International Journal of Engineering Education Vol. 35, No. 4, pp. 1094–1109, 2019
Printed in Great Britain

0949-149X/91 $3.00+0.00

An Investigation of Inter-Stakeholder Dynamics Supportive of STEM, Community-Based Learning*

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Community-based learning (CBL) allows universities to leverage educational interactions with various non-university stakeholders. In a STEM context, CBL often includes service-learning, outreach, mentorship programs, pre-college research fairs, and internships where experiential education commonly provides the pedagogical foundation. Such initiatives are predominantly university-centered and the emphasis is on student or programmatic outcomes. This approach limits the potential synergistic benefits of CBL and can minimize the role of, and outcomes for, non-university stakeholders. The study presented here seeks to further knowledge of how inter-stakeholder dynamics can support STEM CBL outcomes through a qualitative exploration of the interdependencies between stakeholders. Thirty stakeholders from various groups across CBL initiatives organized around a large, public university in South America were interviewed. Interview data was analyzed using a constant comparative method to reveal emergent findings. Findings include characteristics and mechanisms of the relationships that support positive outcomes amongst STEM CBL stakeholders. The findings are structured in three categories: (i) shared purpose; (ii) holistic awareness; and (iii) linked commitment. The empirical findings describing the interdependencies between CBL stakeholders can broaden the current STEM CBL discourse and inform approaches that generate beneficial outcomes for all stakeholders. The extent to which STEM CBL and the supporting relationships are understood in contexts outside the U.S. is limited, a gap in the literature that is addressed through the South American context of this study. Results indicate that an understanding of the inter-stakeholder dynamics can be leveraged to enhance STEM CBL programs by supporting outcomes for all stakeholders.

Keywords: STEM community-based learning; multi-stakeholder; experiential education; community engagement

1. Introduction

Community-based learning (CBL), a pedagogical approach in which a "community" is a partner with a university in supporting learning [1], can promote improvements in engineering and STEM education. Service learning, outreach, mentorship programs, and volunteerism are commonly implemented forms of STEM CBL [2]. Multiple settings and partners can represent the "community," including individuals or groups from government, industry, pre-college, and non-profit institutions, as well as regular citizens [3]. CBL provides opportunities for universities to leverage interactions with institutions outside of the university and to various extents support impact or change within those environments. Collaboration with non-university stakeholders is what distinguishes CBL from other approaches.

CBL can impact engineering and STEM through an increase in pedagogical and demographic diversity, an increase in STEM literacy, the promotion of citizenship, and support an increased production of professionals better prepared to resolve complex challenges. University students, pre-college students, working professionals, and also the broader public can derive educational benefits from this pedagogy [4]. The potential behind these outcomes has led to a substantial increase in the popularity of CBL leading to proliferation across higher education [5, 6]. Yet, theoretically grounded implementation of CBL is challenging [8] and while much potential exist, in practice, CBL can often fall short of attaining outcomes across stakeholder groups. Most STEM CBL is university-focused and/or student-centered, where practice is generally situated in "community" settings as a "real-world" context for education. However, approaches do exist that are centered on partnerships (i.e., university-community partnerships) [9] or the community needs (i.e., community engagement) [8]. Previous studies situate STEM CBL in community engagement, but the integrity of this theoretical grounding is unclear. This can often result in practice being grounded in experiential education/active learning approaches [1]. The theoretical

* Accepted 6 April 2019.

foundations of community engagement have recently undergone substantial advancement producing increased understanding of how reciprocal outcomes can be obtained amongst CBL stakeholders [6]. It has been shown that positive outcomes for all stakeholders can be pursued and are more likely from within strong relationships [7]. Institutions have been shown to perform community engagement at high levels [10]. Yet, ambiguity exists in the research literature as to what extent STEM CBL is situated in experiential education and/or community engagement theory. Furthermore, the empirical and theoretical understanding of the dynamics of STEM CBL relationships is limited which creates a gap in understanding how transitions from experiential education towards community engagement can be supported.

This work seeks to further knowledge in this context through a multi-stakeholder approach that investigates the perspectives of individual STEM CBL participants from differing stakeholder groups around a public, South American University. Using a qualitative approach, in which thirty representatives from stakeholder groups were interviewed, this investigation seeks to answer two research questions: (1) What inter-stakeholder dynamics support characterization of STEM CBL partnerships? (2) In what ways do these dynamics promote participation in and success of STEM CBL?

This research extends existing knowledge through exploring characteristics and mechanisms, which when undertaken by the stakeholders, promote STEM CBL success. The international scope of this work furthers awareness of global practice and how attention to participating stakeholders can support reciprocal partnership.

2. Literature review

Community-based learning serves as the theoretical framework for this study and guided both the research design and the selection of initiatives investigated. Theory from the community engagement and university-community partnerships literature also inform this work. Community engagement (CE) theory provides an understanding of how reciprocal approaches, which support non-university outcomes, can be promoted in CBL. In a university-community partnerships (UCPs) approach, focus is placed on relationship between stakeholders as opposed to focus on initiatives, pedagogical approaches, or CBL learning outcomes. These knowledge-bases collectively inform the outcomes and challenges for the stakeholders involved and justifies the need and value of this research.

CBL has been defined as a "pedagogical tool in which the community becomes a partner in the learning process" [1]. This definition includes various pedagogical approaches, including cooperative education and internships, volunteering and community service, service-learning and for credit activities, co-curricular activities, and outreach. Common examples of STEM CBL include outreach [11], service-learning [12], volunteerism [13, 14], and pre-college research fairs [15]. Various learning outcomes have been investigated within CBL, such as leadership skills, political awareness, civic literacy and citizenship [16], communication skills, student engagement [17], teamwork [18, 19], retention [20], and other outcomes [5, 21].

An engaged campus can interact with local communities through research, teaching, and service. These approaches have be unified across a spectrum by Furco [22]. This unified approach includes internships, field education, service learning, community service, and volunteerism. These approaches can take various forms, such as literacy campaigns, after-school tutoring, neighborhood/social advocacy groups, mentoring programs, and community recreation programs [23]. These outcomes highlight the potential for impacting students through this pedagogy. Swan et al. adopted this unified approach to community-based efforts in the context of engineering education [2]. While Furco and Swan et al. have unified these approaches, the Engineering Education and parallel research communities commonly investigate these CBL approaches separately.

CBL can be grounded in several theoretical foundations: experiential education, active learning, and community engagement, among others. Mooney and Edwards suggest that CBL is generally grounded in experiential learning and is an active learning technique [1], while Swan et al. refer to these initiatives as community engagement [2]. Engineering and STEM education research suggests CBL is commonly grounded in experiential education, where the non-university communities provide a contextual setting for "real-world" learning [21, 24]. Approaches that do not include an explicit consideration of reciprocal outcomes lend to an experiential education orientation, where the communities are leveraged for real-world environments, but not explicitly intended to receive direct, lasting outcomes. Community-based outcomes are suggested, but rarely included as a focus of investigations providing ambiguity. A lack of reciprocity limits most STEM CBL practice from a community-engaged distinction as defined by psychology, social work, or other areas of community-engagement theory and practice [8].

The extent to which community-based outcomes

are pursued in STEM CBL varies greatly. To various extents, practice has included/ran parallel to pedagogical descriptions such as: experiential education, university-community partnerships, community engagement, service-learning, outreach, and extension. Explicit pursuit of non-university outcomes, as within a community engagement orientation, is limited in STEM CBL. Practice is often university-centered, or at a minimum, the research outcomes are oriented towards the university [18, 25]. The investigation of CBL outcomes has primarily centered on university stakeholders with a focus on students and teachers/professors [17, 26]. Investigations into CBL partnerships are limited [27].

As it appears in the literature, STEM CBL is predominantly university-centered. Within this orientation communities/non-university stakeholders provide a context for learning (i.e., experiential education), as opposed to being recipients of learning or other outcomes. As outcomes are strengthened amongst the non-university stakeholders, CBL interactions promote increased reciprocity leading towards a community engagement orientation where social justice and civic outcomes can be a focus [24, 28]. Benefits amongst multiple stakeholders can often be stifled by unbalanced power dynamics [33]. In these cases, one partner dominates needs and outcomes. Power imbalances, mismatches of cultural norms, communication, and other challenges that cause these limitations have been reported in STEM CBL [30]. In STEM CBL the university is often a dominant partner. These challenges can limit outcomes and benefits obtained from both university and non-university stakeholders, impeding on theoretical merits of community engagement. The extent to which community or social justice-oriented outcomes are pursued and obtained in engineering and STEM fields is ambiguous.

Community engagement (CE) has been defined by the Carnegie Foundation's Center for the Advancement of Teaching as the "collaboration between institutions of higher education and their larger communities (local, regional/state, national, global) for the mutually beneficial exchange of knowledge and resources in a context of partnership and reciprocity" [10]. CE theory revolves around the promotion of reciprocal relationships, where shared solutions to problems of mutual interest are developed [8, 31, 32]. Reciprocity is key, and is obtained through managing power dynamics so that each stakeholder group is able to establish high levels of trust and communication, represent its needs, and obtain benefits [8, 33]. This focus on reciprocity points to the critical nature of CBL partnerships, where mutual outcomes are otherwise challenging.

Community engagement has been shown to improve citizenship while providing a larger sense of mission and clarity to stakeholders [19], offset the increasingly business-oriented approach of higher education [34], and minimize the isolation of academic activities in the "ivory tower" [32]. CE can provide positive contributions in government, civil society, and the private sector industry [35] and has been shown to provide for productive and socially robust research outcomes, foster economic growth, develop social capital, and drive social change among other outcomes with social, economic, environmental, and cultural implications [36]. CBL can support an increase in pedagogical and demographic diversity, an increase in STEM literacy, and promote an increased production of STEM professionals better prepared to impact impending grand challenges [19]. CBL partnerships can promote awareness of, access to, and success in the STEM fields, and therefore, can provide an approach to obtaining broader participation of underrepresented populations [2, 37].

When CBL activities are grounded in community engagement they have exhibited a variety of advantages and have been shown to be fruitful in many different environments [3, 32]. The inclusion of reciprocal outcomes and the pursuit social justice shift CBL from grounding in experiential education into that of community-engagement. Many challenges limit the ability to maintain reciprocal implementation of CBL. Ideally, community engagement relationships are established to provide mutual benefits through exchange and partnership (i.e., collaboration), as opposed to relationships based on the exchange of resources (i.e., transaction), or those in which one stakeholder is dominant. Approaches that are centered around partnerships exist under multiple names: University-Community Partnerships (UCPs), school-community partnerships, and others. These efforts have resulted in frameworks for investigating partnerships [38].

When CBL is based in CE it has shown effectiveness in democratizing education [19] and provides an approach to extend the STEM fields into communities that are under resourced [23]. Substantial attention has been directed towards shifting the use of one-way model of delivery of services (extension and outreach) towards a two-way model of engagement and partnership as a lasting way to improve society [19, 39]. This has resulted in a surge of interest in community engagement [40] promoting the second wave of community engagement research [6] where added rigor and legitimacy is leveraged to improve to these efforts [41]. As a

result, further investigation is needed from these contexts to support appropriate power dynamics and reciprocity and mechanisms for transitioning from one-way to reciprocal approaches.

Research into university-community partnerships have investigated CBL relationships and established useful frameworks. These frameworks and approaches can build knowledge around these relationships and promote reciprocal outcomes [8, 31]. The extent to which these have been utilized in STEM contexts is limited and most relationships are built around CBL initiatives (transactional), and do not originate from partnership (transitional or transformational) [27]. Further investigation into STEM CBL both in the U.S. and abroad can yield insight specifically relevant to STEM CBL to support strengthening the dynamics between stakeholders. Collectively, these elements justify the need for research into the interdependencies between STEM CBL stakeholders. As shown, further investigation into the extent to which multi-stakeholder outcomes are pursued as well as the mechanisms for transitioning from one-way/university-centered to reciprocal CBL approaches is merited.

3. Research structure

This work investigates the inter-stakeholder dynamics that support STEM CBL initiatives around a large public university in São Paulo, Brazil. São Paulo is home to nearly 12 million people and serves nearly 21 million living within the metro area [42]. As the financial capital of Brazil, it is also home to a wide range of business, non-profit, and academic institutions. Brazil has struggled to recruit and retain a strong STEM workforce to compete at a global level, and STEM fields are particularly affected by a lack of diversity in higher education. From 2001 to 2009, the number of engineering graduates in Brazil grew by only 1% (as compared to 66% for liberal arts studies) [43]. In 2010, Brazil invested $24.9 billion in research and development, but while a substantial percentage of these funds were committed to STEM education, programmatic impact is a challenge due to limited interest in, and access to these fields. To date, only 16% of Brazilian youth entering the higher education system, a figure significantly lower than the Organization for Economic Co-operation and Development (OECD) global average of 32% [44].

Based on the racial demographics of the country, increasing diverse educational attainment is a necessity in order to meet workforce needs. Brazil has implemented affirmative action programs, requiring that 50% of students at federal universities come from state schools and that the racial composition of the student body matches that of the affiliated Brazilian state. However, many administrators and scholars are concerned about the preparation of students from lower performing schools and the country's ability to sustain demographic changes [44]. Generating appropriate motivation, perceptions, awareness, and access to higher education, in general and specifically for STEM careers, are important requirements for Brazil to realize these goals. CBL is one means that can promote gains to support these policies.

While this work is focused on STEM CBL and participating stakeholder groups, the research is initiated around individuals who participate in STEM CBL around a large public university. In this work, relationships are defined as interactions that sustain engineering and STEM CBL initiatives. The local initiatives investigated include university-level service learning, pre-college science fairs, K-12 outreach and mentoring, and pre-college research internships. Each initiative can be comprised of various activities. For example, a mentoring program can consist of several types of activities: the program directors creating the program, the program directors coordinating meetings times and program structures, and the mentors and mentees spending time together. Collectively, these activities comprise the initiative. Stakeholders refers to institutional groups and its members (individuals). The stakeholder groups selected for this research are comprised of institutions and individuals who strive to improve the integrity of engineering or STEM education and the workforce pipeline through implementing, supporting, or participating in educational activities. When collaborating across stakeholder groups in support of STEM learning outcomes the effort is categorized as CBL for the purposes of this research, while the individuals involved may not recognize this distinction. An initiative can have several institutions or organizations from the same or differing stakeholder groups as participants. For example, within a pre-college science fair, multiple universities collaborate together with other members from other stakeholder categories, i.e. government representatives and industry (funding and professional support) and K-12 institutions (student participants). While each initiative does not involve all stakeholder categories, potential for their involvement can often exist. Participants do not necessarily interact with all stakeholder groups or participants in an initiative. For example, participating students in a mentoring program may not be exposed to the university professor who coordinates the program, but instead, only the student mentor and their pre-college instructor.

As a result of this structure, this research investi-

gates characteristics of the relationships between individuals from different stakeholder groups who partner around STEM CBL initiatives as well as the processes which support the characteristics.

4. Research methods

This research employs a qualitative approach through interviews conducted to obtain perspectives across differing stakeholder groups active in STEM CBL. A constant comparative approach was used to analyze transcripts of thirty interviews from across the five stakeholder groups (i.e., Government, Industry, Non-Profit, Pre-College, and University) to support answers the two research questions.

Initial interview subjects were pursued from within a large public university in Brazil. Individuals active in STEM CBL were selected amongst the first interviews. From this point, additional interview subjects were recruited through the snowball sampling method [45], where each interview subject suggested additional subjects. This approach allowed for access to subjects involved in relationships and/or participants in the ongoing CBL initiatives within the area of investigation. Interview suggestions were encouraged from across the stakeholder groups and local STEM CBL initiatives. Each purposefully-sampled interview subject has been or at the time of interview was connected to an initiative linked to the university. Distribution of stakeholder roles of the interview participants is shown in Table 1.

The participants included four university administrators, six professors, three graduate students pursuing Ph.D.'s in engineering disciplines, and one student in the final year of undergraduate education; two pre-college administrators, four pre-college teachers, and three pre-college students in their final year prior to pursuing higher education. The initiatives amongst which these interview subjects were connected with include pre-college science fairs, university-based co-curricular activities (including outreach, extension, and mentorship programs), credit-bearing service learning activities, and research internships for pre-college students.

Table 1. Interview Stakeholder Categorization

Stakeholder Group	Number	Interviewee Role
Industry	2	2 educational program directors
University	14	4 administrators, 6 professors, 4 students (3 graduate; 1 undergraduate)
Non-Profit	3	2 directors, 1 staff member
Pre-College	9	2 administrators, 4 teachers, 3 students
Government	2	2 educational program directors

A semi-structured interview protocol [46] based on a synthesis of three different sources from the broadening participation and community engagement literature was developed for data collection. The Weerts and Sandmann's framework was designed to evaluate barriers and enablers to university engagement [40]. The Carnegie Community Engagement classification has been used to evaluate campus commitment to engagement [10]. The NSF "Framework for Broadening Participation" provides useful metrics for broadening participation in STEM [37]. Selected prompts and approaches from these established sources were used to pursue understanding of the dynamics amongst the CBL stakeholders. Interview participants were asked their thoughts on CBL and its role within society, academics and learning, the roles and perspective of different stakeholders, and the interdependencies between the stakeholder groups. The interviews sought to examine the extent to which the subjects, their colleagues, or institutions participated in STEM CBL; the reasoning in support or against participation; the outcomes of STEM CBL participation; and the ways in which the interdependencies between the stakeholders could be strengthened. Interviews were conducted in the Portuguese language. The interviews varied in length between 30–100 minutes, were audio recorded, and transcribed for analysis. The data was de-identified using pseudonyms and analyzed from the original Portuguese text. The excerpts presented in this work were translated by the first author and verified with the assistance of native Portuguese-speaking individuals.

A constant comparative method [47, 48] was used to identify and delineate patterns in participants' lived experience around CBL participation. More specifically, the transcripts were coded for statements that described significant facets of participants' experience in the STEM CBL settings in experience-near terms [52]. This initial topic coding [45] of the data led to an understanding of STEM CBL barriers, enablers, and other characteristics [30]. Looking across these topic codes, an interpretive coding step revealed explanatory patterns that provide an understanding of dynamics that promote participation and support positive outcomes. The qualitative data analysis tool NVivo [53] was used to facilitate this iterative analysis process and ensure consistency of the emerging interpretations [54].

Two researchers performed the qualitative analysis. Researcher 1 (male, bi-racial—Black/Latino, American with a PhD in electrical engineering)

performed the interviews, initial coding, and analysis. Researcher 2 (male, Caucasian, German with PhD in engineering education), with a background in qualitative research [54–56], reviewed coded elements and emergent outcomes through regular discussions towards consensus between the two researchers.

5. Research findings

Analysis of the interview data supported three categories of emergent findings. The categories represent characteristics of stakeholder relationships that support STEM CBL. The categories include: shared purpose, holistic awareness, and linked commitment. Each category is described by mechanisms that support the development of the characteristic. The findings are shown in Fig. 1.

5.1 Shared purpose within STEM CBL

The "Shared Purpose" characteristic is when stakeholder purposes intersect in ways that support contributions to STEM CBL. The mechanisms which facilitate shared purpose include: (1) interpreting a purpose in STEM and/or education, (2) articulating an institutional mission that supports STEM/education/CBL, (3) aligning institutional objectives with STEM CBL, and (4) prioritizing institutional demands/responsibilities in ways that support STEM CBL.

5.1.1 Interpreting a purpose in STEM and/or Education

The "Interpreting Educational Purpose" mechanism refers to an institution embracing a role or position within society, education, and/or the STEM fields in ways that provide contributions to CBL. A pre-college educational coordinator who structures STEM curricula in a public school, Angelo, provides a reflection on the purpose of several stakeholders.

> "*The purpose of school I think is singular: education, learning; I think it has to be singular. And it does not have to be separated: primary school, high school, and higher education. You can separate schools, only that the purpose, I think, has to be the same. So, the purpose of schooling, it has to be singular*." (Angelo, Coordinator, K-12)

This perspective proposes a shared societal purpose between Pre-college and University institutions. Amongst the stakeholders, some of the institutions are obligated to contribute to STEM education (i.e. University, Pre-College, Governmental stakeholders). However, a purpose that seeks to positively impact local communities or perform CBL is not often an obligation. Tensions can arise when stakeholders consider the extent to which a STEM professional should pursue community involvement. This is described by Tiago, a university graduate student pursuing a PhD in electrical engineering that has a history of CBL participation.

> "*If you were to say the engineer's goal is to contribute to the local community, most would say no, it is not. The engineer has the goal of making the company he works for earn more money. I think that is the biggest cultural barrier, the belief that the engineer does not have this role. The engineer is really that person who does not have to worry about the outside world, only with his work, to do his job well*." (Tiago, Student, University)

The data shows that the extent to which stakeholders valued local community needs varied greatly. The support for STEM and/or educational

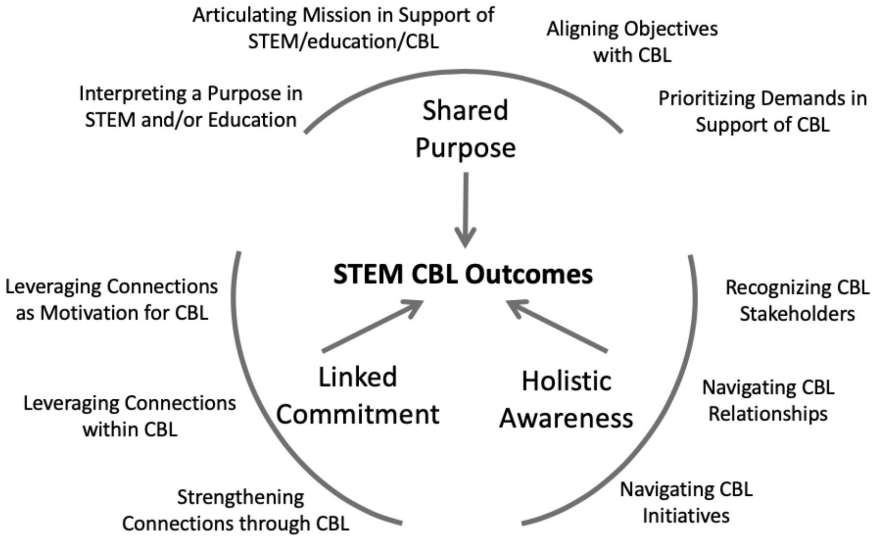

Fig. 1. Categories which represent characteristics of and mechanisms in stakeholder relationship which support STEM CBL outcomes.

initiatives appeared more commonly. These interpretations of purpose and societal roles can dictate the value prescribed to participating in STEM CBL.

Many different factors were shown to influence the purposes that the stakeholders pursue including regulations imposed by government and funding agencies, cultural understanding of institutional roles, and the needs and assets of each stakeholder. Common purposes that were shown to provide for alignment in purpose across stakeholders include strengthening the STEM workforce, broadening participation in STEM, promoting STEM literacy, and supporting educational outcomes. Some additional outcomes that are not aligned with education were pursued include marketing of products, corporate responsibility, and improving or maintaining positive public perceptions. While this mechanism correlates to a vision or mission of an institution or group, it was found that in this context purpose is not often articulated or is a value that runs secondary to primary functions.

5.1.2 Articulating mission

Purposes pursued are often articulated through institutional missions and/or manifested through culture. The data indicates that institutions that articulate a mission or direction that contains language promoting service, educational, and/or societal contributions provide opportunities for members to contribute STEM CBL. This is illustrated by Adhara, a Pre-College teacher, with a Ph.D. in a STEM field and substantial experience as a researcher in industry.

> "*. . . each institution has a goal. Each has its purpose. But the university is the tripod of teaching, research, and service. Then at least the university should follow these three objectives and these objectives should be aligned with what society needs*." (Adhara, Teacher, Pre-College)

This excerpt considers the intersections between the pre-college institution in which Adhara teaches and nearby universities. The service component of this mission referred to above indicates a purpose to contribute to societal advancement.

Institutional purpose and/or mission can reveal the extent to which members receive institutional support towards CBL and as a result the extent to which they are willing/able to participate. Institutions/groups with missions aligned with STEM CBL may receive more support than those without. Educational institutions (i.e., pre-college, university, and non-profit) often exhibit such missions and cultures. A broad range of purposes and missions were represented by the institutions of those interviewed. Some exhibit missions and cultures clearly aligned with STEM education and/or CBL, while others exhibit little to no alignment. Whereas the interpreting a purpose mechanism suggests being able to vision or embody a purpose aligned with STEM CBL, this mechanism specifically includes articulating missions/objectives. The extent to which a mission is articulated can moderate its impact. Members may not always be familiar with an institutional mission or competing values may create confusion. A lack of clarity can provide an opportunity for differing interpretations, as illustrated by Danilo, a University administrator who oversees community-based efforts.

> "*. . . there is a political decision to be taken. [Stakeholders] would have to revisit what's the purpose of [each institution]. The hardest thing is that [institutions] are subjected to the processes establishing [norms, evaluations, and funding]*" (Danilo, Administrator, University)

An articulated institutional mission that aligns with CBL allows members to directly contribute to outcomes. Without strongly articulated and aligned missions, participants must decide how to prioritize resources that can be committed to STEM CBL. In cases where mission does not align, individuals must commit substantial effort to so that participation is complementary to their institutional roles. Otherwise, individuals must be willing to sacrifice professional development to participate despite institutional support or do so on their own time in addition to their professional responsibilities.

5.1.3 Aligning objectives

Stakeholder interdependencies can be leveraged through synergies around institutional purpose and mission. This is developed through the "Aligning Institutional Objectives" mechanism. The interview participants often suggested there is substantial opportunity for the stakeholders to partner towards contributions in STEM. However, many suggested this potential is stifled due to misalignment of culture, processes, and goals amongst the stakeholders. The challenge of aligning efforts between stakeholders was illustrated by Regina, a pre-college STEM teacher at a public school.

> "*I can visualize much more on how the University could help people and less in the opposite direction. For example: an engineering student, how could he benefit from a [pre-college] school? Psychology, education? In those [disciplines] it's pretty obvious. Now what is more distant [such as engineering] is more difficult*." (Regina—Teacher—K12)

As described, it can be difficult for stakeholders to understand how contributions can be made to the STEM fields, education, and/or CBL. The ways these fields can be aligned with stakeholder purpose or the needs of communities through CBL can be challenging to understand.

Alignment with institutional mission is critical in order for members to obtain support and resources towards CBL participation. Maria, a Governmental employee that focuses on public education and pre-college curricula, recognizes the gap between university culture and STEM CBL. She suggests that what is helpful for a community is not often valued by the university. This is highlighted by the perception that STEM CBL practice is often characterized as charity and not a core professional activity.

> *"I do not think [CBL] has to be a volunteer activity, I think it is an activity that is as important as any other, it is as important as publishing papers, it is as important as lecturing to undergraduates. I think they should be on the same level. I think the proper workload of professors could be a little more relaxed for this, divided, where the professor is required to spend so many hours in the classroom . . . If it is, for example, by participating [in CBL], I think those hours could be part of the workload of the professor, that's a start. So, I think this has to be evaluated, and it has to be a university strategy.*" (Maria, Educational Policy, Government)

STEM CBL participation and outcomes do not often align with stakeholders' primary responsibilities, as illustrated here by a university faculty context. Amongst those interviewed, STEM CBL contributions were rarely considered primary, illustrating the challenge of alignment with institutional processes. The data indicated that institutions can encourage, or at a minimum tolerate, its members' participation in additional activities in line with their professional efforts. It was shown that many of the interview subjects believe CBL can detract from primary obligations, yet provides outcomes that can be important to both the institution and society. In these cases, individuals are often willing to look past institutional priorities, work extra hours, or find other ways to support. This mechanism extends beyond acknowledging that CBL participation is possible, as described by the previous two mechanisms, and into consideration of how such participation is situated within the participants institutional responsibilities.

5.1.4 Prioritizing demands

The interview subjects rarely viewed the stakeholder institutions as highly prioritizing STEM CBL. This supports the "Prioritizing Institutional Demands" mechanism, where it is necessary for participants to prioritize CBL amongst multiple demands in order to contribute. Institutions and members were seen to prioritize institutional demands, navigate tradeoffs, and make sacrifices to participate. This was seen when participation does not align with or competes with primary institutional roles and responsibilities. This prioritization is reflected by Daniel, a university graduate student in systems engineering who supports CBL initiatives as part of his academic responsibilities, in his interpretation of academic merit.

> "*I [do not think many institutions value CBL], without a doubt, no. I think the question must also be asked around the career structure of the [university] professor. [CBL] counts very little with regard to professors in general. What counts in professor and university ranking are publications of articles in renowned journals, typical international journals. A [CBL] project for most categories of professors counts for very little. So, this already shows how the [University] treats [CBL].*" (Daniel, Student, University)

The ways in which these pressures are dealt with was discussed by Raquel, a University professor in Computer Science who leads a CBL initiative.

> "*Even though I know that my career could be 'delayed' I made a choice [to participate in CBL]. I could already be a full professor. I still am not, but it's worth it in terms of merit. For example, in the review for full professor my scores were not so good and I had the impression that my [CBL] activities did not count for anything. Although it takes a significant portion of my time, I took little advantage of these activities to have research results as I had the perception that research was one thing and [CBL] another, I did not realize that there may be more synergy between the two*" (Raquel, Professor, University)

This presents a significant challenge to initiatives and can lead to limited leadership and support available within STEM CBL. For positive outcomes to be realized, institutional leadership can provide parallel or complementary pathways for its members to obtain institutional advancement through participation. As such, it was shown that leadership which provides for time and other resources towards CBL contributions can alleviate challenges, lessen burden, and promote positive outcomes.

In summary, these findings imply that STEM CBL participation is more likely to be supported by institutions in which CBL is prioritized or a respected institutional function. Through recognizing that STEM CBL can unify stakeholder objectives and that participants from across stakeholder groups have resources to offer and/or receive from these partnerships, shared purpose is a strong element that provides a foundation for positive outcomes.

5.2 Holistic awareness in CBL

"Holistic Awareness" is a characteristic in which participants are able to consider and/or integrate the assets, needs, and/or cultures of those from other stakeholder groups within STEM CBL. Three mechanisms support the development of this characteristic: (1) recognizing the CBL stakeholders, (2) navigating the CBL relationship, and (3) navigating CBL activities.

5.2.1 Recognizing the CBL stakeholders

The data indicates that the stakeholder institutions can be linked through contributions to STEM and/or education. Those who are able to understand these links and leverage a holistic awareness of the potential stakeholders, stakeholder relationships, and the CBL initiatives appear capable in furthering CBL outcomes. This is referred to as the "Recognizing the CBL Stakeholders" mechanism. Initiatives and relationships can often be perceived as a black box, limiting holistic understanding. This is described by João, a director of a non-profit that promotes STEM education and leadership.

> "*Now, I would not know how to say, I do not know, I never thought about it. . . What would be an ideal [CBL] partnership?*" (João—Program Director—Non-Profit)

CBL can be limited in cases where partners have not considered the stakeholders or initiatives in a holistic manner. A holistic approach to CBL participation leverages knowledge of the interdependencies between stakeholders for effective implementation and the development of outcomes.

5.2.2 Navigating CBL relationships

Differing stakeholder institutions and groups can contribute to STEM CBL initiatives. Each can have differing cultures, norms, and structures. This can make navigating relationships challenging. For example, the following excerpt describes the complexity exhibited within pre-college institutions, as described by Angelo a course coordinator at private pre-college school.

> "*This school, is divided from top to bottom, it has the director, it has a vice-director, there is the administrative manager who will [take care of] employees . . . school manager, and the general coordinator, who takes care of the pedagogical part, directly with teachers. The general coordinator, has three area coordinators, and I am coordinator of the technical area that we call Natural Sciences and Mathematics. My job here is to be the in school coordinator, and my role with the teachers is to do what. . .? strategies for studies to teach students, links between content, and we work with learning guide to prepare activities for students.*" (Angelo—Administrator—K12)

Institutional complexity was exhibited across the stakeholder groups. Each can exhibit multiple levels, where for example, pre-college stakeholders can include individual schools, groups of schools, and districts. Each can contain a diverse membership which can include principals, students, parents, instructors, and administrators. The modes of communication (email versus phone call), language use (academic and technical language versus conversational), and time scales (semester versus fiscal calendars) create challenges in communication, alignment, and the ability to maintain relationships. Those who can recognize these factors, and are able to make appropriate adjustments can promote successful relationships. As a result, STEM CBL success was shown to be impacted through the participation of committed participants whose experience, personal relationships, and ability to navigate CBL supports outcomes, as described by Adhara.

> "*All this culture that I acquired at the university, I brought with me . . . I brought it here to the [pre-college] school. It was very recent, so it was very much present in me. I arrived, I talked to the director, the director said "look, it will be complicated, because here at the school we have nothing." And really in the laboratory I had nothing. I went there and started doing this project with [a funding institution], it was approved and we started to acquire the equipment to begin working. But, it was me that brought the university project development ability that I had from [where I studied], I brought it. That is, ushered in a culture . . . and it could be developed in another school as well.*" (Adhara—Teacher—K12)

Each stakeholder/institutional group's goals, while parallel, can differ substantially leading to challenges in implementing STEM CBL. The diversity amongst the stakeholders, the wide variety of CBL interactions, and differing structures and cultures, and the desired outcomes amongst the stakeholder groups creates substantial complexity. Individuals with holistic knowledge can support alignment of these differences which can be critical to successful navigation of CBL relationships. Without these individuals, the challenges present can result in a loss of time and considerable frustration, potentially limiting outcomes. While the "recognizing stakeholders" mechanism refers to understanding who could be present and provide contributions to CBL, this mechanism involves understanding effective forms of access and communication to participating stakeholders.

5.2.3 Navigating the CBL initiatives

CBL can be challenging to implement, as a contextual development suitable to each local context is required. A one-size-fits all approach can be detrimental. Each stakeholder institution/group can exhibit differing values, missions, needs and priorities. As described by Danilo, the dynamics of effective implementation with one stakeholder/setting can often fail if replicated.

> "*I had an engagement project in a community near here and the Dean called me to ask for a [transferrable] project based on [a current project]. And that does not exist. Because [CBL] is the channel of communication between the university and society then it depends on the type of communication that you want to establish. There is no single rule. But it is important that the [CBL] activity not be understood as a provision of services because if it is, it loses its meaning. There are other*

institutions that do that." (Danilo—Administrator—University)

Additionally, several interview subjects suggested it is difficult to develop STEM CBL in ways that connects technical content to community need in an accessible way to broad audiences This is presented by José, an engineering professor who has participated in multiple initiatives.

"*[CBL] may be more difficult in engineering, unless you can adequately align the activity you are doing with the technical program. For some things it is possible, in other areas it is easier. In the areas of humanities, like in Sociology, it is easier, because the interaction becomes your own object of research, a lot of people have done it. In the natural sciences, [CBL] can be much more difficult. The community is not very interested*." (José—Professor—University)

CBL relationships, activities, and outcomes are challenging to assess and evaluate, are context specific, and often require a nuanced contextual understanding. The wide-ranging complexities require substantial effort and initiatives are generally implemented with limited resources, as an excerpt from Raquel describes.

"*A teacher who coordinates an initiative alone does not have time to do all of this. We need to start having more resources to support these activities and to systemize this information so that the teacher can spend less time and obtain more results so that more people are interested. It takes a communication person who articulates these channels, someone institutional. This person does not exist within the structure. The University has the potential to do a lot but the structure needs to be established*." (Raquel—Assistant Professor—University)

This complexity can cause challenges between individuals, institutions, and stakeholder groups to limit outcomes. As a result, many participants rely on personal relationships or previous experience that allows access to or knowledge of the other stakeholder groups. Individuals who have intimate experiences in multiple stakeholder roles (i.e., Adhara), have gained fluency across stakeholder groups, and are able to understand the needs from multiple stakeholder perspectives. Such experience across stakeholder groups can provide for holistic awareness. Whereas the prior mechanisms involved awareness and ability to interact with stakeholders, this mechanism more specifically includes negotiating value from inter-stakeholder interactions. This was shown to most often take place during implementation of the CBL activities.

In summary, these findings imply that the more knowledgeable an individual or group is about the complexities of STEM CBL, the more likely successful outcomes can be obtained. Stakeholder characteristics as well as CBL implementation were shown to be very complex. An understanding of this complex nature as well as an understanding of the interdependencies between each stakeholder provides this holistic awareness which supports successful relationships.

5.3 Linked commitment within CBL partnerships

Commitment to STEM CBL was shown to be an impactful characteristic amongst stakeholder relationships throughout the data. When this commitment is exhibited across the stakeholder groups it provides for connections between stakeholders and basis for successful relationships. This characteristic is exhibited through the stakeholder's connections to the CBL initiatives as well connections to the needs and challenges of the targeted CBL beneficiaries. Three mechanisms are shown to promote the ability for stakeholders to leverage such commitment: (1) leveraging socio-emotional connections as motivation to participate, (2) leveraging socio-emotional connections within activities, and (3) strengthening/reinforcing socio-emotional connections through participation.

5.3.1 Leveraging connections as motivation to participate in CBL

As STEM CBL participation is often voluntary and performed in addition to primary institutional demands motivation towards participation emerged as a critical factor. Motivation to participate was shown to be commonly driven by empathetic connections to the individuals, institutions, or the community beneficiaries. This is captured by the "Leveraging Socio-Emotional Connections" mechanism. Socio-emotional connections were shown to support increased passion and motivation for the initiatives as well as sustained commitment throughout the CBL efforts. Adhara described her motivation to participate in initiatives.

"*[I participate in CBL] because I like it. . . I don't like to see children in the streets, people going hungry . . . I don't like to see this reality. I don't like seeing it. So then, what is my objective? It is to train these people, so much so that that child can go to school. And when they have a little time, they can help their mom doing some things, creating some kinds of artisanal crafts. And because in my reality, I don't like seeing that poverty . . . so if I can help to take these people out of their misery, people in the street of which I can help contribute, I am going to do my part*." (Adhara—Teacher—K12)

In this excerpt, Adhara repeatedly states how she does not like to see suffering in fellow citizens. The excerpt shows a deep connection to the challenges and struggles of others, which in turn serve as a driving force for her to act through STEM CBL. Throughout the interviews, stakeholders who excelled exhibited high levels of empathy. The data indicates that a high level of commitment and

empathy can allow participants to look past the challenges of CBL and compassionately connect and participate. Those who show commitment can rely strongly on it as motivation to persist through the associated challenges associated. The data indicates that those who were involved care.

5.3.2 Leveraging connections during CBL activities

Socio-emotional connections were consistently exhibited within the data as subjects discussed STEM CBL participation. Bruno, a professor at a small public university, who has led a long-running pre-college, research internship program, stated.

> "*I do not think much of [my personal benefit in performing CBL], in fact. I think that my gain is the success of my students, because I could assist at some point so that they could progress. For me, it is pleasant to have this, I have students who are taking [up] the idea [of performing research]. Are picking up the idea [of STEM participation], are moving forward and are achieving. I get sad when one [student] arrives at a point and stops... not that I think everyone has to choose [STEM] and such. So, for me it is pleasurable... Now that's a gain, I really think so.*" (Bruno—Professor—University)

These strong socio-emotional connections with students were shown to provide for quality mentorship. This mentorship can act as a driving force in effective and sustained relationships. A pre-college student in her final year of a public school, states.

> "*In close collaboration, having someone close to you, telling you, "you can achieve, you can do it." I think everyone needs a person who is on their side, giving them support and positive energy, while there may be people or even yourself who thinks you cannot achieve. If you have that thought, you will not get anywhere. If someone you know shows that they believe in you, you, for sure, with that support and the support of other people, you will achieve.*" (Clarissa—Student—K12)

Personal and emotional connection were shown to be developed through mentoring relationships and friendships. For example, many subjects discussed long-time volunteers or participants who have had or continue to have a family member or close friend that participates. These connections can motivate and support decisions to participate, which often requires justification to employers or the dedication of additional time. Additionally, individuals leveraged past experiences, where they remember their struggles through pre-college or other stages of STEM education or professional work. These individuals recognize education's transformative potential and want to provide such opportunities to others. Whereas the previous mechanism presented involves motivation and leveraging socio-emotional connection prior to activities, this mechanism involves leveraging these connections during activities.

5.3.3 Strengthening connections through STEM CBL participation

Participating in STEM CBL activities appears to strengthen or reinforce socio-emotional connections exhibited by participating stakeholders. Flavio, university administrator who supports CBL initiatives, highlighted this point.

> "*Some are born with a sense of justice, but it is learned through experience. People who have their lives transformed by social support generally want to do the same... give back the same good.*" (Flávio—Administrator—University)

Socio-emotional connections were shown to not only provide success during CBL activities but also further motivation to participate in CBL in the future creating a cyclical mechanism for the success of CBL initiatives. Antonio, a director of a NGO which contributes to initiatives, suggested such continuity.

> "*Yes, [empathy can be developed]. When one is not closed [-minded], yes, but I feel certain barriers at the university. Sometimes when we want to do some things with a partner there, it is quite difficult. On the other hand, with others, it is very easy. But a lot of people there are difficult [. . .] Those who are afraid, it's easy [to convince them]. Try it once. Work with one student, commit to this challenge. For me, this can fall into sentimentality, to me it is passion. If you are passionate about what you do, you like to share that with others, you like to make this work, to uncover, to help, to work together. I think it is passion, if people have passion, anything they do is with pleasure, it radiates. You can pass it.*" (Antonio—Director—NGO)

Participants and the beneficiaries of STEM CBL initiatives are able to recognize individuals who are willing to support their development. These types of individuals promote successful relationships and contribute greatly to the success of CBL initiatives.

6. Discussion

The interview data contained rich insight into characteristics which promote success in STEM, community-based learning initiatives around a large, public university in Brazil. These findings were synthesized from interviews of CBL participants from across multiple stakeholder roles. This section contextualizes the findings within STEM CBL and provides reinforcement of these findings with respect to the academic literature. The implications of this research are highlighted in the following section.

Shared purpose is a characteristic of STEM CBL relationships that helps stakeholders recognize that contributions can be complementary to the purpose and/or mission of multiple stakeholders. Several purposes commonly pursued by stakeholders include: strengthening the STEM workforce,

broadening diverse participation in STEM, promoting STEM literacy, and/ or supporting educational outcomes of students. These platforms can be leveraged to form or sustain partnership between stakeholders.

The purposes/directions pursued by institutions and groups are often articulated through the use of mission statements. Missions have been described as visible and powerful articulations that provide guidance around overarching, long-term purposes of an institution as well as what an institution aspires to be [61, 62]. Missions serve as reflections of how institutions position themselves and approach their larger societal and educational purposes [58]. Institutional missions provide direction to members by communicating goals, outcomes, and values. Various factors, such as institutional type or geographical context, have been shown to impact the types of missions universities and other institutions pursue. In the U.S., public and land-grant universities have been shown to pursue missions in line with CBL [57]. Missions can help determine how an institution prioritizes participation.

While some institutions have missions in place, not all are clearly articulated which can lead to misalignment and inefficiency [57]. A lack of clarity or leadership around the extent to which individuals are supported to contribute to STEM CBL activities can cause challenges. In institutions with missions that are not strongly articulated or not aligned with CBL, participants must decide how to prioritize their CBL dedicated time and resources. Within a system containing conflicting demands, stakeholders face a dilemma in addressing multiple and competing demands [59] where satisfying one demand may impede the success of another [60] In these cases, individuals must commit substantial effort to align their institutional roles and actions with that of STEM CBL. Individuals must be willing to sacrifice professional development or other elements to participate in CBL within settings with limited to no institutional support.

A clearly articulated institutional mission that aligns with CBL provides a foundation upon which members can contribute to outcomes. Missions or similar statements can indicate an ability/ desire for institutions/groups to support positive partnerships. This would suggest that stakeholders with missions and purposes aligned with CBL, STEM workforce development, STEM education, and other similar areas can provide for effective partnership. A mission that reflects the needs of multiple stakeholders across society can provide a positive foundation. If institutional members are supported by their institutions in CBL, more opportunity for contributions to CBL outcomes can be established.

With or without supportive missions, there can be difficulty in aligning the strengths or assets from one stakeholder to the needs of another. Holistic awareness provides the ability to consider and/or integrate the assets, needs, and culture of those from other stakeholder groups. A holistic approach to participation leverages knowledge of the interdependencies between stakeholders for effective implementation and the development of outcomes. Knowledge of how to navigate the complexities of these relationships and implementation limits the impact of challenges and can lead to positive outcomes for multiple stakeholders.

Furthermore, STEM CBL activities are strongly impacted by personal relationships. The initiatives can be supported by individuals, groups, and institutions that display high levels of commitment to and care for STEM CBL and targeted beneficiaries. These personal relationships provide access to resources as well as an enhanced ability to navigate complexity and challenges. Past or first-hand experience within another stakeholder group supports successful navigation through challenges. Commitment and care are shown to be directed at the STEM CBL communities or individuals supported, the initiatives, and outcomes.

Due to the challenges of implementation, as well as STEM CBL often not being a primary responsibility or role of stakeholders, participating in initiatives often requires substantial effort. Those who participate can often be overburdened. Additionally, outcomes are not often tangible or directly related to career objectives. These factors create a need for increased motivation and commitment. Those who participate at high levels exhibit high levels of care. While it was evident that some rely on experience within different stakeholder groups to navigate and overcome challenges, those with high-levels of commitment overcome these challenges through personal relationships and/or high levels of persistence and motivation. Caring and dedicating extra time can make up for awareness and knowledge of the other stakeholder roles. High levels of commitment can strengthen personal ties and relationships. Personal relationships with participants were exhibited in multiple ways including; the populations being targeted as beneficiaries (i.e., K-12 students, family members, or those in need), or deep personal connections to the causes supported (i.e., under-resourced schools, the hungry, STEM education).

Participants are able to recognize those who are committed and have student interest in mind. Participants can be drawn to these types of individuals and strong relationships can be established as a

result. Working under strong support and mentorship activities can amplify student success [61]. Such personal relationships with mentors, faculty, and fellow students has been shown correlate to students' sense of belonging which leads to deeper connection with their education [62]. Empathy can help identify great individual participants and institutional cultures that can promote success. STEM CBL participation shows potential for developing empathy [30].

Overall, this study reinforced that STEM CBL can promote the development of holistic engineers and perhaps support progress towards a holistic society. There is substantial value in the stakeholder institutions working together to promote STEM educational needs and workforce development. Together the stakeholders can broaden diverse participation in STEM, as well as link educational, governmental, and business processes to societal needs and social justice. The challenge lies in performing this work effectively within transformational partnerships and towards reciprocal outcomes. While this study is oriented towards the inter-stakeholder dynamics and not student learning outcomes, the findings suggest that strong partnerships can provide a fruitful foundation upon which learning outcomes can be pursued across stakeholder groups. We hope that the findings of this study can contribute to further enhancing STEM CBL so that this approach can reach its full potential of transforming education and ultimately society as envisioned by a participant in this study.

> "*If within the universities [community-based learning] is elevated... If people prescribe into this philosophy, if people enter this wave, people who leave the university will change things outside [of it]. If within [the university] there is not, he/she will go out [of the university] and there will be no change*". (Roger—Professor—University)

7. Research implications

Focus on the inter-stakeholder dynamics of STEM CBL can provide insight into the characteristics, mechanism, and challenges from the perspectives of the stakeholders. Such an approach can also provide further clarity on the extent to which community-based outcomes are pursued and obtained. The interdependencies between stakeholders provide a context for furthering knowledge of the dynamics of CBL relationships, the needs of non-university stakeholders, and the limiting factors of reciprocity.

For positive outcomes, institutional leadership, which can be highlighted through formalized mission statements, can provide parallel or complementary pathways for its members to obtain institutional advancement through CBL participation. The more knowledge and awareness each stakeholder can develop of the other stakeholders can inform interdependencies and expand their ability to take positive actions. Empathy and care can support this alignment and can help institutions and participants look beyond the associated challenges and instead acknowledge the substantial rewards of these practices. Spreading awareness of the supportive mechanisms within relationships as well as encouraging stakeholder consideration of potential roles, perceptions, and goals can enhance outcomes. Holistic awareness supports the ability to align purposes. Ultimately, regardless of the mechanism, those who 'buy-in'' to the concept of community engagement and CBL, recognize its value, participate, and commit themselves to leveraging STEM CBL as a part of their lives.

As presented within the community engagement literature, partnerships are the core of effective CBL from a community-engaged paradigm [9, 63]. A strong partnership that has the support of institutional leadership allows members to establish lasting relationships. In engineering and STEM lasting relationships provide an approach to lasting and mutual outcomes as opposed to transactional relationships [27]. Building strong relationships can provide a foundation to support alignment between stakeholders. Even when goals or outcomes are differing, purposes can potentially be aligned. Through alignment of institutional demands and STEM CBL outcomes, CBL participation can be performed in ways which do not jeopardize primary goals, but instead enhance outcomes and return. This research provides empirical analysis of the inter-stakeholder dynamics within STEM CBL contexts. Its practice is shown to take place within a complex environment which requires leadership and support, care, patience, and persistence, as well as an understanding of the positionality of multiple stakeholders. The diversity amongst the stakeholders creates substantial complexity. Relationships among CBL stakeholders minimize the challenges of CBL implementation while isolation between the stakeholders can limit collaboration. Relationships can provide a foundation for effective collaboration and support the successful development of outcomes for the stakeholders involved.

This research refers to the spectrum of community-based learning approaches in that they involve experiential education and to differing extents may be grounded in community-engagement. Within this scope of CBL efforts, STEM education, workforce development, promoting innovation, and corporate social responsibility are common outcomes and goals pursued by participating stakeholders. A community-engaged approach to CBL includes the

direct pursuit of outcomes for the ''community'' and/or a social justice element of positive contributions for the community members and stakeholder groups.

8. Conclusion

CBL approaches are prevalent in various forms in STEM learning contexts and promise both experiential learning outcomes for students and broader benefits for society. Current approaches tend to focus on educational or programmatic outcomes thus limiting the consideration of how CBL relationships can be beneficial for all stakeholder. Such mutually beneficial relationships can enhance societal outcomes and contribute to the sustainable success of programs. This study investigated CBL inter-stakeholder dynamics at a large public university in Brazil to identify patterns and dynamics that characterize relationships that can lead to sustained and positive outcomes for those involved. Interviews with 30 stakeholders from various groups were conducted and qualitatively analyzed. The findings indicate that (i) shared purpose (ii) holistic awareness, and (iii) linked commitment characterize stakeholder relationships that support mutually beneficial outcomes. Shared purpose involves leveraging the commonalities of stakeholders' objectives and goals in ways that support contributions to STEM CBL. Holistic awareness promotes acknowledgement of the assets, needs, and/or cultures of those from other stakeholder groups within STEM CBL. Linked commitment provides a foundation for strong connections between stakeholders and towards CBL initiatives and outcomes. The results of this work can inform the holistic development of STEM CBL programming by providing a sense of the nuanced characteristics and interpersonal dynamics that are crucial for sustained program success. Such consideration can support a transition from experiential education to community engagement. For CBL researchers, the present study points to the need to investigate the specific contextual needs, behaviors, and goals of different stakeholder groups across the wide range of CBL approaches and institutional settings.

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