Factors leading to sustainable social impact on the affected communities of engineering service learning projects

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ABSTRACT

University engineering programs across the USA engage in service learning projects. These projects involve student teams designing and implementing products or solutions for communities in need, often in developing nations. There has been much research done relating to pedagogy and the impact of these programs on student learning. However, less research has been done on measuring the impact of these programs on the affected communities. This paper examines factors that practitioners believe are related to successfully delivering a desirable and transferable solution to affected communities. The authors identified 49 distinct factors from the literature that implicitly or explicitly are suggested to contribute to successful project outcomes. Formed as postulates in this paper, these 49 factors have been separated into 5 categories to assist understanding and implementing these factors into service learning programs. Lastly, different methods of analyzing and measuring project success and impact are discussed. Future methods for proving the viability of the 49 postulates are discussed as well.

1. Introduction

Engineering programs at universities across the USA participate in service learning programs where student teams design and implement projects aimed at improving lives in developing nations. As we plan, implement, and evaluate service learning opportunities it is worth asking "do these projects have a lasting impact on the communities served?" and "how can we create a real impact that leads to long term benefits for affected communities?"

The upward trend in service learning programs over the last 20 years has created a wealth of past experiences to learn from LaPorte et al. (2017). Reflection on the success and failures of projects has helped develop the current best practices (LaPorte et al., 2017; Muñoz, 2014; Dean and Van Bossuyt, 2014). While there are many educational methods centered on how these programs should be run, research has primarily focused on the educational impact of these programs on student learning. There is less research on the impact of these programs on the communities served.

In order to discuss the factors that contribute to a successful project's impact on a community, we must first define success and impact. We will use the definition of success suggested by George and Shams (2007) as delivering a solution that is desirable and transferable to the community. For a service learning project, we also hope that this solution improves the quality of life in at least 1 of 11 social impact categories (Stevenson et al., 2018; Rainock et al., 2018). Furthermore, we hope that this impact will be sustainable over time (Mattson et al., 2019).

Despite all of the research in the literature, there is little quantitative analysis on the factors that lead to project success and long-term impact of service learning projects on affected communities. The purpose of this paper is to identify factors of success as well as means of analyzing project success so that future research can be used to better understand best practices.

While many scholars agree upon the factors that lead to success, many of these university programs do not publish their metrics for success in archival sources. Furthermore, there is a lack of general consensus on how success should be measured. Without using and analyzing metrics that measure the success of service learning projects, engineering service learning programs may not be reaching their full potential for creating a positive social impact. Given that there is not a tradition of using specific methods to determine project success, methods that have been used are discussed in Section 4 of this paper.

Additionally, the majority of the published literature is written from the practitioner perspective. Only 5 of the 38 papers included in the literature review contain evaluation from the affected communities. While the practitioner perspective is valuable, the authors acknowledge

that additional research is needed that centers on impact as seen by the affected community.

First, this paper describes the methodology used for determining the 49 postulates presented herein. Then we examine the postulates and categorize them for ease of discussion and application. Factor categories presented are: : Institutional Support and Logistics, Community Interaction, Student Preparation, Design and Technical, and Implementation Trips. The postulates in each category are compared and discussed. Methods to analyze the postulates to determine their impact on service learning project success are also discussed.

2. Methodology

The authors performed a literature review of 38 papers to extract factors practitioners believe are connected to the success of service learning projects. Factors related to success were stated both explicitly and implicitly in the literature reviewed. However, the majority of factors were not stated explicitly. The authors examined the sentiments and reflections of practitioners as they discussed the project results.

The literature review focused only on archival literature. While non-peer-reviewed resources such as white papers, project presentations, and project reports would provide additional information, these sources likely lack the rigorous review process that characterizes the published literature. Additionally, the authors believe the literature reviewed for this paper still captures many of the perspectives that would be gained from including non-academic literature. For example, service work performed as part of service learning courses were mentioned in 14 papers, club related work in 6 papers, academic research related in 12 papers, and work done by professional organizations or NGOs in 16 papers. While this work is not necessarily specific to engineering service learning, it is applicable due to being projects of a similar nature in a similar context. Including these papers helped capture the perspectives of practitioners that would have been missed by limiting the literature review.

The acceptance criteria for including a paper was that the paper identified or suggested a factor that led to sustained success or sustainable impact for the impacted criteria. It was not necessary that the paper provide evidence that a given factor lead to success of the project. The majority of papers reviewed did not explicitly state the methods by which they determined a project was successful or how they determined which factors contributed to it. The set of postulates in this paper is based on the assumption that the paper's original authors were correct about the suggested factors contributing to success. The scope of this paper is to identify the factors believed by practitioners and/or by the affected communities to lead to success. However, each suggestion was considered by the authors of this paper to be reasonable and worthy of inclusion to the list of postulated factors.

The single most common reason for rejecting papers was that the majority of papers read summarized the described projects and discussed the results, but did not link the outcomes to actions taken by the practitioners in any way.

The literature review was performed in three separate stages: Stage 1: The authors included papers which they were already aware of, and then added to the set of papers through literature review. The first set of search terms for papers included the words: humanitarian, university, college, higher education, projects, competitions, viability, sustainability, engineering. The first stage identified approximately 40 papers. These were then reviewed. After reviewing the set of 40 papers, approximately 15 identified one or more factor(s) leading to success and were included in the paper.

Stage 2: After the first round of accepted papers, search terms were refined to better encapsulate the papers that were providing useful results. Three separate searches were performed. Each search included the terms service learning and engineering. The first set of additional terms were success, outcome, issues, and problems. The second set of additional terms was global development and community. The last set

Table 1
Breakdown of postulate by category.

Postulate category	# of Postulates
Institutional support and logistics	11
Community interaction	12
Student preparation	11
Design and technical	20
Implementation trips	7

of terms was social impact. The number of included papers at the end of this stage was approximately 30.

Stage 3: Additional papers were added by searching the papers that cited the papers included in Stages 1–2, and searching the papers cited by papers in rounds 1–2. This led to 8 additional papers and a total of 38 papers cited.

The papers presented do not represent all possible relevant literature. However, the authors believe the papers included present a reasonable and relevant sample. The papers reviewed present a wide range of practitioners perspectives. While there are fewer papers which include the affected community perspective (5 out of 38), this is due to a lack of published literature written from the community perspective. The authors acknowledge that additional insights from the community perspective could potentially change the lists of postulates. While the literature is limited by the lack of community perspective, the authors believe that the list of postulates presented are a good sample of practitioner perspectives.

3. Postulated factors leading to project success

This section discusses factors that experienced practitioners believe are linked to project success. Factors are given as inputs or processes rather than output measures or characteristics. While the goal of development engineering is to achieve positive outcomes in affected communities, it is through the inputs and processes of the projects that these goals are achieved.

The authors identified 49 distinct factors leading to success for engineering service projects in the literature. These factors were extracted from papers which examined projects from many different contexts including: service learning courses, non-governmental organizations, student clubs, university-sponsored capstone projects, student competitions, and community-sponsored projects. These papers provide a broad range of perspectives from not only service learning class projects, but projects in closely related contexts as well.

The majority of factors leading to success were cited multiple times by different authors. We acknowledge that there were some minor disagreements, such as papers by Lewis and Suhr et al. suggesting that partnering with an NGO hindered student ability to communicate with those in impacted communities (Lewis, 2014; Suhr et al., 2014) where as other papers suggested that working with an NGO was beneficial (Sandekian et al., 2014; Amadei et al., 2009). Overall the literature agreed on which factors lead to success, differing only in the importance given to each factor in their specific contexts.

The postulated factors of success were grouped by the authors into five subcategories which are: Institutional Support and Logistics, Community Interaction, Student Preparation, Design and Technical, and Implementation Trips. 12 of the 49 postulates were assigned to multiple subcategories as they were viewed by the authors as belonging to both groups (see Table 1).

3.1. Institutional support and logistics

This section discusses the postulates in Table 2 which are related to institutional support and project logistics. Engineering service learning programs come with logistical challenges that require the attention of the institutions supporting them. These types of challenges identified in

Table 2
Postulated logistical factors.

Postulate #	Postulate. projects benefit from:	Authors cited
L1	Sufficient project funding	George and Shams (2007), Green et al. (2004), Mac Mahon and Gill (2018), Muñoz (2014), Rodriguez (2014), Suhr et al. (2014), Thode et al. (2011)
L2	Maintaining university support of the project	George and Shams (2007), Rodriguez (2014), Suhr et al. (2014)
L3/CI1	Working with an NGO partner to contact the community	Amadei et al. (2009), Green et al. (2004), **Lewis (2014), Sandekian et al. (2014), **Suhr et al. (2014)
L4	Working with a community partner	Bixler et al. (2014), George and Shams (2007), Gorski et al. (2016), Jue (2011), Lewis (2014), Mac Mahon and Gill (2018), Mattson and Wood (2014), Wood and Mattson (2019)
L5/TD5	Ensuring that materials needed for the project are available to the affected community	Chou and Austin-Breneman (2018), George and Shams (2007), Levine et al. (2017), Mac Mahon and Gill (2018), McComb et al. (2018), Polito and Husfeld (2005)
L6/TD7	Selecting the proper project	Bixler et al. (2014), Eitzel et al. (2018), George and Shams (2007), Mac Mahon and Gill (2018)
L7	Cooperating with the local government	Mattson and Wood (2014)
L8/TD11	Continued involvement with the community after project instillation	Amadei et al. (2009), Bixler et al. (2014), Jue (2011), Mac Mahon and Gill (2018), Muñoz (2014)
L9	Successfully navigating legal issues	Suhr et al. (2014)
L10/TD13	Long term project involvement (greater than 1 year)	Amadei et al. (2009), George and Shams (2007), Lewis (2014), Mac Mahon and Gill (2018), Wood and Mattson (2019)
L11/TD 14	Regularly evaluating the project	Amadei et al. (2009), Gorski et al. (2016)
		** designates sources that disagree with the given postulate

the literature include: securing funding, selecting a project, choosing a community partner, and supporting projects over an extended period of time.

Because engineering service learning projects generally do not result in the creation of businesses or profit, the literature stresses the importance of considering the need for long term funding to sustain or maintain solutions for both those completing the project and the affected communities (Thode et al., 2011; Suhr et al., 2014; Rodriguez, 2014; Muñoz, 2014; Mac Mahon and Gill, 2018). While funding is generally regarded as important, principles for establishing the amount of funding were not discussed. For example, papers stated that it was important that a project have sufficient funding without discussing what might qualify as such. Knowing the social impact per dollar of a project would be useful in acquiring funding and garnering support for the project (Mattson et al., 2016).

Two other important aspects of service learning projects found in the literature are choosing a project and selecting a community partner. The difference between success and failure can often be selecting the right project (George and Shams, 2007; Bixler et al., 2014; Mac Mahon and Gill, 2018; Eitzel et al., 2018).

Because most service learning projects take place internationally, it is vital to work with a community partner. The literature agrees that working with someone in the community is key to project success (Wood and Mattson, 2019; Jue, 2011; Mattson and Wood, 2014; Lewis, 2014; Gorski et al., 2016; George and Shams, 2007; Mac Mahon and Gill, 2018). Studies have shown that working with community partners facilitates communication with those directly affected by the project and helps teams identify and adapt to the community's needs (Wood and Mattson, 2019).

While the literature agrees that working with a community partner is beneficial, there is disagreement about who that partner should be. Green suggests that working with an established non-profit or governmental organization is beneficial to project success, while Lewis and Suhr et al. suggest that working directly with community leaders is more effective (Lewis, 2014; Suhr et al., 2014). Several authors preferred working with established organizations because they have previous experience, and community relationships (Green et al., 2004; Amadei et al., 2009; Sandekian et al., 2014). Lewis prefers working directly with partners who are part of the community because it allows students to have more direct relationships with the community, thus placing the engineers closer to the problem being solved (Lewis, 2014). Mac Mahon and Gill also noted that outside organizations often have

uncertain funding and priorities, which could make a partnership unsustainable in the long run (Mac Mahon and Gill, 2018). Suhr. et al. indicated that working with NGOs added extra bureaucracy to the project process which lead to delays and communication errors (Suhr et al., 2014).

One issue that plagues both student projects and development engineering in general is that projects are often designed, implemented, and then left in developing nations without implementing long-term plans to continue the project or ensure long-term sustainability. Running projects that only focus on the short term has often resulted in broken and unused projects that fail to serve their communities (Dean and Van Bossuyt, 2014). An increased focus on sustainability from the beginning of a project has been found to be one of the most important factors to long-term sustainability (Jue, 2011; Gorski et al., 2016; Muñoz, 2014; Mattson et al., 2019). This long-term focus can include designing a durable product (Mac Mahon and Gill, 2018), providing spare parts (McComb et al., 2018), ensuring that medium to long-term project support is available (Mac Mahon and Gill, 2018), and ensuring that the proper distribution channels are in place for sustainable implementation (McComb et al., 2018; Mattson and Wood, 2014). This may also include personal long-term involvement with the affected communities (Amadei et al., 2009; George and Shams, 2007; Lewis, 2014; Mac Mahon and Gill, 2018; Wood and Mattson, 2019). Multiple studies agree that longer-term involvement is beneficial to sustainable project impact and success (Wood and Mattson, 2019; Lewis, 2014; George and Shams, 2007; Mac Mahon and Gill, 2018).

3.2. Community interaction

This section discusses the postulates in Table 3 related to interactions with the communities served. The most cited factor for sustainable success in the literature review was understanding the needs of the affected community (Wood and Mattson, 2019; LaPorte et al., 2017; Wood and Mattson, 2016; Lewis, 2014; Mattson and Wood, 2014; George and Shams, 2007; Wasley et al., 2017; Zanello et al., 2017). Practitioners agreed that understanding the needs of the affected community allows student teams to focus their efforts into designing solutions that reach benchmark goals in areas of importance to the affected community.

One way to understand the needs of the community is to involve them in the design process. Co-design with the affected communities is one of the practices suggested by practitioners to create better trust,

Table 3
Postulated community interaction factors.

Postulate #	Postulate. projects benefit from:	Authors cited
CI1/L3	Working with an NGO partner to contact the community	Amadei et al. (2009), Green et al. (2004), **Lewis (2014), Sandekian et al. (2014), **Suhr et al. (2014)
CI2	Having continued relationships with the served community	Amadei et al. (2009), Bixler et al. (2014), George and Shams (2007), Lewis (2014), Mac Mahon and Gill (2018), Polito and Husfeld (2005), Ranger and Mantzavinou (2018), Soto and Dzwonczyk (2015), Tucker et al. (2013)
CI3/TD2	Understanding the needs of the affected community	George and Shams (2007), LaPorte et al. (2017), Lewis (2014), Mattson and Wood (2014), Soto and Dzwonczyk (2015), Tucker et al. (2013), Wasley et al. (2017), Mattson et al. (2019), Mattson et al. (2016), Zanello et al. (2017)
CI4/TD3	Involving members of the affected community in the design process	Chou and Austin-Breneman (2018), Eitzel et al. (2018), Lewis (2014), Mac Mahon and Gill (2018), Mattson and Wood (2014), Muñoz (2014), Ranger and Mantzavinou (2018), Soto and Dzwonczyk (2015), Thode et al. (2011), Tucker et al. (2013), Wood and Mattson (2019)
CI5/IT2	Testing the product in the affected community	George and Shams (2007), Mattson and Wood (2014)
CI6	Ensuring the tools and skills required to maintain the project exist in the target community	Chou and Austin-Breneman (2018), Gorski et al. (2016), Levine et al. (2017), Mac Mahon and Gill (2018), Polito and Husfeld (2005)
CI7	Having the support of the affected community	Eitzel et al. (2018), George and Shams (2007), Glade et al. (2014), Gorski et al. (2016), Lewis (2014), Mac Mahon and Gill (2018), Thode et al. (2011)
CI8	Having volunteers or workers that live in affected community	Bixler et al. (2014), George and Shams (2007), Gorski et al. (2016), Muñoz (2014), Thode et al. (2011)
CI9	Consistent communication with members of the affected community	Glade et al. (2014), Lewis (2014), Polito and Husfeld (2005), Rodriguez (2014), Sandekian et al. (2014), Swan et al. (2005)
CI10	Having multiple contacts in the affected community	Suhr et al. (2014)
CI11/TD15	Involving the affected community in developing the project plan	Mac Mahon and Gill (2018), Muñoz (2014), Soto and Dzwonczyk (2015), Tucker et al. (2013)
CI12	Having someone that speaks the same language as members of the affected community	George and Shams (2007), Levine et al. (2017), Lewis (2014), Polito and Husfeld (2005), Soto and Dzwonczyk (2015), Wood and Mattson (2019)
		** designates sources that disagree with the given postulate

communication, and understanding of technical constraints (Mattson and Wood, 2014; Thode et al., 2011; Lewis, 2014; Muñoz, 2014; Tucker et al., 2013; Mac Mahon and Gill, 2018; Chou and Austin-Breneman, 2018; Ranger and Mantzavinou, 2018; Eitzel et al., 2018; Levine et al., 2017). Co-design is also helpful in enabling the community and making the most of local capabilities (Eitzel et al., 2018). One example of this is working with locals to identify materials and manufacturing capabilities much more quickly and effectively than remote research (Chou and Austin-Breneman, 2018).

Another factor that is regarded by the literature as important in creating a project that meets the needs of the community is building positive relationships with the community. Continued relationships with the affected communities have been shown to foster better communication and build trust that allows for better collaboration (Wood and Mattson, 2019; Mac Mahon and Gill, 2018; Ranger and Mantzavinou, 2018). The literature agrees that working with one community over a longer period contributes to better relationships and successful projects (Lewis, 2014; George and Shams, 2007; Polito and Husfeld, 2005). Maintaining this community support is regarded as important in creating a project with sustainable impact (Thode et al., 2011; Glade et al., 2014; Lewis, 2014; Gorski et al., 2016; George and Shams, 2007; Bixler et al., 2014; Amadei et al., 2009; Ranger and Mantzavinou, 2018). Having volunteers or workers that live in the community is one way practitioners have found to effectively maintain these partnerships (Thode et al., 2011; Gorski et al., 2016; Muñoz, 2014; George and Shams, 2007).

Consistent communication is regarded by practitioners as vital for understanding community needs, building trust, handling logistics, and managing expectations (Jue, 2011; Mattson and Wood, 2014; Lewis, 2014; Gorski et al., 2016). Furthermore, good communication is imperative in other factors such as relationship with affected communities and community involvement. Although there is agreement in the literature on the importance of communication, there are many different avenues of communication that could be researched to determine which medium of communication is most effective.

Being able to speak the same language as members of the affected community has been shown to have a positive impact on communication and on project success (Wood and Mattson, 2019; Levine et al., 2017). Speaking the language helps designers receive more relevant information and is generally regarded in the literature as beneficial to the overall success of projects (Wood and Mattson, 2019; Lewis, 2014; George and Shams, 2007; Polito and Husfeld, 2005; Soto and Dzwonczyk, 2015). Speaking the local language helps not only in gathering more knowledge about technical factors and user needs (Wood and Mattson, 2016), but also in contextualizing local culture (Levine et al., 2017).

3.3. Student preparation

This section discusses the postulates in Table 4 related to the preparation of students participating in service learning projects. Those running service learning programs have noted that university students often lack the technical experience and soft skills necessary to manage the complex problems presented by development projects (Dean and Van Bossuyt, 2014; Wood and Mattson, 2014). Another area of concern is that many students lack understanding of the affected community and their needs. Several authors found that a failing to understanding the affected communities culturally and socially was a main factor in ineffective projects (Mattson and Wood, 2014; Lewis, 2014; LaPorte et al., 2017; Mac Mahon and Gill, 2018). There are several ways to mitigate this issue and help student teams be successful.

While some service learning programs operated through student clubs only, a majority included some type of course work. Several authors mentioned the positive impact that course work had on the students' abilities and the performance of their projects (Lewis, 2014; Rodriguez, 2014; Dean and Van Bossuyt, 2014; Zelenika and Pearce, 2014; Ranger and Mantzavinou, 2018). Practitioners believe that course work should include technical aspects as well as social and cultural aspects (Lewis, 2014; Rodriguez, 2014; Dean and Van Bossuyt, 2014; Polito and Husfeld, 2005; Zelenika and Pearce, 2014).

Table 4

Postulated student preparation factors.

Postulate #	Postulate. projects benefit from:	Authors cited
SP1	Student mentors with relevant technical experience	Glade et al. (2014), Green et al. (2004). Ranger and Mantzavinou (2018), Rodriguez (2014), Soto and Dzwonczyk (2015)
SP2	Integrating Social Science principles into student coursework	Bixler et al. (2014), Dean and Van Bossuyt (2014), Lewis (2014), Polito and Husfeld (2005), Zelenika and Pearce (2014)
SP3	Integrating or requiring coursework for student participation in the project	Bixler et al. (2014), Dean and Van Bossuyt (2014), Lewis (2014), Ranger and Mantzavinou (2018), Rodriguez (2014), Zelenika and Pearce (2014)
SP4	Students with previous technical experience	Dean and Van Bossuyt (2014), Green et al. (2004), Lewis (2014)
SP5	Maintaining low student turn over	Dean and Van Bossuyt (2014)
SP6	Good communication between team members	George and Shams (2007), Polito and Husfeld (2005)
SP7	Assigning team members specific project roles	Polito and Husfeld (2005), Soto and Dzwonczyk (2015)
SP8	Cultural preparation for students involved in the project	George and Shams (2007), Polito and Husfeld (2005), Ranger and Mantzavinou (2018)
SP9	Utilizing multidisciplinary teams	Bixler et al. (2014) , Green et al. (2004), Jue (2011), Polito and Husfeld (2005), Rodriguez (2014)
SP10	Transferring knowledge between past teams and current teams	Dean and Van Bossuyt (2014), George and Shams (2007), LaPorte et al. (2017)
SP11	Students with the proper motivation for participating	Green et al. (2004), LaPorte et al. (2017), Polito and Husfeld (2005), Rodriguez (2014)

Other important factors include the formation and guiding of teams. The literature suggests that selecting students with proper motivations for participating, such as a desire to learn and serve others, helps students stay motivated throughout the project and leads to more successful projects (LaPorte et al., 2017; Rodriguez, 2014; Green et al., 2004; Polito and Husfeld, 2005; Mac Mahon and Gill, 2018). The literature also agrees that selecting students with previous technical experience and utilizing multidisciplinary teams helps teams have the skills and diversity of thought necessary to successfully create a design that benefits the affected communities (Lewis, 2014; Dean and Van Bossuyt, 2014; Green et al., 2004; Jue, 2011; Rodriguez, 2014). Providing teams with mentors that have project-specific technical experience, development engineering experience, and time to work with students have also been found by practitioners to help in that regard (Glade et al., 2014; Rodriguez, 2014; Soto and Dzwonczyk, 2015). Ranger & Mantzavinou stated that weekly meetings between student design teams and their mentors were crucial to the success of student projects (Ranger and Mantzavinou, 2018).

Another issue facing engineering service learning programs is student turn over (Dean and Van Bossuyt, 2014). Many development projects last longer than the term, semester, or year that students are involved. Practitioners have found that when students pass through projects, much of the knowledge learned by students is lost to turnover. New students then have to re-solve problems that have already been solved (Dean and Van Bossuyt, 2014). The literature finds that successful knowledge transfer between incoming and outgoing students has a strong impact on project success. (Dean and Van Bossuyt, 2014; LaPorte et al., 2017; Ranger and Mantzavinou, 2018).

There are several methods that can be used to ensure this information is transferred to and used by students. One method practitioners have found to prevent loss of information due to turnover is continuously incorporating new students into the projects (Muñoz, 2014; Dean and Van Bossuyt, 2014). Another method is to have members of past projects come and educate members of current projects to inform them of best engineering, social, and cultural practices. This process was instituted at the Engineering Without Borders chapter at the Colorado School of Mines as a result of a study by Laporte et al. and led to increased project impact (LaPorte et al., 2017). This practice has also been a long-standing tradition in the Global Engineering Outreach program at Brigham Young University and has contributed to increased sustainability and social impact (Lewis, 2014).

Additionally, Ranger and Mantzavinou found that students that worked on service learning projects early in their collegiate career were more likely to do additional work on projects through internships, partnerships with communities, or even through the creation of businesses. Utilizing underclassmen in their course helped contribute to 62% of student projects progressing after the completion of the course (Ranger and Mantzavinou, 2018).

The variety of student preparation factors in the literature is demonstrative of different program styles, educational philosophies, and program capabilities of various institution. However, little research has been done comparing methods, only evaluating current methods independently. The assessment methodologies discussed in Section 4 aid in the comparison and evaluation of programs and practices so that program directors can adjust their programs to create higher levels of sustainable impact on affected communities.

3.4. Design and technical factors

This section discusses the postulates in Table 5 related to the design and technical aspects of engineering service learning projects. Unfortunately, as noted by Green et al. (2004), service learning projects often fail to be technically sound, are overly complicated, or unsustainable in developing nation communities. Furthermore, misunderstanding the needs of communities can lead to projects failing to solve the problem at hand and waste community resources (Wood and Mattson, 2016). Some of the prominent practices suggested by the literature to mitigate this are co-design with the affected community, consistent design reviews to ensure project quality, and considering implementation and sustainability from the beginning of the project (Lewis, 2014; Dean and Van Bossuyt, 2014; Gorski et al., 2016)

The most common cause of failure in over 40 international development projects identified by Wood and Mattson (2016) was failing to correctly identify community needs in developing nations. As discussed in the section on community relations, the literature agrees that co-design leads to better communication with the affected community and increased understanding of social and technical constraints (Mattson and Wood, 2014; Thode et al., 2011; Lewis, 2014; Muñoz, 2014). Focusing on the needs of the community throughout the design process is an important factor contributing to project success (Lewis, 2014; Wood and Mattson, 2016).

Another technical practice suggested in the literature to help ensure that the technical aspects of engineering service learning projects are met is holding technical design reviews (Lewis, 2014; Ranger and Mantzavinou, 2018). Design reviews involve engineers, stakeholders, and experts who meet to describe the problem at hand and evaluate the current progress in light of the project goals. In this regard, design

Table 5
Postulated technical & design factors.

Postulate #	Postulate. projects benefit from:	Authors cited
TD1	Having concrete short term goals	George and Shams (2007), Jue (2011), Ranger and Mantzavinou (2018)
TD2/CI3	Understanding the needs of the affected community	George and Shams (2007), LaPorte et al. (2017), Lewis (2014), Mattson and Wood (2014), Soto and Dzwonczyk (2015), Tucker et al. (2013), Wasley et al. (2017), Mattson et al. (2019), Mattson et al. (2016), Zanello et al. (2017)
TD3/CI4	Involving members of the affected community in the design process	Chou and Austin-Breneman (2018), Eitzel et al. (2018), Lewis (2014), Mac Mahon and Gill (2018), Mattson and Wood (2014), Muñoz (2014), Ranger and Mantzavinou (2018), Soto and Dzwonczyk (2015), Thode et al. (2011), Tucker et al. (2013), Wood and Mattson (2019)
TD4	Holding formal design reviews	Dean and Van Bossuyt (2014), Gorski et al. (2016), Lewis (2014), Ranger and Mantzavinou (2018)
TD5/L5	Ensuring that materials needed for the project are available in the affected community	Chou and Austin-Breneman (2018), George and Shams (2007), Levine et al. (2017), Mac Mahon and Gill (2018), McComb et al. (2018), Polito and Husfeld (2005)
TD6	Avoiding solutions that are overly technologically advanced	Green et al. (2004), Mac Mahon and Gill (2018), Soto and Dzwonczyk (2015)
TD7/L6	Selecting the proper project	Bixler et al. (2014), Eitzel et al. (2018), George and Shams (2007), Mac Mahon and Gill (2018)
TD8	Providing appropriate documentation and manuals for operation of the project to the affected community	George and Shams (2007), Polito and Husfeld (2005), Soto and Dzwonczyk (2015)
TD9	Long term project flexibility	Chou and Austin-Breneman (2018), Dean and Van Bossuyt (2014), Eitzel et al. (2018), Jue (2011), Levine et al. (2017), Mattson et al. (2019), Polito and Husfeld (2005), Thode et al. (2011)
TD10/CI6	Ensuring the tools and skills required to maintain the project exist in the target community	Chou and Austin-Breneman (2018), Gorski et al. (2016), Levine et al. (2017), Mac Mahon and Gill (2018), Polito and Husfeld (2005)
TD11/L8	Continued involvement with the community after the instillation of the project	Amadei et al. (2009), Bixler et al. (2014), Jue (2011), Mac Mahon and Gill (2018), Muñoz (2014)
TD12	Having definitive project deadlines	Dean and Van Bossuyt (2014)
TD13/L10	Long term project involvement (greater than 1 year or term)	George and Shams (2007), Lewis (2014), Wood and Mattson (2019)
TD14/L11	Regularly evaluating the project	Amadei et al. (2009), Gorski et al. (2016)
TD15/CI11	Involving the affected community in developing the project plan	Mac Mahon and Gill (2018), Muñoz (2014), Soto and Dzwonczyk (2015), Tucker et al. (2013)
TD16	Considering long term implementation from the beginning	Amadei et al. (2009), Gorski et al. (2016), Green et al. (2004), Jue (2011), McComb et al. (2018), Muñoz (2014), Ranger and Mantzavinou (2018), Soto and Dzwonczyk (2015)
TD17/IT6	Conducting in-country project assessment	Glade et al. (2014), LaPorte et al. (2017), Lewis (2014), Rodriguez (2014)
TD18	Multiple project iterations	Chou and Austin-Breneman (2018), Levine et al. (2017)
TD19	Producing a low cost project	McComb et al. (2018), Thacker et al. (2017)
TD20	Designing for usability	Mac Mahon and Gill (2018), McComb et al. (2018), Thacker et al. (2017)

Table 6
Postulated implementation trip factors.

Postulate #	Postulate. projects benefit from:	Authors cited
IT 1	Visiting the affected community multiple times	George and Shams (2007), Glade et al. (2014), Lewis (2014)
IT 2	Testing the product in the affected community	George and Shams (2007), Mattson and Wood (2014)
IT 3	Careful planning of implementation trip logistics	Bixler et al. (2014), George and Shams (2007), Green et al. (2004)
IT 4	Ensuring sufficient time to complete tasks and make adaptations during implementation trip	Chou and Austin-Breneman (2018), George and Shams (2007), Mac Mahon and Gill (2018), Swan et al. (2005)
IT 5	Securing assets to prevent theft	Thode et al. (2011)
IT 6/TD17	Conducting in-country project assessment	Glade et al. (2014), LaPorte et al. (2017), Lewis (2014), Rodriguez (2014)
IT 7	Visiting the affected community before starting the project	Bixler et al. (2014), George and Shams (2007), LaPorte et al. (2017), Polito and Husfeld (2005), Wood and Mattson (2019)

reviews serve two purposes: to ensure technical soundness, and to ensure that the given solution works for the end user.

Lack of technical knowledge is one of the factors identified by Wood and Mattson (2016) as one of the main causes for failure in development projects in the developing world. Ensuring that project teams have sufficient technical skills is especially important for service learning projects (Lewis, 2014; Dean and Van Bossuyt, 2014). Practitioners suggest that design reviews with experienced mentors produces a higher level of technical soundness (Glade et al., 2014; Rodriguez, 2014).

Another important technique for ironing out technical challenges is iterating through several rounds of prototypes (Levine et al., 2017; Chou and Austin-Breneman, 2018). A study of small manufacturing enterprises in Eastern Africa by Chou and Austin-Breneman (2018) found that most of these enterprises used 2–6 prototypes per project, with several participants using upward of 20 prototypes. Multiple iterations are useful for engineering service learning projects to reach technical requirements, as well as for adjusting products to the local technical and cultural environment in which they are implemented.

Furthermore, design reviews help students understand the affected community and how their project fits into the context of the specific community. A flaw many engineers in developed nations face while trying to serve impoverished communities is that they make flawed assumptions about needs (Wood and Mattson, 2016). Design reviews allow experienced mentors who have taken multiple trips to

Table 7
Postulate checklist.

Postulate #	Postulate. projects benefit from:	Comments	User score
L1	Sufficient project funding		
L2	Maintaining university support of the project		
L3/CI1	Working with an NGO partner to contact the community		
L4	Working with a community partner		
L5/TD5	Ensuring that materials needed for the project are available to the affected community		
L6/TD7	Selecting the proper project		
L7	Cooperating with the local government		
L8/TD11	Continued involvement with the community after project instillation		
L9	Successfully navigating legal issues		
L10/TD13	Long term project involvement (greater than 1 year)		
L11/TD14	Regularly evaluating the project		
CI2	Having continued relationships with the served community		
CI3/TD2	Understanding the needs of the affected community		
CI4/TD3	Involving members of the affected community in the design process		
CI5/IT2	Testing the product in the affected community		
CI6/TD10	Ensuring the tools and skills required to maintain the project exist in the target community		
CI7	Having the support of the affected community		
CI8	Having volunteers or workers that live in the affected community		
CI9	Consistent communication with members of the affected community		
CI10	Having multiple contacts in the affected community		
CI11/TD15	Involving the affected community in developing the project plan		
CI12	Having someone that speaks the same language as members of the affected community		
SP1	Student mentors with relevant technical experience		
SP2	Integrating Social Science principles into student coursework		
SP3	Integrating or requiring course work for student participation in the project		
SP4	Students with previous technical experience		
SP5	Maintaining low student turn over		
SP6	Good communication between team members		
SP7	Assigning team members specific project roles		
SP8	Cultural preparation for students involved in the project		
SP9	Utilizing multidisciplinary teams		
SP10	Transferring knowledge between past teams and current teams		
SP11	Students with the proper motivation for participating		
TD1	Having concrete short term goals		
TD4	Holding formal design reviews		
TD6	Avoiding solutions that are overly technologically advanced		
TD8	Providing appropriate documentation and manuals for operation of the project to the affected community		
TD9	Long term project flexibility		
TD12	Having definitive project deadlines		
TD16	Considering long term implementation from the beginning		
TD17/IT6	Conducting in-country project assessment		
TD18	Multiple project iterations		
TD19	Producing a low cost project		
TD20	Designing for usability		
IT1	Visiting the affected community multiple times		
IT3	Careful planning of implementation trip logistics		
IT4	Ensuring sufficient time to complete tasks and make adaptations during implementation trip		
IT5	Securing assets to prevent theft		
IT7	Visiting the affected community before starting the project		

the community to share their knowledge and help students understand the affected communities. This understanding ultimately helps create a better product that serves the real needs of the affected community (Mattson and Wood, 2014; Lewis, 2014; LaPorte et al., 2017).

Because projects will typically be implemented in communities that are different from the community in which they are designed, it is important that design teams take into account the sustainability of their solutions. Both planning for continued involvement and considering how the project will be sustained after implementation contribute to more successful projects (Jue, 2011; Muñoz, 2014; Gorski et al., 2016; Green et al., 2004; Soto and Dzwonczyk, 2015; Amadei et al., 2009; Ranger and Mantzavinou, 2018).

Some ways to ensure that a project can be implemented successfully include ensuring that the project can be completed using materials, tools, and skills available to the community (George and Shams, 2007; Polito and Husfeld, 2005; Gorski et al., 2016; McComb et al., 2018; Levine et al., 2017; Chou and Austin-Breneman, 2018; Mac Mahon and Gill, 2018). Designers should also ensure that proper documentation is kept and transferred to the affected community. These documents, plans, and instructions should be in a form that is understandable to

and appropriate for the community (George and Shams, 2007; Polito and Husfeld, 2005; Soto and Dzwonczyk, 2015).

For projects that involve a one-time implementation, it is important to ensure that long-term technical support is provided or available to sustain the project (Mac Mahon and Gill, 2018). For those that involve the continuous creation of a product it is also important to design a product that has a low enough price for the area in which it is implemented (McComb et al., 2018; Thacker et al., 2017) and to ensure that the product can be properly distributed (McComb et al., 2018).

3.5. Implementation trips

This section discusses the postulates in Table 6 related to implementation field trips. Perhaps the most important part of engineering service learning programs are implementation field trips. On implementation trips projects are presented to the community. Projects are tested, changes are made as needed, and project knowledge is transferred to the community. Past projects can also be assessed and future projects can be scouted.

One way to prepare for the uncertainties and difficulties of implementing a project in a different community is to visit the community

before a project starts, or before the project is completed (Wood and Mattson, 2019; LaPorte et al., 2017; George and Shams, 2007; Polito and Husfeld, 2005). This helps engineering students better understand technical and social constraints which contributes to project success.

Once projects are sufficiently complete and ready to implement, it is important to prepare for a successful trip. Carefully planning trip logistics helps prevent travel difficulties, and planning sufficient time during the trip allows for adjusting to unforeseen circumstances and making project adjustments (George and Shams, 2007; Green et al., 2004; Swan et al., 2005; Mac Mahon and Gill, 2018; Chou and Austin-Breneman, 2018).

Testing the product in the affected community is important for both assessing the impact and making changes as needed (Mattson and Wood, 2014). Project assessment yields valuable information that contributes to project sustainability and the success of future projects (Lewis, 2014; Glade et al., 2014; LaPorte et al., 2017; Rodriguez, 2014).

The literature agrees upon benefits of making trips to the affected community before projects are started, during implementation, and post implementation. It should come as no surprise that making multiple trips to the community is a factor that leads to project success, but it is often outside the scope of a student's single semester service learning experience (Lewis, 2014; Rodriguez, 2014).

3.6. Utilizing the postulates presented

The main purpose of summarizing the literature and presenting postulates is so that practitioners may utilize them in their service learning projects. Table 7 is a checklist with all 46 postulates. Postulates are listed, then space is given for comments, and a third column has a space for practitioners to score themselves on how well they are considering the given postulate in their project. The authors suggest using a scoring system of **-** for doing poorly in an area, a **0** for not considering the postulate, and a **+** for doing well in an area. Other scoring methods may be used. The purpose of this worksheet is not to create a total project score, but rather to score each postulate individually to help practitioners give proper consideration to areas that may need additional attention.

4. Reviewing methodologies used to analyze project success

While the authors of the original papers believe that there is validity to the postulated factors for success, only 6 out of the 38 papers reviewed reported their methodology and metrics for determining the success of the projects described. The list of 49 postulates therefore represents the collective knowledge of the Engineering Service Learning and Engineering for Global Development Communities, but does not serve as a list of rigorously proven success factors.

Given that there is not a tradition of using specific methods to determine project success, we present methods used by the practitioners in the 6 papers that included description of their methodology and metrics in the literature reviewed for this paper. Future attempts at better understanding the factors leading to project success depend on evaluating whether or not a project was successful. These evaluations were often performed in the current literature to some extent, but typically the literature did not report success metrics or criteria, and did not include the perspective of the affected community. All determinations of success should include the affected communities. Once it has been determined if a project was successful or not, additional examination can be taken into identifying which factors contributed to the success of the project.

These various efforts are presented in this section to inform the reader on the strategies that were taken by the authors of papers included in the literature reviewed to determine project success. Understanding these methodologies provides useful background information on the postulates and on what methods could be used in future work to refine the list of postulates given in this paper.

4.1. Qualitative analysis methods

The literature generally agrees upon the need for analysis and improvement to ensure positive social impacts for the communities that are being served, but as Stevenson et al. note, there are few metrics and little consistency (Stevenson et al., 2018). Several different methods have been used to gain insight into what impacts these projects have, and what contributes positively to these impacts.

A common method to discover factors leading to success has been post project reflection (Soto and Dzwonczyk, 2015; Muñoz, 2014). This method involves asking students and professors what worked and what did not after the implementation of the project. This method is used by Muñoz (2014), Rodriguez (2014), Suhr et al. (2014) among many others. This leads to useful information, but there are several issues with this methodology.

One issue with such an approach is that the relatively small sample size fails to reveal the breadth of knowledge to analyze and supply generally applicable knowledge. Large sample sizes are not necessary for analytic generalization, but engineering service learning projects cover such a wide array of circumstances that only examining a few projects is insufficient. Nevertheless even small sample sizes yield valuable insights. The paper by Suhr et al. (2014) focuses on only the first project done by Engineers Without Borders—University of Idaho chapter. The paper provides great insight on the difficulties of starting up a project, but much of the information is useful only situationally.

Another issue with this approach is that it does not provide long-term insight. Given that there is an interest in the long-term sustainability and impact of projects, greater attention should be given to studies that occur over a large enough period of time to show sustainability.

Mattson et al. (2016), Rodriguez (2014), and Muñoz (2014) examined several projects over a sustained period of time. This allows for follow-up, project iteration, and community feedback. The findings of these studies provide deeper, concrete, and nuanced information that is significantly more useful to those embarking in developmental engineering opportunities.

Another weakness with such a small sample size is that it does not lend itself to statistical analysis and recognition of patterns. A study by Jue (2011) interviews past winners of the MIT IDEAS Service Learning Project competition. In the study, Jue interviews only competition winners that had completed the competition at least 5 years earlier. By interviewing a larger sample size that had long term opportunities to succeed or fail, Jue was able to discover several trends with valuable information on what factors contributed to long-term sustainability such as utilizing multidisciplinary teams, having concrete short-term goals, and planning on long-term implementation early on (Jue, 2011). Although the study provides valuable and widely applicable information, it still lacks statistical analysis needed to quantify, prove, and compare the importance of the factors the author uncovers.

4.2. Quantitative analysis methods

The study by Wood and Mattson (2016) provides a quantitative method of statistical analysis that many other studies have lacked. In the study, failure reports by the Engineering Without Borders—Canada Chapter were compiled and analyzed linguistically to determine the most common factors for failure in international development process. After these reports had been completed, statistical tests were performed to correlate several factors and group the answers into different categories with little inter-categorical statistical correlation (Wood and Mattson, 2016). Thus allowing the authors to state with confidence that the seven most common causes they discovered were indeed independent of each other. This methodology is important because it is able to take a large sample size, run statistical analysis, and synthesize the results in a way that is both mathematically rigorous and easy to understand.

The approach by Wood & Mattson provides valuable insight from the engineers who worked on the project, but it lacks input from those in the affected communities. A study by Coetzee and Nell (2018) provides a methodology for this. The study was done by researchers at North-West University in South Africa. The research created a survey that was given to members of the three communities in which NWU has a campus. The surveys asked community members about the impact of various university activities on their lives. The sample size was chosen to be representative of the population in ethnicity, gender, age, and location. This survey allows the university to see which efforts were actually having a positive impact on the community.

The results of the study were significant enough that they lead to several program changes by North-West University to better focus resources to achieve the impact desired by the university and the community. One downside of the study however, is that the resources and community cooperation required for this study were large, and institutions may not have the time, resources, or community cooperation to produce such results. However, the approaches are still valid on a smaller scale and would be a valuable addition to other methods previously mentioned.

4.3. Predicting impact and universal metrics

One idea that is still absent from studies such as those done by Jue, Wood and Mattson, and Coetzee and Nell are universal metrics. A universal metric is a method of measuring impact that is applicable and comparable in all situations. The benefits of a universal impact metric as noted by Stevenson et al. (2018) are that they allow for easier comparison of impacts.

The method designed by Stevenson et al. (2018) is based on the United Nations Development Programme Index. The UNDPI lists several different dimensions of quality of life that are applicable across all spheres such as health, economic benefit, security, education, etc. This allows those analyzing the impact of products to have concrete numbers showing the impact. The UNDPI is a national score, but the universal impact metric is applicable to individuals or communities to determine how a product would impact them specifically (Stevenson et al., 2018).

Another benefit of a universal impact metric is that it would reduce the cost and complexity of analysis. As noted, several evaluation methods in this literature review required either long time periods such as Muñoz (2014), statistical analysis such as Wood and Mattson (2016) or in depth surveys with extremely large sample sizes such as Coetzee and Nell (2018). The metric developed by Stevenson et al. (2018) requires only a survey with a sample size of 30–40 people to customize the measured impact to any product or community.

The most valuable part of a universal impact metric is the ability to predict the impact before a project is completed. This would allow users to have a better understanding of the community they are serving and compare how design decisions would impact future users (Stevenson et al., 2018). Combining impact predictions with best practices and methods would have the capability to increase the sustainability and impact of community development and service-learning projects.

5. Future work

As noted in the analysis of factors given as well as the analysis of research methods, there is a lack of quantitative evaluation of the effectiveness of engineering service learning programs in creating a positive social impact in the affected communities. Future work should also make greater efforts to include the community perspective. This perspective will be especially valuable related to the evaluation of project success and factors leading to project success. Such evaluations could help lead to an improved list of postulates.

Another potential area of inquiry is how factors relating to project success relate to factors leading to educational success for engineering service learning. Some connections have been made, such as the

structure of semester based projects hindering project success (Dean and Van Bossuyt, 2014). A greater understanding of the trade-offs and relationships between student learning and project success could lead to both improved educational and project outcomes.

6. Conclusion

Engineering service learning programs are a growing part of the engineering education community and have a great potential to do good in developing communities, but often fail to reach their goals for long-term sustainability. Research up to this point has been focused primarily on the impact of service-learning projects on students, but less research has been done on the impact of these projects on the affected communities. Qualitative analysis of past case studies have revealed a plethora of factors that could increase the likelihood of positive sustained impact on affected communities. It is hoped that by applying these factors, service learning projects will be more likely to deliver solutions that are desirable and transferable to the served communities. Consequently it is hoped that these solutions will be sustainable over time.

The authors have reviewed the literature and extracted 49 factors, presented as postulates, that are suggested by the practitioners to lead to project success. These postulates came from a variety of different fields and experience, but are generally applicable and represent the reflections and suggested best practice of many practitioners. These postulates have been separated into 5 categories related to various aspects of service learning projects. These categories are: Institutional Support and Logistics, Community Interaction, Student Preparation, Design and Technical, and Implementation Trips.

With so many factors to consider, it is difficult to know how each factor affects success. The authors have examined and discussed several methods including qualitative methods, quantitative methods. While past methods of qualitative analysis have provided useful information, implementing quantitative analysis and predictive universal metrics would greatly increase the understanding of what leads to sustainable impact on the served communities in developing nations. Understanding which factors are most likely to lead to sustainable positive impact on served communities would allow service learning projects to succeed at a higher rate and reach their goals of improving lives in affected communities.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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