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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 46 distinct factors from the literature that implicitly or explicitly are suggested to contribute to successful project outcomes. Formed as postulates in this paper, these 46 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 46 postulates are discussed as well.

Keywords

Service Learning, Impact Assessment, Best Practices

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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 and others plan for, carry out, and evaluate service learning opportunities it is worth asking: do these projects have a lasting impact on the communities served? How can we create a real impact that leads to long term benefits for affected communities?

With the upward trend in service learning programs over the last 20 years, there is a wealth of past experiences to learn from [1]. Reflection on the success and failures of projects has helped develop the current best practices [1–3]. While there are many educational methods centered on how these programs should be run, research has primarily focused on the effect of these programs on student learning. There is less research on the impact of these programs on the communities served.

In order to discuss 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 & Shams (2007) as delivering a solution that is desirable and transferable to the community [4]. 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 [5, 6]. Furthermore, we hope that this impact will be sustainable over time [7].

Despite all of the research in the literature, there is very little quantitative analysis on the factors that lead to project success and long term impact of service learning projects on affected

communities. While many scholars agree upon factors that lead to success, many of these university programs do not have metrics for success, and 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. The purpose of this paper is to identify factors of success that can be measured and means of analyzing them quantitatively so that best practices can be improved.

First, this paper discusses the methodology used for determining the 46 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 factors, and implementation trips. 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. In this paper we identify possible factors that lead to success, and discuss but do not yet execute methods that would be appropriate to show the effectiveness of these postulates. The later is the focus of future work.

2 Methodology

The authors performed a literature review of 29 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. Some of the factors were also stated negatively by practitioners and restated by the authors in a positive form that captures the negative factor. For example, a paper saying that not having clear concrete-short term goals was detrimental to project success would show that the practitioner believed that having short term goals would contribute to a successful project.

The literature reviewed covered a wide spectrum of fields and experience. It is important to note that the context for each of the studies cited was different. For examples, case studies reviewed came from service learning courses, student clubs, university sponsored competitions, and professional organizations. Therefore some principles may be more applicable in certain situations.

Some of the postulates came from case studies of continuing university sponsored service learning programs such as studies by Jeu, Munoz, and Rodriguez [2, 8, 9]. These principles are applicable to best practices and suggestions for similar programs. The study by Suhr et al. focused specifically on the *creation* of a university sponsored service-learning program [10]. Some of the principles of this study are not generally applicable, but the specific knowledge related to creating a new program may be valuable to those who are creating their own program. The method used by Wood & Mattson was used to analyze the Engineers Without Borders—Canada Chapter [11]. The international focus of the paper by Wood & Mattson is less university focused than other projects, but the methods are generally applicable and the suggestions given in the paper are considered valuable to the majority of engineering service learning programs that involve international community development. Although the studies cited have different focuses, the present paper assumes the principles taken from one field can be useful in another field and help provide a broader and more full picture of what factors lead to successful service learning projects.

3 POSTULATED FACTORS LEADING TO PROJECT SUCCESS

This section discusses factors that practitioners believe are linked to project success. Factors are given as inputs or processes rather than output measures or characteristics. While the goal of the paper 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 46 distinct factors leading to success for engineering service projects in the literature. These factors were extracted from papers which examined projects from may different contexts including: non-governmental organizations, student clubs, university-sponsored capstone projects, student competitions, and community-sponsored projects. The context of each source has been considered to give background information on why the listed factors would lead to sustainability.

The majority of factors leading to success were cited multiple times by different authors. We acknowledge that here 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 [10, 12] where as other papers suggested that working with an NGO was beneficial [13, 14]. Overall the literature agreed upon which factors lead to success, differing only in the importance given to each factor in their specific contexts.

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	17
Implementation Trips	7

3.1 Institutional Support and Logistics

While 46 different factors or postulates have been identified in the review of the literature, many factors are related. In order to better understand these factors, they have been divided into five categories: institutional support and logistics, community interaction, student preparation, design and technical considerations, and implementation trips. Some of the postulates fit into multiple categories. The breakdown of postulates per category are given in Table 1. Lists of postulates for each of the 5 categories are listed in Tables 2-6.

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 the literature include: securing funding, selecting a project and 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 for both those completing the project and the affected communities to consider the need for long term funding to sustain or maintain solutions [2, 9, 10, 15]. While funding is generally regarded as important, principles for establishing the amount of funding is not discussed, for example it is not discussed if maintenance costs should be calculated and doubled or tripled, or who has been shown to to be more effective at securing funds. Knowing the social impact per dollar of a project would be useful in acquiring funding and garnering support for the project [16].

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 [4, 17]. This is postulate L6.

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 [4, 8, 12, 18–20]. 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 [18].

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 [10, 12]. Several authors preferred working with established organizations because they have previous experience, and community relationships [13, 14, 21]. 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 [12]. Suhr. et al indicated that working with NGOs added extra bureaucracy to the project process which lead to delays and communication errors [10].

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 been found to often result in broken and unused projects that fail to serve their communities [3]. 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 [2, 7, 8, 20]. Furthermore, it is generally beneficial to plan on longer term and post implementation p involvement. Multiple studies agree that longer term involvement is beneficial to sustainable project impact and success [4, 12, 18].

3.2 Community Interaction

This section discuses the postulates in Table 3 related to interactions with the communities served. The most cited factor to sustainable success in the literature review was understanding the needs of the affected community [1, 4, 11, 12, 18, 19]. Practitioners agreed that understanding the needs of the affected community allows student teams to focus their efforts into designing something that reaches 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, communication, and understanding of technical constraints [2, 12, 15, 19, 22].

Another factor that is regarded by the literature as important in creating a project that meets the needs of the community is to build positive relationships with the community. Continued relationships with the affected communities has been shown to foster better communication and builds trust that allows for better collaboration [18]. The literature agrees that working with one community over a longer period contributes to better relationships and successful projects [4, 12, 23]. Maintaining this community support is regarded as important in creating a project with sustainable impact [4, 12, 14, 15, 17, 20, 24]. Having volunteers or workers that live in the community is one way practitioners have found to effectively maintain these partnerships [2, 4, 15, 20].

Consistent communication is regarded by practitioners as vital for understanding community needs, building trust, handling logistics, and managing expectations [8, 12, 19, 20]. Furthermore good communication is imperative in several other related factors such as relationship with affected community and community involvement. Although there is agreement in the literature on the importance of communication, there are many different avenues for communication that could be researched to determine which

Table 2. **Postulated Logistical Factors**

Postulate #	Postulate. Projects Benefit From:	Authors Cited
L1	Sufficient project funding	Thode et al. 2011, Suhr et al. 2014, Rodriguez et al. 2014, Muñoz 2014, George & Shams 2007, Green et. Al 2004
L2	Maintaining university support of the project	Suhr et al. 2014, Rodriguez et al. 2014, George & Shams 2007
L3	Working with an NGO partner to contact the community	Green et. al 2014, **Lewis 2014, **Suhr et al. 2014, Amadei et al. 2009, Sandekian et al. 2014
L4	Working with a community partner	Wood & Mattson 2019, Jeu 2011, Mattson & Wood 2014, Lewis 2014, Gorski et al. 2016, George & Shams 2007, Bixler et al. 2014
L5	Ensuring that materials needed for the project are available to the affected community	George and Shams 2007, Polito & Husfeld 2005
L6	Selecting the proper project	George & Shams 2007, Bixler 2014
L7	Cooperating with the local government	Mattson & Wood 2014
L8	Continued involvement with the community after project instillation	Jeu 2011, Muñoz 2014, Bixler et al. 2014, Amadei et al. 2009
L9	Successfully navigating legal issues	Suhr et al. 2014,
L10	Long term project involvement (greater than 1 year)	Wood & Mattson 2019, Lewis 2014, George & Shams 2007, Amadei et al. 2009
L11	Regularly evaluating the project	Gorski et al. 2016, Amadei et al. 2009
	** designates sources that disagree with the given postulate	

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 [18]. Speaking the language helps designers receive more relevant information and is generally regarded in the literature as beneficial to the overall success of projects [4, 12, 18, 23, 25].

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 deal with the complex problems presented by development projects [3, 26]. Another area of concern is that many students lack understanding of the affected community and their needs. Several authors found that a failure to have cultural and social understanding was a main factor in ineffective projects [1, 12, 19]. 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 [3, 9, 12, 27]. Practitioners believe that course work should include technical aspects as well as social and cultural aspects [3, 9, 12, 23, 27].

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 [1, 9, 21, 23]. 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 [3, 8, 9, 12, 21]. Providing teams with mentors that have project specific technical experience, developmental engineering experience, and time to work with students has also been found by practitioners to help in that regard [9, 24, 25].

Another issue facing engineering service learning programs is student turn over [3]. 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 turn over, and new students have to re-solve problems that have already been solved [3]. The literature finds that successful knowledge transfer between incoming and out going students has a strong impact on project success [1, 3].

There are several methods that can be used to ensure that 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 [2, 3]. 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 pro-

Table 3. **Postulated Community Interaction Factors**

Postulate #	Postulate. Projects Benefit From:	Authors Cited
CI1	Working with an NGO partner to contact the community	Green et. Al 2014, **Lewis 2014, **Suhr et al. 2014, Sandekian et al. 2014, Amadei et. al 2009
CI2	Having continued relationships with the served community	Lewis 2014, George & Shams 2007, Polito & Husfeld 2005, Soto et. al 2015, Bixler et. al 2014, Tucker et. al 2013, Amadei et. al 2009
CI3	Understanding the needs of the affected community	Wood & Mattson 2019, Mattson & Wood 2014, Lewis 2014, Laporte et al. 2017, Wood and Mattson 2016, George & Shams 2007, Soto et. al 2015, Tucker et. al 2013
CI4	Involving members of the affected community in the design process	Wood & Mattson 2019, Mattson & Wood 2014, Thode et al. 2011, Lewis 2014, Muñoz 2014, Soto et. al 2015, Tucker et. al 2013
CI5	Testing the product in the affected community	Mattson & Wood 2014, George & Shams 2007
CI6	Ensuring the tools and skills required to maintain the project exist in the target community	Gorski et al. 2016, Polito & Husfeld 2005
CI7	Having the support of the affected community	Thode et al. 2011, Glade et al. 2014, Lewis 2014, Gorski et al. 2016, George & Shams 2007
CI8	Having volunteers or workers that live in affected community	Thode et al. 2011, Gorski et al. 2016, Muñoz 2014, George & Shams 2007, Bixler et. al 2014
CI9	Consistent communication with members of the affected community	Glade et al. 2014, Lewis 2014, Rodriguez et al. 2014, Swan et al. 2005, Polito & Husfeld, Sandekian et. al 2014 2005
CI10	Having multiple contacts in the affected community	Suhr et al. 2014,
CI11	Involving the affected community in developing the project plan	Muñoz 2014, Soto et. al 2015, Tucker et. al 2013
CI12	Having someone that speaks the same language as members of the affected community	Wood & Mattson 2019, Lewis 2014, George & Shams 2007. Polito & Husfeld 2005, Soto et. al 2015
	** designates sources that disagree with the given postulate	

cess 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 lead to increased project impact [1]. 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 [12].

The variety of factors listed is demonstrative of different program styles, educational philosophies, and program capabilities. However little research has been done comparing methods, only evaluating current methods independently. The methodologies discussed later in the paper allow for comparison and evaluation of these factors so that program directors could adjust their programs to create high 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 [21]. Furthermore misunderstanding the needs of communities can lead to projects failing to solve the problem at hand and waste community resources [11]. 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 [3, 12, 20]

The most common cause of failure in over 100 international development projects identified by Wood & Mattson (2016) was failing to correctly identify community needs in developing nations [11]. 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 [2, 12, 15, 19]. Focusing on the needs of the community throughout the design process is given as an important factor contributing to project success [11, 12].

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 [12]. Design reviews involve engineers, stakeholders, and experts who meet go over the problem at hand and evaluate the current progress in light of the project goals. In this regard, design reviews serve two purposes; which are to ensure technical soundness, and to ensure that the given solution works for the end user.

Table 4. **Postulated Student Preparation Factors**

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

Lack of technical knowledge is one of the factors identified by Wood & Mattson (2016) as one of the main causes for failure in development projects in the developing world [11]. Ensuring that project teams have sufficient technical skills is especially important for service learning projects [3, 12] For student projects especially, practitioners suggest that design reviews with experienced mentors produce a higher level of technical soundness [9, 24].

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 [11]. Design reviews allow experienced mentors who ideally have taken multiple trips to the community to share their knowledge and helps students understand the affected communities. This understanding ultimately helps create a better product that serves the real needs of the affected community [1, 12, 19].

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 [2, 8, 14, 20, 21, 25].

Ways to ensure that a project can be implemented successfully include ensuring that the project can be completed using materials available to the community and tools and skills available to the community [4, 20, 23]. 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 [4, 23, 25].

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, tested, changes are made as needed, project knowledge is transferred to the community, past projects can 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 [1,4,18,23]. This helps engineering students better understand technical and social constraints and contributes to project success.

When projects are sufficiently complete and ready to implement, it is important to be prepared for a successful trip. Carefully planing trip logistics helps prevent travel difficulties, and planning sufficient time during the trip allows for adjusting to unforeseen circumstances and making project adjustments [4, 21, 28].

Testing the product in the affected community is important for both assessing the impact and making changes as needed [19]. Project assessment yields valuable information that contributes to project sustainability and the success of future projects [1, 9, 12, 24].

The literature agrees upon benefits of making trips to the af-

Table 5. **Postulated Technical & Design Factors**

Postulate #	Postulate. Projects Benefit From:	Authors Cited
TD1	Having concrete short term goals	Jeu 2011, George & Shams 2017
TD2	Understanding the needs of the affected community	Wood & Mattson 2019, Mattson & Wood 2014, Lewis 2014, Laporte et al. 2017, Wood and Mattson 2016, George & Shams 2007, Soto et. al 2015, Tucker et al. 2013
TD3	Involving members of the affected community in the design process	Mattson & Wood 2014, Thode et al. 2011, Lewis 2014, Muñoz 2014, Soto et. al 2015, Tucker et al. 2013
TD4	Holding formal design reviews	Lewis 2014, Dean & Bossuyt 2014, Gorski et al. 2016
TD5	Ensuring that materials needed for the project are available in the affected community	George and Shams 2007, Polito & Husfeld 2005
TD6	Avoiding solutions that are overly technologically advanced	Green et. al 2005, Soto et al. 2015
TD7	Selecting the Proper Project	George & Shams 2007, Bixler et al. 2014
TD8	Providing appropriate documentation and manuals for operation of the project to the affected community	George & Shams 2007, Polito & Husfeld 2005, Soto et al. 2015
TD9	Long term project flexibility	Mattson & Wood 2019, Jeu 2011, Thode et al. 2011, Dean & Bossuyt 2014, Polito & Husfeld 2005
TD10	Ensuring the tools and skills required to maintain the project exist in the target community	Gorski et al. 2016, Polito & Husfeld 2005
TD11	Continued involvement with the community after the instillation of the project	Jeu 2011, Muñoz 2014, Soto et. al 2015, Tucker et al. 2013
TD12	Having definitive project deadlines	Dean & Bossuyt 2014
TD13	Long term project involvement (greater than 1 year or term)	Wood & Mattson 2019, Lewis 2014, George & Shams 2007
TD14	Regularly evaluating the project	Gorski et al. 2016, Amadei et. al 2009
TD15	Involving the affected community in developing the project plan	Muñoz 2014, Soto et al. 2015, Tucker et al. 2013
TD16	Considering long term implementation from the beginning	Jeu 2011, Gorski et al. 2016, Muñoz 2014. Green et. al 2004, Soto et al. 2015, Amadei et al. 2009
TD17	Conducting in-country project assessment	Lewis 2014, Glade et al., Laporte et al. 2017, Rodriguez et al. 2014,

Table 6. **Postulated Implementation Trip Factors**

Postulate #	Postulate. Projects Benefit From:	Authors Cited
IT 1	Visiting the affected community multiple times	Glade et al. 2014, Lewis 2014, George & Shams 2007
IT 2	Testing the product in the affected community	Mattson & Wood 2014, George & Shams 2007
IT 3	Careful plan of implementation trip logistics	George & Shams 2007, Green et. al 2004, Bixler et al. 2014
IT 4	Ensuring sufficient time to complete tasks and make adaptations during implementation trip	George & Shams 2007, Swan et. al 2005,
IT 5	Securing assets to prevent theft	Thode et al. 2011
IT 6	Conducting in-country project assessment	Lewis 2014, Glade et al., Laporte et al. 2017, Rodriguez et al. 2014,
IT 7	Visiting the affected community before starting the project	Wood & Mattson 2019, Laporte et al. 2017, George & Shams 2007, Polito & Husfeld 2005, Bixler et al. 2014

fected 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 [9, 12].

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, however the idea is not to create a total project score, but rather a score for each postulate so that all postulates are given proper consideration.

4 GUIDELINES FOR DEVELOPING METHODOLOGIES OF ANALYZING IMPACT AND SUSTAINABILITY

This section discusses methodologies for analyzing the impact and sustainability of the postulates presented in this paper. Being able to analyze postulates and determine their contribution to project success is valuable because it allows those running service learning projects to manage their resources and conduct more successful projects. There are a variety of both qualitative and quantitative methods to evaluate and measure the success of service learning projects.

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. notes there are few metrics with little consistency [5]. 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 [2, 25]. This method involves asking students and professors what worked and what didn't after the implementation of the project. This method is used by Munoz, Rodriguez et al., and Suhr et al. among many others [2, 9, 10]. 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 aren't 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. focuses on only the first project done by Engineers Without Borders—University of Idaho chapter [10]. The paper provides great insights on the difficulties of starting up a project, but much of the information is useful only situationally.

Another issue with the common methodology is that it doesn't provide long term insight. In this study we are particularly interested in the long term sustainability and impact of projects, which requires that we weight more heavily studies that occur over a large enough time period to show sustainability.

Mattson et al. (2016), Rodriguez et al.(2014), and Munoz (2014) examined several projects over a sustained period of time [2, 9, 16]. 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 Jeu (2011) interviews past winners of the MIT IDEAS Service Learning Project competition. In the study, Jeu 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, Jeu 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 [8]. 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 she uncovers.

4.2 Quantitative Analysis Methods

The study by Wood & Mattson in 2016 provides a quantitative method of statistical analysis that other studies had 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 answers into different categories with little intercategorical statistical correlation [11]. 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 & Nell in 2018 provides a methodology for this [29]. 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 what really was making an impact.

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 down side of the study however is that the resources and community cooperation required for this study were very large, and many 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 all of the other methods previously mentioned.

4.3 Predicting Impact and Universal Metrics

One idea that is still absent from studies such as those done by Jeu, Wood & Mattson, and Coetzee & 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. are that they allow for easier comparison of impacts, methods that are customizable so as to not require the invention of new methods, and easier use by designers and engineers [5].

The method designed by Stevenson et al. is based on the United Nations Development Programme Index [5]. 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 [5]

Another benefit of a universal impact metric is that it would reduce the cost and complexity of analysis. As noted, the more successful and applicable studies in this literature review require either long time periods such as Munoz, statistical analysis such as Wood & Mattson or in depth surveys with extremely large sample sizes such as Coetzee & Nell [2, 11, 29]. The metric developed by Stevenson et al. requires only a survey with a sample size of 30-40 people to customize the measured impact to any product or community [5].

The most valuable part of a universal impact metric is the ability to predict 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 [5]. Combining impact predictions with best practices and methods (as discussed in a later section of this review) would have the capability to increase the sustainability and impact of community development and service-learning projects.

4.4 Analysis and Comparison of Metrics

Presented with such a wide variety of methods used in many different situations, the user is left to wonder which methods and studies provide the best information. The purpose of this section is to compare and contrast the methods used by researchers, as well as their contexts so that the user can best decide which methods and practices will be useful to their particular situation.

The simple method of interviewing participants is a method that is easy to implement and provides general insights and wisdom from project participants [2, 9, 10]. Studies of this type are weak in their ability to provide general or widely applicable information. Much of the information is project specific and does not directly translate to future projects. Using larger sample sizes over long periods of time can remedy the weakness of the method, but quantitative interviews are still weak in their generalities [2, 8, 9].

Qualitative analysis methods can be improved by performing analysis over a wide range of products. This can be done using general analysis and observation [8]. Qualitative methods can be improved by statistical analysis such as the methods used by Wood & Mattson and Coetzee & Nell [11, 29]. It is important to note that Wood & Mattson differed from Coetzee & Nell in that they analyzed the feedback given by the engineers involved in the developments developed as opposed to the community focused approach chosen by Coetzee & Nell [11, 29]. Feedback from both engineers working on the project and members of the affected community have their merits, and the usefulness of one or the other depends on whether the engineering design process or the impact of potential products is more desirable. Qualitative methods utilizing feedback from engineers working on the project and from the affected community may be combined. Munoz used a combined methodology in his 2014 paper; albeit his combined method analyzed these factors qualitatively instead of analytically, yet it yielded positive results [2]. An analytical study that quantitatively contrasts and compares the factors of success given by the engineers and by the community would be extremely valuable. However, even one of the methods used by Wood & Mattson or Coetzee & Nell would be an effective choice for researching the sustainability of projects [11, 29].

The universal metric impact developed by Stevenson et al [5] is an attractive method of evaluation because it offers several advantages over other methods such as ease of comparability, application across all situations, and the ability to predict impact [5]. Unfortunately, this method is relatively new and has yet to be proven across a large sample size of case studies. Initially this method will require the service learning community to adapt, but in the future may be the best practice.

5 RESEARCH GAP

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. This also includes a lack of the comprehensive research into the various factors that have been found qualitatively to increase likelihood of project success. Further quantitative research of

these factors using the methods discussed under the quantitative methods section would provide a clearer picture of how engineering service learning programs could be improved.

6 CONCLUSION

In conclusion, engineering service learning programs are a growing part of the community development industry that have a great potential to do good in developing communities, but often fail to reach their goals. 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 has revealed a plethora of factors that could increase the likelihood of positive sustained impact on affected communities. It is hoped that by applying these principles that service learning projects will be more likely to deliver solutions that are desirable and transferable to the served communities, and that these solutions will be sustainable over time.

The authors have reviewed the literature and extracted 46 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 factors, 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 their affected communities.

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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	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		
IT1	Visiting the affected community multiple times		
IT3	Careful plan 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		