^{8, 13}.

However, the conundrum of engineering's place in the academic landscape again poses some important implications here. If engineering curricula is integrated within a foreground of traditional STEM content area courses, then teachers and students are still held accountable for content teaching and learning as delineated by state standards, the achievement of which is often measured by high-stakes standardized testing. To this point, however, past studies have shown that engineering approaches to teaching and learning STEM content have led to gains in student learning^{5, 15}. Even still, in such an integrated STEM approach, "...it is challenging to design assessments that are effective for both discipline specific and integrated learning"¹⁴. Thus, the assessment considerations for an engineering service-learning is complex, to say the least. Nevertheless, as the literature continues to develop in the best practices for precollege engineering education, perhaps a mixed-methods approach in which performance-based as well as standardized/traditional assessments are both features of the assessment strategies in an engineering service-learning program. Of course, the essential mainstays of validity, reliability, and fairness²⁹ as well as relevancy to the greater academic context in which the service-learning program is incorporated should be the primary driving considerations in any assessment decisions.

Limitations and Future Work

This paper sought to elucidate some of the various pedagogical factors that may inform the development process of precollege service-learning engineering curricula. Though there is a lack for such curricula, a synthesis of the wealth of service-learning literature with the burgeoning P-12 engineering education research offers a potential framework to better facilitate the incorporation of the service-learning pedagogy into precollege engineering efforts. However, while this paper attempted to address some of these considerations pertaining to the context, project selection, and assessment paradigms of these efforts, there are still other considerations not discussed here that are of equal importance. A few of these additional considerations include: objectives and strategies for evaluating precollege engineering service-learning

programs; heuristics for extrapolating conclusions out of outcomes data evaluating engineering service-learning curricula; and, strategies for evaluating impacts on and outcomes for the community partners. Perhaps most pressingly though, future work should examine the best practices for assessing student learning and service outcomes more thoroughly. Nevertheless, the present framework serves as a nascent effort which bears the potential to give rise to a more comprehensive one in the future.

Within the framework presented here, it would be instructive to transpose these various layers of context, project-selection, and assessment onto each other to better visualize how these factors may influence each other. It would also be beneficial to map the pedagogical characteristics of existing models of preservice service-learning engineering curricula such as that of the EPICS K-12 and Engineering for All programs onto the conceptualizations presented here. Doing so could potentially better synthesize and elucidate the emerging models for this pedagogy.

Above all, the service-learning pedagogy appears to be a promising strategy for the integration of authentic engineering curricula into the 21st century American education landscape. This becomes especially true when one considers the research showing that service-learning oriented curricula is linked to increased interest and retention in engineering among women and underrepresented minorities, two demographic groups that need increased representation in the engineering field^{18,34}. Furthermore, the service-learning pedagogy inherently possesses problem- and project- based features that necessarily demand situating learning in an authentic setting, qualities which have been identified by the NAE as potentially beneficial to teaching the engineering design process and/or for the implementation of integrated STEM curricula¹⁴. For these reasons and more, any efforts that explore the incorporation of engineering service-learning pedagogy early in the educational path are arguably worthwhile.

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