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# Characterizing STEM Community-Based Learning Through the Interstakeholder Dynamics Within a Three-tiered Model

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**Abstract**

Community-Based Learning (CBL) within science, technology, engineering, and mathematics (STEM) has the potential for positive student learning outcomes while also promoting beneficial outcomes in partner communities, yet complexity of practice can often obscure or limit these outcomes. Emergent behavior makes realizing outcomes, especially those for the community, difficult. A systems-level approach can minimize some complexity, yet empirical evidence of how STEM CBL is structured is limited. A three-tiered model (i.e., Community, Program, and Individual levels) is used as a structural framework to analyze two case studies to answer: How do three system levels describe the STEM CBL practitioners, their actions, and goals? Thematic analysis of data generated through participant-observation within two purposefully selected cases establishes a foundation for how these system levels can impact practice. Distribution of effort across the three levels can support well-rounded CBL practice and advance the voices of all practitioners, but especially those with less power.

*Keywords: community-based learning, interstakeholder dynamics, STEM*

Community-based learning (CBL), a pedagogical approach in which local communities participate as partners in learning (Mooney & Edwards, 2001), shows substantial value in educating developing science, technology, engineering, and mathematics (STEM) professionals while supporting broader societal outcomes such as STEM literacy, workforce development, and the design and implementation of solutions. Within STEM disciplines, CBL is most commonly implemented as service-learning, outreach, and volunteerism (Johri & Olds, 2014). CBL differs from other pedagogies through its community-based context and its potential for local impact, where in theory, benefits can manifest for all participating practitioners and stakeholder categories. In underserved communities, CBL has the potential to support social justice (Mitchell, 2008; Nieusma & Riley, 2010) and broaden participation (Young et al., 2017). At the university, CBL can support college students' development of critically needed professional skills in engineering, such as leadership, empathy, and citizenship, as well as teaching engineers to grapple with "wicked problems" while leveraging globalization for positive outcomes (Bielefeldt & Canney, 2014; Delaine et al., 2015).

Despite the potential for positive and transformational outcomes, CBL often fails to reach its theoretical potential (Baum, 2000) and can have unintended negative outcomes. For example, in contexts where students are charged with creating solutions for local challenges, without careful training, students engaging in CBL can reinforce stereotypes or deliver unnecessary, inappropriate, and expensive solutions (Mitchell et al., 2012). Therefore, university-based CBL practitioners must be careful to respect community partners and minimize harm while pursuing positive outcomes. University stakeholders in CBL partnerships may find it difficult to maintain this balance because they often hold more influence. It is

broadly recognized that reciprocity, or "the relationships between the 'service providers' and 'service receivers' and the mutuality between their needs and outcomes" (Henry & Breyfogle, 2006, p. 27), should be a goal of any CBL effort. Without emphasis on reciprocity, there is a greater potential for negative repercussions for the stakeholders; however, the dynamics of CBL reciprocity in STEM contexts are poorly understood. Therefore, further knowledge is needed to support such reciprocal implementation of STEM CBL to protect community partners, produce positive community outcomes, and promote social justice.

The purpose of this research is to provide a cohesive overview of STEM CBL practice through a synthesis across two case studies. This research results in a model that describes STEM CBL using three system levels—community, program, and individual—as proposed by the National Research Council (NRC) for informal STEM learning (NRC, 2015). This study empirically investigates two purposefully selected STEM CBL efforts that originated from a single university. After situating this work in the literature, the case study research methods employed are described. A thematic analysis of participant-observation data within the selected cases establishes a foundation for how the system levels are manifested in practice. Three levels are used to describe the interstakeholder dynamics of STEM CBL practitioners and their actions and goals. This research can further knowledge of STEM CBL through advancing structural understanding within the complexity of practice to promote well-rounded approaches to CBL participation and the dynamics between stakeholders toward positive and reciprocal university and community outcomes.

## Literature Review

Community-based learning is distinct from other pedagogies in its use of community contexts and settings outside the university and the pursuit of nonuniversity outcomes. As higher education is increasingly called upon to deliver public good, CBL pedagogies have proliferated (Dostilio, 2017). Furco (2003) included service-learning, outreach, and volunteerism, as well as field education and internship, within a spectrum of pedagogies for community-engaged education. Swan et al. (2014) adopted this spectrum for use within an engineering context. Unifying these pedagogies under a CBL umbrella provides for a holistic examination of their impact rather than placing emphasis on the specific implementation of each pedagogy independently. Holistic approaches can center the implications of partnerships upon which they are based and the outcomes produced by CBL, as well as support the systematic advancement of CBL through attention to the structures and dynamics of partnerships, by highlighting misalignments in practitioner actions and revealing the impacts on stakeholder groups and the intended CBL beneficiaries. Recent research on CBL within STEM contexts has predominantly focused on single pedagogical approaches, such as service-learning (Garcia et al., 2013; Oakes et al., 2014), outreach (Jeffers et al., 2004; Sadler et al., 2018), or volunteerism (Baytiyeh & Naja, 2014), leaving this unified CBL approach underexplored.

CBL can be implemented in various ways. Approaches can be centered on university or student outcomes through experiential education (Chan, 2012; Mooney & Edwards, 2001); reciprocal and integrated outcomes can be pursued across stakeholders and beneficiaries (Gilbert et al., 2015; Henry & Breyfogle, 2006; Weerts & Sandmann, 2008); or implementation can center community needs through democratic, participatory, or critical approaches (Crabtree, 2008; Dostilio, 2014; Miller, 2008). The approach and its implementation can strongly impact the outcomes and the extent to which they are negative or positive. Negative outcomes, including reinforcement of stereotypes and social hierarchy, have been reported, whereas positive outcomes can include social justice and institutional change (Chupp & Joseph, 2010).

The community engagement literature is in agreement that grounding CBL initiatives in partnership is critical. Consequently, a rich discussion on the characteristics of university–community partnerships has emerged (Drahota et al., 2016; Suarez-Balcazar et al., 2005). It has been shown that partnerships that embody shared values are more likely to minimize harmful impacts and support reciprocity within community and university outcomes (Dostilio, 2017; Drahota et al., 2016). Bartel et al. (2019), in a review of the ways university–community partnerships function, recognized three themes across prior investigations: (1) focus on how well partnerships work and factors

that lead to success, (2) examination of the ways partnerships fail and what factors are connected to these failures, and (3) previous and new models of structuring partnerships in an effort to strengthen drivers of successful partnerships and to promote Themes 1 and 2. Strier (2010) found several crucial factors to be acknowledged in the process of partnership management: role perspectives, group affiliation, institutional context, power relations, the organizational culture of the partnership, and the societal perceptions of social problems addressed by the partnership. Broadly, communication, respect, and trust across practitioners are understood to be critical to CBL partnership (Bartel et al., 2019; Mitchell, 2008; Suarez-Balcazar et al., 2005), as are mutuality, supportive leadership, and university immersion and asset building (Taylor et al., 2004). Multiple factors have been shown to inhibit CBL partnership, including power dynamics, cultural norms, and communication (Maurrasse, 2002).

Relationships across CBL stakeholder groups establish social networks that consist of a series of interpersonal relationships (Bringle & Hatcher, 2002) within which cultural differences add to the complexity of interactions (Bender, 1993; Bringle & Hatcher, 2002). Additionally, CBL partnerships are highly affected by structural forces, organizational cultures, and local contexts (Strier, 2010). Structural factors, including the type of university, mission, and institutional capacity, as well as the challenges faced by the partners and intended beneficiaries, have been shown to be impactful (Holland & Gelmon, 1998). Collectively, these factors contribute to the complexity of CBL in practice (Bringle & Hatcher, 2002; Strier, 2010). Due to these factors, frameworks that support understanding the dynamics of these partnerships can support the advancement of CBL to further knowledge of the ways in which the partnerships and the structures within CBL impact practice and the resulting outcomes.

In STEM fields, CBL initiatives have shown the potential to promote positive outcomes such as promoting STEM literacy and providing engineering solutions to communities in need (Bielefeldt et al., 2010; Oakes et al., 2014). Student outcomes often include strengthened professional skills, hands-on abilities, cultural competence, academic and life skill development, and sense of civic/social responsibility (Astin & Sax, 1998; Bielefeldt et al., 2010). Community outcomes include volunteers and sources of human capital, STEM solutions within the community's areas of need, and educational programming (Baillie, 2006; Leydens & Lucena, 2014; Nieusma & Riley, 2010). However, without careful management of these partnerships, unintended negative consequences can emerge, such as reinforcing negative stereotypes across stakeholder groups or the development of projects not useful to community partners (Nieusma & Riley, 2010).

These factors point to a need to investigate the dynamics of partnership within a STEM context. With CBL proliferating in the STEM fields and increased funding and attention being directed at STEM education, it is important to investigate CBL within this specific context. Several noteworthy STEM-based models characterize community engagement. Thompson and Jesiek's (2017) transactional, cooperative, and communal (TCC) model for service-learning in engineering includes three types of partnership: (1) transactional, where distinct boundaries exist between partners; (2) cooperative, in which some partners intentionally work together; and (3) communal, where deeper partnerships are grounded through common values. In another study, Eilam et al. (2016) presented a conceptual model for STEM outreach within university operations that highlights distinctions between "top-down" (led through university governance) and "bottom-up" (grassroots) efforts as essential to STEM outreach. Recently, researchers have investigated a single CBL system leveraging a holistic approach through qualitative research on the dynamics between differing stakeholder groups (Delaine et al., 2015; Delaine et al., 2019). Although recent efforts within STEM have increasingly called for reciprocity and community-oriented outcomes (Baillie, 2006; Nieusma & Riley, 2010), much work is still to be done to further the impact of emergent research on community engagement within STEM contexts.

In summary, a number of researchers have offered suggestions for how to improve university–community partnerships. These efforts provide substantial grounding for the dynamics within CBL partnerships and ways to improve these partnerships, yet investigations situated within engineering or STEM disciplines remain underexplored. Although prior studies have leveraged a systems-level

approach to CBL, structural models for CBL based on empirical evidence, grounded in theory, and that take a sufficient systems-level perspective are limited (Strier, 2010). Few studies leverage a unified approach to CBL within STEM contexts to clarify some of the complexities of CBL partnerships in practice (Delaine et al., 2015; Delaine et al., 2019). Non-STEM literature offers worthy suggestions, such as developing a shared a commitment, building mutual relationships, and supporting members of the community, but few studies investigate how such practice is structured (Mitchell, 2008; Rosenberger, 2014) or examine these principles at play in actual partnerships (Bartel et al., 2019). Further research is needed regarding the "broader system in which these relationships between universities and communities exist as well as opportunities for enhanced sustainability" (Barnes et al., 2009, p. 17), especially with a focus on how these dynamics intersect with structures of STEM CBL practice.

## Theoretical Framework: Community, Program, and Individual Levels

The National Research Council (2015) describes informal STEM learning environments using the holistic concept of a "STEM learning ecosystem," a term referring to all the STEM assets in a student's community. As shown within the context of informal STEM education, a host of factors impact learning and engagement: setting (both designed and naturalistic), people and networks of people, and everyday encounters with STEM (NRC, 2015). Others have employed three-tiered models to analyze various forms of CBL (Chupp & Joseph, 2010; Mulroy, 2004). The NRC suggests a three-tiered approach to evaluating informal STEM ecosystems, recognizing the separation between individual outcomes, program-level outcomes, and community- or ecosystem-level outcomes, as shown in Figure 1. It is suggested that this approach can support understanding how informal learning affects outcomes across settings and time. In the present study, this framework is leveraged to investigate the impacts of these levels across STEM CBL partnerships in practice. Although there has been research on independent levels (Bringle & Hatcher, 2002; Mulroy, 2004) and at a system level (Head, 2007; McNall et al., 2015), efforts that integrate understand-

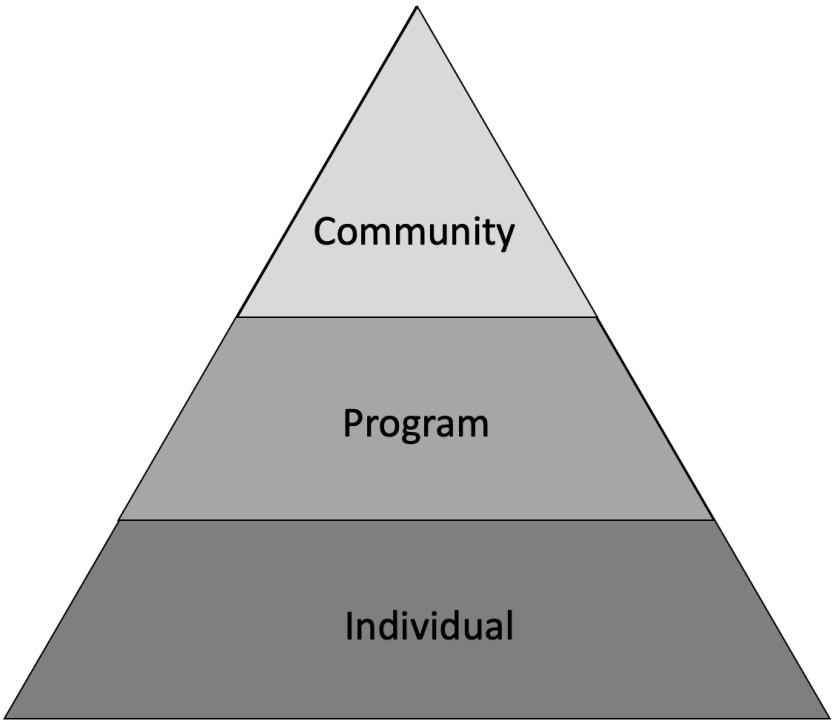


*Figure 1.* Three-level Framework

ing of partnerships or actions taken across these levels are limited.

In this research, the word *landscape* is preferred to *ecosystem* (as used by the NRC), due to the limited cohesion exhibited across the stakeholder groups within the investigated context. Prior investigations into community outreach have suggested that "a fragile outreach landscape, [that is] highly diverse, operating in a perpetual 'start–stop' model and mostly lacking institutional ownership" exists (Eilam et al., 2016, p. 421). Similar disconnected behaviors were exhibited within the CBL cases studied, and as a result, terminology implying a high level of interconnectivity (i.e., ecosystem) does not accurately describe the context studied.

Leveraging the three-tiered NRC system structure as an overarching framework, this work seeks to present an exploratory model that describes CBL practitioners, their interactions, and their goals across these levels. By understanding the implications that levels may have on the who, how, and why of CBL, this work furthers knowledge in the STEM CBL context to improve research and practice. The investigation presented answers the following research question: How do the three system levels (community, program, and individual) describe the STEM CBL practitioners, their actions, and their goals?

## Method

This research used a case study method (Creswell, 2013; Yin, 2017) to focus on the characteristics of STEM CBL initiatives. Case study methods can retain the holistic and meaningful characteristics of the research context while providing insight into small group behaviors and organizational and managerial processes within their natural settings (Yin, 2017). In this work, the two STEM CBL efforts from within a single university were purposefully selected for an in-depth exploration of the context within a multicase study structure. In each case, multiple sources of evidence were captured to investigate the research question. Pseudonyms of both institutions and individuals are used for confidentiality, and all research has been conducted under IRB human subjects approval.

### Empirical STEM CBL Context

The host institution, "Universidade Brasil Estadual" (UBE), in which the study originates, is a public university for high-achieving students in Brazil. It is a comprehensive university with a rich history, situated on a beautiful campus in a large city. For context, in Brazil, public universities are considered more prestigious than private universities, and are free for students who are able to gain admission through standardized testing. These placement exams are highly competitive, and only a small fraction of the student population is admitted. UBE is a comprehensive research university with several colleges and multiple degree-granting programs at both undergraduate and graduate levels.

Various STEM CBL activities exist within the local geographic region of the university. These include precollege research fairs and competitions (regional, national, and international), cocurricular service-learning and outreach, credit-bearing service-learning, volunteerism, and research internships within university laboratories. Some CBL initiatives within the landscape were shown to have limited or no affiliation with the university, whereas others were implemented in partnership with the College of Engineering at UBE.

Despite plentiful CBL activities, the culture of UBE is inclined toward academic excellence and research rather than community-based or socially oriented efforts. The institution maintains a university-wide administrative office that oversees and tracks what it calls "extension" activities that involve the broader public, yet only a small number of faculty, staff, and students maintain and implement these efforts. As a result, the individuals active in CBL often have strong networks and are well-respected among the students but are overburdened and carry multiple competing responsibilities.

Among the STEM CBL initiatives present within the investigated landscape, two initiatives were selected for case study analysis in a multiple-case design to support the study's robustness (Yin, 2017). The criteria used to select the CBL initiatives for case study included (a) the ability to obtain deep access into the efforts, (b) the alignment of the efforts with the host university, (c) maturity and scope of work, and (d) the extent to which the initiatives are aligned with community need and socially oriented outcomes, teaching, and learning. The cases selected for this research were (1) the

STEM Pre-College Research Fair, and (2) the Technical Citizen Collaborative.

### Data Collection

This empirical study was conducted from April 2014 through April 2016 through participant observation (Glesne, 2016). Qualitative observations, through field and descriptive notes (Glesne 2016; McCall & Simmons, 1969), were collected for insight into interpersonal behaviors and motives (Yin, 2017). Observations were conducted by the author as a full participant (Glesne, 2016) from within various roles with each CBL case. These roles included participation in meetings/committees, serving as a judge/evaluator, supporting the development and implementation of the CBL efforts, and interacting with practitioners and beneficiaries from within the CBL activities. Throughout the research the author maintained daily research logs that captured thoughts, reflections, and observations of each case (Glesne, 2016). Meeting minutes were captured during formal meetings both from the author's notes and through formal meeting minutes captured by practitioners involved with the meetings. Documents were obtained from each case that include but are not limited to meeting agendas, promotional materials, email, and other communications.

### Data Analysis

Data were qualitatively analyzed using NVivo software (Richards, 2014) to facilitate an iterative thematic analysis process and ensure consistency of the emerging interpretations from the data. Thematic analysis provides a flexible research tool that supports rich and detailed accounts through the analysis and reporting of patterns within data (Braun & Clarke, 2006). Initial topic coding of the transcribed data was performed in a deductive manner, where codes were not assigned to fit into a preexisting theory. Within this step, the emergence of system levels was recognized. An interpretive coding step was then performed using a three-tiered structure of codes to reveal explanatory patterns that provide an understanding of the dynamics involved between CBL practice and system levels. Elements and details captured from within the two representative cases are presented to provide an understanding of the context of each case and to highlight the scenarios in which the three system levels are revealed.

### Study Limitations

The research was conducted within a single international context. As a result, any particularities that may be cultural artifacts of the region, the university, or other contextual factors may be manifested in the model. These factors must be considered for adaptation into another context. Further study is necessary to determine the extent to which this model provides for transferrable results. Although this research sought to leverage an approach that captures perspectives of multiple stakeholders, the data collection and conversation within the research originated from a university orientation. This could tend to make the model university centric. Perhaps different configurations of the model could be developed in the absence of the power and influence the university can hold within these partnerships. Additionally, the author is a proponent of STEM CBL and seeks to support the advancement of this pedagogy through evidence-based practice. This positionality may impact the findings of this work. It should also be noted that although the author followed participant-observation protocols and method, the author was still embedded as part of the system.

## Study Cases

Each case is presented to explore the "who," "how," and "why" of STEM CBL practice to provide a contextual description and highlight the complexity of practice between stakeholders. The stakeholder groups, institutions, and individuals that participate, as well as the various roles embodied, are presented as the "who." The actions taken within the conceptualization, organizing, planning, implementation, and debriefing of each case comprise the "how." The justification for contributions to CBL represent the "why." Descriptions of both cases are followed by a synthesis across cases with respect to the three-tiered framework.

### Case 1: The STEM Pre-College Research Fair

Described as a national movement to stimulate young scientists (grades 6–12), the STEM Pre-College Research Fair initiative has sought to support creativity, innovation, STEM proficiency, and research skills on a national scale for nearly 20 years. The initiative is a national cornerstone in Brazil for its ability to support the development

of STEM researchers and professionals. Throughout its history, this initiative has established a strong pipeline of alumni and a strong network of schools, leading to considerable education and workforce impact in the STEM field. Winners from regional fairs across Brazil compete at the national level, with winners moving on to compete at an international competition. This case study focuses on the national event, although the other associated events (regional and international fairs) are closely intertwined.

As a participant–researcher within this case study context, the author served in various roles, including member of the organizational team, evaluator judge of the research projects at multiple fairs, resource to the regional and international fairs and participants, English-language expert, committee member for the national delegation traveling to the global competition, and support/mentor role at the national and international competition. The author participated in two of the national fairs central to the case, as well as three regional fairs and one international fair.

### *Who*

The Pre-College Research Fair initiative is supported by practitioners from across the stakeholder groups. From within the university, the event is led by an associate professor, Camila. Camila is a visionary, serving as the heart of the event as both the public face and mobilizer of resources. She leads this initiative in parallel to her technical research that she performs as an engineering professor. Camila has made an exceptional commitment to this initiative, working countless hours and contributing heavily to all aspects of this event. Unfortunately, with respect to her university promotion, her CBL contributions are not respected as much as technical research, grant funds, and publications, so her career trajectory may have been stifled by these contributions. Another strong contributor, Lourdes, works within an educational outreach role within her large company. Lourdes mobilizes resources (i.e., funding, meeting spaces, giveaways and prizes) by promoting the value of this initiative to her superiors at her company. She makes personal contributions to many of the national, regional, and international fairs by committing her time and energy to the event. Complementing Camila's role, Lourdes's contributions are tied to her primary professional responsibilities. Lourdes is often very present in person at associated activities, yet her role consists more of providing resources than supporting the implementation of the national fair. She therefore must continue to present the value of the initiative to her company.

Camila has developed an established infrastructure of committed organizations and individuals who support the event. Supporting Camila at the university is a small but strong organizing team of administrative staff and graduate and undergraduate students. The team is structured hierarchically, so that a core team of long-time members often manages more recent additions to the team. The individuals on the core organizing team, some of whom participated in the fair as students, have established a strong commitment to this initiative. Alejandro, for example, is a current graduate student who participated in the event when he was a precollege student. The fair supported his academic development and, as a result of participation and his hard work as a student, he earned admission into UBE. Now he serves in a leadership role on the core university team. This team dedicates an entire week in December to supporting the event, as well as countless hours throughout the calendar year. This core team serves as the primary driving force within this CBL initiative. The team members work in close partnership with each other and have established strong relationships with many supporters and volunteers from precollege schools, industry, and government groups. Although the event is supported by the university, the primary responsibilities fall to the organizing team. Their interactions with participants and each other, as well as the intensity of work needed to implement the national fair, exhibit a high level of dedication. From the conceptualization and planning to the on-the-ground implementation of the event, this team is constantly present and ready to support. For example, when a glitch arose within the system built to collect the judges' marks on the student research projects, Alejandro and the team worked around the clock to solve the issue prior to the event.

Several individuals and institutions have long-term relationships with the STEM Pre-College Research Fair. These individuals come from industry, government, nonprofit groups, and precollege stakeholder groups. They provide links to financial contributions, resources for space and infrastructure

(i.e., housing meetings and workshops at the company), and expertise on workforce needs and professional experience. These individuals often serve as role models during the fair, as they walk around and chat with the participating precollege students. They serve as judges and often bring their peers, providing links to the other STEM professionals and expanding the network of those supportive of the fair. One such individual is Bella, who works for the Ministry of Education in support of STEM education. Bella obtains small government grants to support the event and promotes national discussions of the value of STEM education to the country to support maintaining the initiative as a governmental priority. As the event has a successful history across almost 20 years, student alumni of the event have created a nonprofit group that supports the development of the participating precollege students. Led by Erika, this nonprofit organization supports student success at the national and international levels, pursues job and internship placement for participants, offers role modeling and mentoring, and provides judges and consultants. Additional nonprofit organizations (primarily from educational sectors) provide funding, publish articles, and offer expertise at the event.

Around 10 precollege administrators and teachers exhibited deep commitment to the fair, as evidenced by their annual dedication to the student participants during the event. One such teacher is Ivan, who has brought students from his precollege school to the event for 9 straight years. The schools and districts of Ivan and his peer teachers have had steady participation, regularly sending multiple high-quality projects to the national and international levels of competition. Their school districts have developed pipelines of interested students who commit long hours and effort to advance research projects. Within certain regions of the country, as a result of Ivan and his peers' efforts, participation in the STEM research fairs has gained a strong cultural hold. In these regions and school districts, many students participate in the fairs, the school curricula are aligned with STEM and research development, and the teachers and community are able to support many students to be successful and even achieve and win at the international level.

The precollege students and schools are primary beneficiaries of this initiative. Students can further their educational development (both technical and professional skills), teachers and schools can enhance their curricula (through the research projects), and all parties can gain exposure to and interaction with a wide variety of professionals during and after the fair. The precollege students work hard to advance their projects, recognizing the potential for educational advancement that this established platform offers. One exemplar student is Theo, an aspiring physician/researcher in his second-to-last year of primary school who hopes to pursue a career in robotics. During this case study, Theo traveled to the event with Ivan and peers from his school in hopes of success at the fair. Theo was fascinated by the quality of judges and their ability to dissect his work quickly and pose questions that furthered his own understanding of his work. Theo responded well to the questions and won the competition, earning a place in the international STEM fair. After the victory, he and Ivan ecstatically exchanged big hugs and danced with the rest of their peers from their school, as he is one step closer to achieving his dream of being a physician and researcher.

### *How*

The individuals and institutions involved support this CBL initiative through planning, implementation, debriefing, review, and conceptualization. Planning activities were primarily coordinated by Alejandro and the university-based administrative team. The team meetings were well organized and effective, accomplishing ambitious agendas within meetings. The experience of the team was evident as they drew from prior outcomes for continual improvements. The team met weekly as a unit and with Camila but worked in close proximity and in constant communication. Finances, logistics, recruitment, evaluation, standards, and other elements were commonly discussed. This team would often meet with representatives from the other stakeholder groups for alignment with each other's needs, about once every other month at a minimum and almost weekly prior to the national fair.

As an example, meetings with Lourdes typically considered how to optimize the value of her company's financial contributions through programming and branding. Although the event is well-respected, annual implementation requires substantial financial negotiation as the event is

not supported through endowment or on a sustainable platform. Even with financial contributions from multiple entities and sectors, variations in the policies and financial status of those who contribute can leave the budget for the STEM research fair in flux from year to year, requiring substantial fundraising efforts. Lourdes, as she has been able to continually obtain funds from her company for the event, provided insight to the team on best approaches for obtaining funding from other institutions.

Concurrently, during the fair Alejandro led the core organizing team through daily planning and debriefing meetings. For example, Alejandro and the team met with Erika from the alumni nonprofit and reflected on the best ways to enhance student performance and how the members of the organization would be most effective during the fair. The precollege practitioners prepared in similar ways, with precollege teachers supporting the student research efforts toward their strongest showing at the fairs. The competing students and their teachers invested many hours, often in and outside their classes, to produce strong research results. Those with the most experience would often reach out to the network of individuals and the university team for support and links to academics who might support the research.

During the 3-day event itself and immediately surrounding it, practitioners from across the stakeholder groups worked closely together toward the success of the fair. During the event, while newer practitioners were focused on one role at a time, those with experience within the research fair often enacted multiple roles. For example, most of the K–12 students have one role: to present their research to judges or peers. Students with more experience may serve as mock judges to support their peers. Those in the leadership roles (e.g., Camila, Ivan, Lourdes) oversee the success of their colleagues at the fair. They mingle and interact with those from other stakeholder groups, subtly highlighting return on investment for financial contributions; judge posters; and have casual or directed conversations about the STEM fields with academics and students.

Immediately after the event, debriefing discussions captured successes and limitations, as participants were already beginning to plan the next year's event. Practitioners debriefed to discuss future needs and improvements. The precollege students and their instructors discussed successes and limitations. Industry and government representatives discussed the extent to which their contributions provided value, the return on investment, and how future contributions could be made. The organizational team debriefed formally, an action primarily performed by just the core organizational team, but with some practitioners from other stakeholder groups also participating (i.e., Camila, precollege instructors, and nonprofit representatives). The organizing team would revisit the elements of the fair to a substantial extent, reviewing all elements from the sequence in which the judges reviewed posters and provided scores to the general trends observed in the students' performance. These reviews have led to continued improvements of the effort from year to year.

Efforts to conceptualize and broadly consider the approach and scope of the fair were limited. As efforts were being made to strengthen the regional and local fairs, Ivan and Camila would meet at various times throughout these efforts to conceptualize approaches and needs within these smaller, more emergent fairs. Their conversations focused mainly on how to attract more students, train more teachers for advising roles, and grow the infrastructure and integrity of the fairs.

### *Why*

Several goals and justifications are pursued within this initiative by the practitioners from the differing stakeholder groups. Most broadly, the goals of the national-level fair and network of regional fairs include stimulating STEM workforce development, supporting society through education and innovation, providing links between precollege schools and universities, and promoting interactions between students and researchers/scientists from different backgrounds. From youth as young as 12 years old to professionals approaching retirement, the research fair is a platform where many can make contributions and benefit from the exposure to and development in STEM research toward increasing the integrity and capacity of the STEM pipeline on a national level. The different stakeholder groups pursue outcomes that parallel this overarching goal. For example, Lourdes pursues several outcomes on behalf of her company: promoting corporate social responsibility,

gaining market share through effective marketing, building brand loyalty within future STEM professionals, and developing and growing the future workforce so that her company may have suitable employees to hire in the future. Bella, within her governmental role, advances development of the STEM workforce by supporting innovation and economic strength through contributions to precollege STEM education, which can provide returns on both educational and economic development. The goals pursued by practitioners from nonprofit roles, represented by Erika and her peers, are oriented toward supporting important social causes, giving back to communities in need, or contributing to passion projects. The educational stakeholders (precollege and university), Camila, Alejandro, and Ivan, pursue the primary goal of improving STEM education, broadening participation in STEM—particularly that of underrepresented racial minorities and women—and supporting the future STEM workforce.

Because the national research fair winners would earn an opportunity to compete at the international level, this event also served as a platform for national pride. Students like Theo, who qualify for the international competition, obtain press exposure for themselves, their teachers, and their schools, and those who are awarded prizes at the international level can obtain substantial recognition for their performance both from those involved with the event and other national media outlets. As a result, the performance of the national representatives in the international fair is evaluated against global peers and fosters discussion of how to strengthen infrastructure for optimal performance.

### Case 2: The Technical Citizen Collaborative

The Technical Citizen Collaborative is a university-based group of individuals within the engineering program who seek to implement projects with socially beneficial objectives to strengthen the relationship between UBE, its engineering efforts, and local social need. These projects seek to foster the development of social responsibility and recognition of the importance of social action in university engineering efforts to impact members of local communities. The collaborative serves as a clearinghouse to both university students and professors who are seeking to include or strengthen the integration of these objectives within the undergraduate engineering curriculum. Support is provided to stakeholders from outside the university who may be looking for engineering solutions or guidance on local challenges. The collaborative supports a wide variety of projects at the university, provides links to partners, and pursues funding opportunities in support of the projects.

As a participant–researcher within this case, the author served in various roles, including member of the administrative board, supporting the planning and implementation of initiatives, facilitating and supporting the implementation of activities, and observing activities while not participating.

#### *Who*

The core contributors of the Technical Citizen Collaborative are from within UBE. The collaborative is led by several faculty members, Roger, Antonio, and Edson, and one college administrator, Erika, all of whom have strong conviction and interest in linking university efforts to social need. Roger initiated the collaborative in 2004, and since then, this core team has served as board members to manage and support its success. This team dedicates a substantial number of hours to the collaborative, meeting weekly for 1–2 hours in addition to their primary responsibilities in the university, and they have done so since the collaborative's inception. Student representatives serve on the board in annual terms that can be repeated. Gabriella is a third-year undergraduate in systems engineering who is a long-term volunteer on the board. She provides student voice and supports website development, student recruitment, and other collaborative needs as they emerge. A part-time administrative staff member, Luciana, provides support by maintaining documentation, obtaining supplies, and maintaining the finances and structures of the group. Other undergraduate engineering students, such as Flavio, partner with the collaborative to align senior design projects to local community needs. The collaborative is responsible for a small room in an engineering building at UBE that serves as headquarters and is often used by students to work on projects and store materials. An industry partner, Lucas, provides support through financial contributions and resources, but does not otherwise contribute to the projects. Additional university pro-

fessors and students make contributions to the collaborative through their participation in various projects that provide support, services, and education to various targeted community beneficiaries.

The targeted beneficiaries include but are not limited to the UBE custodial staff, local primary school students and teachers, youth from a nearby underserved neighborhood, incarcerated individuals, the elderly, and citizens from a variety of venues both formal (schools, museums) and informal (street fairs, parks, markets). These projects' beneficiaries were not commonly involved in planning, although sometimes discussions and questionnaires were conducted within these groups to adapt the project efforts to their needs.

*How*

The board's primary function is that of a clearinghouse. It brokers relationships between representatives from across the stakeholder groups interested in making contributions through the collaborative and the engineering program at UBE. The primary interactions of the collaborative included planning for the needs of its projects and the beneficiaries, implementing the projects, and marketing the presence and services of the collaborative within UBE and the targeted communities. Administrative work was also needed so that the collaborative could continue to run effectively and show its impact within UBE. Projects, all of which support local communities through student development, are grouped into two categories: short-term and extensive. Short-term projects involve partnering with communities in need toward the delivery of educational/socially inclined activities and solutions. Short-term projects fall into three main categories: (1) hands-on efforts to promote interest and awareness in STEM education, (2) education to develop STEM literacy and abilities, and (3) the delivery of services such as supporting accessibility in technology for the differently abled. For these types of experiences, the board and/or students from the collaborative would either travel to the communities or invite them to campus to implement the short-term projects. Examples include a hands-on STEM education workshop that used street-racing carts to teach design and engineering to local youth from underserved communities, and a series of computer skills courses for university custodial staff, the majority of whom are from low-income backgrounds.

The street-racing cart project was offered annually, for 10 to 20 preteens who are invited to the campus for a workshop around building and racing the carts. Through two afternoons, preteens from a nearby community learn elements of design and get exposed to university students as mentors. Amanda was a preteen student participant in the cart design activity. She lives in a nearby underresourced neighborhood that struggles with limited infrastructure and opportunity, leading to crime. She and her peers enjoyed the activity and appreciated visiting the beautiful campus as they designed, built, and painted their racing carts. At the end of the activity, the students participated in a ceremony to receive certificates branded by UBE, a gesture intended to provide motivation to pursue academic excellence and a sense of belonging within the prestigious university.

The computer course for custodial staff comprised a series of six lessons, developed and offered weekly by undergraduate students to support the ability of custodial staff to gain and further computer skills. Vinicius, who, like his custodial colleagues, is from a low socioeconomic status, represents participants in this class. The course was offered on campus so the staff could easily attend after their shifts. From this project, the collaborative sought to develop computer literacy for groups that had little prior exposure to academics or computing to support their empowerment and future employment opportunities.

In contrast to the short-term initiatives, extensive projects are those connected to engineering undergraduate students' senior design projects, a requirement to graduate. Only a small percentage of UBE students pursue these extensive projects. One exemplar is the project of Flavio and his team, who were working to develop a device that supported reading for the visually impaired. Other extensive projects included a system to support increased recycling on campus to facilitate the process for custodial staff, and the development of a virtual learning platform to support the continuing education of those who have been incarcerated.

At board meetings, Roger, Antonio, Edson, Erika, and Gabriella review upcoming projects as well as the successes and challenges of prior projects. They discuss how to support the project teams toward successful implementation and resolve any of the collaborative's organizational needs. These

meetings are the primary opportunity for the collaborative to review its performance and the extent to which it is accomplishing its mission. Students are involved in the board meetings in several ways. For example, Gabriella is present each week and provides input from a student perspective to represent the needs and challenges of her peers on an ongoing basis. Flavio attended at least two collaborative board meetings to align his senior design team's project with individuals affected by visual impairment. The collaborative supported this project through contacting and communicating with some potential nonprofit partners. At a follow-up meeting, Flavio returned and was connected to a nonprofit via email. The collaborative's board offered continued assistance in establishing a connection in support of the project's ongoing success. At the board meetings, students like Flavio presented ideas, obtained feedback, and learned of community partners and ways they can be linked to the project.

In weeks prior to short-term projects, the board interacts closely with the undergraduate students who lead the project to provide any necessary support. Additional meetings outside the board meetings are sometimes organized to accomplish this. The implementation of the short-term projects is primarily led and developed by students. The student teams develop the projects of interest and are the primary individuals implementing the project. Substantial student effort is directed toward making sure that the project agendas and materials are established so that the targeted beneficiaries' experience is smooth and positive. The board builds and maintains relationships with community members to offset year-to-year student turnover, which can inhibit long-term relationships. Roger and an additional board member are often present during implementation of the short-term projects to provide any needed support on site. Within each of the projects, the board primarily facilitates and supports any student needs, such as providing access to buildings and being the legal supervisors of the event.

Every other year, the board holds a retreat for the collaborative off campus, in the offices of an industry partner, Lucas, who makes financial contributions to the group, sponsors projects, and provides space in his company's office. Lucas is welcoming but serves primarily as a benefactor rather than supports the internal needs of the collaborative. During these review meetings, the board sets an ambitious agenda to revisit its organizational charter, partnerships, and outcomes to determine future needs and potential adjustments.

### *Why*

The core objective of the Technical Citizen Collaborative is to promote socially responsible engineering practice within undergraduate and cocurricular education at UBE while supporting impact in local communities. Broadly, the goal is to support a shift in the culture of engineering so that engineers more readily recognize the need for a human-centered approach to engineering. Whereas the university is known for its technical excellence, the core leadership team supports student development and social outcomes through opportunities for students to complement the technical curriculum with socially inclined efforts. The existence of this collaborative provides an outlet for the college to support community engagement and to allow support to return to the public that funds its existence. Additionally, it provides platforms where stakeholder groups can interact within what would otherwise be a highly theoretical and technologically inclined engineering program. The short-term and extensive projects provide platforms upon which those from across the stakeholder groups can make contributions to social causes.

Through these socially inclined projects Gabriella, Flavio, and other undergraduate students are able to develop professional and leadership skills, as well as to understand more deeply how social objectives can be included in engineering. Additionally, these projects provide opportunities for students to impress potential employers with meaningful projects that highlight leadership skills and socially inclined goals. Many students also recognize the privilege of attending a renowned public university and hold desires to give back to the local community. A few participating students come from underprivileged or underrepresented backgrounds themselves and want to find ways to connect their education with their own communities. Industry representatives recognize the collaborative as a mechanism to support the university and meet company objectives toward social responsibility.

Finally, the targeted beneficiaries of the projects, such as Amanda, the preteen who participated in the race cart project, and

Vinicius, the custodial staff member learning computing, can benefit from the exposure to the CBL programming involved with each project. Although resources for STEM education can be limited, especially within underresourced communities, these projects provide brief outlets that may be valuable in the development of the STEM awareness or skills of the beneficiaries. Broader alignment of these efforts could help these projects be situated within a pipeline of efforts that truly support the development of these beneficiaries within STEM education.

## Results

These case studies highlight the dynamics of STEM CBL practice. The data from within each context indicate that CBL practice can be situated within a three-tiered system structure, similar to that proposed by the NRC framework for informal STEM education (NRC, 2015) that we employ as the theoretical framework for this study. In the following section, both cases are synthesized in an analysis across cases to present a holistic representation of the dynamics at play within STEM CBL practice at each level.

### Tier 1: Community Level

The community level involves the positioning and alignment of the stakeholder groups in relation to the other stakeholders, STEM, education, and CBL. At this level, philosophical approaches to CBL and the aspirational goals pursued were negotiated. Those present during community-level interactions, most commonly those within leadership roles, could work to strategically determine (1) why contributions to CBL are sought and if participation is of value, (2) what contributions to CBL can be made, (3) what outcomes can result from CBL participation, (4) what type of CBL can produce desired outcomes, (5) how to align goals with the other stakeholder groups and targeted beneficiaries, and (6) how to obtain resources to accomplish the efforts through internal mobilization and/or strategically seeking contributions from other stakeholder groups. Practitioners from across the stakeholder groups can potentially make contributions at the community level. The data from the two cases indicated that community-level interactions were not common, and when they happened it was primarily through those in leadership roles. During community-level interactions, since high-level planning is pursued, CBL participants and beneficiaries are considered in broad definitions that often reflect the stakeholder groups (i.e., precollege, university, nonprofit, industry, and government) rather than specific groups of individuals (such as individuals like Amanda or students from a particular school or classroom). Community-level interactions commonly take place prior to and after CBL initiatives. Through community-level meetings, leaders shape and reflect on outcomes, review/consider approaches to data collection and analysis, and capture successes/limitations of goals and objectives across stakeholders. Participation from practitioners across the stakeholder groups is critical for community-level efforts, as it enables alignment. A lack of community-level planning can leave participants unclear about potential outcomes and how CBL efforts link those from across stakeholder groups.

As one example, in the national research fair initiative, Camila, Lourdes, and Ivan had brief informal discussions on how to strengthen participation and success within particular regions of the country. They sought to work together to see how they can replicate the rapid growth seen in Ivan's region, where many students participate in the fairs at a high level and many schools have established a culture of participation, to support the growth of other regions and school districts. These discussions were oriented toward the broad success of the STEM research fair initiative within the region, and not linked to the specifics of any one demographic or stakeholder. In an example from the Technical Citizen Collaborative, explicit community-level activities were limited, with the closest approximation to community-level interactions witnessed during data collection being the biannual planning meetings. However, these meetings were primarily situated within the program level. This limitation resulted in the collaborative contributing to important but unlinked initiatives. With community-level planning, the Technical Citizen Collaborative could establish a pipeline of complementary precollege initiatives to support continued development of the students it reaches.

Several limitations and factors hinder community-level efforts. One challenge involves capturing the voice and needs of those across the stakeholder groups, par-

ticularly the vulnerable and underserved. Since the efforts at this level as observed were constrained to those in leadership roles, certain populations were excluded. Potential reasons for this omission include perceptions of limited knowledge or expertise to support meaningful contributions, and the challenges of efficiently capturing voice and input from multiple demographics with differing needs. As a result, many were not represented. For example, neither in the case of the STEM Pre-College Research Fair nor the Technical Citizen Collaborative were the target beneficiaries, or even individuals who could speak on their behalf, present or providing substantial input to the conceptualization and direction of the CBL initiatives.

Providing time or bandwidth for community-level interactions presents an additional limitation. Many CBL initiatives operate under time and resource constraints. Further, tension often exists between practitioners' primary responsibilities and CBL. Therefore, efforts that could sustain community-level interactions instead are relegated toward program- or individual-level interactions. As a result, interactions of the practitioners were rarely explicitly centered at the community level. No global planning meetings in which representatives from across all stakeholder categories were present were observed. Instead, it was more common for key leaders to meet for informal discussions. They then relayed information between and across stakeholder groups, rather than practitioners from the stakeholder groups coming together for intentional community-level efforts.

Finally, realizing the many potential outcomes CBL has to offer at the broadest level (i.e., workforce development, broadening participation, and improving STEM education) is a challenge. These outcomes are difficult and impractical to measure in practice. Measurement of outcomes at this level occurs across long time spans and is expensive and difficult to obtain. As a result, data collection and assessment at this level is rare. The STEM Pre-College Research Fair has collected comprehensive data from its participants from year to year, but due to the challenges of research with minors and the cost of longitudinal analysis, measuring the impacts of the fair is difficult. In the Technical Citizen Collaborative, the projects are dispersed across many small communities. Although survey data is collected concerning the quality of each project, the projects are primarily centered on ensuring positive interactions rather than understanding the broad societal impact of the collaborative.

**Tier 2: Program Level**

At the program level, focus is placed on conceptualization and planning of specific CBL initiatives. In the two cases observed, these interactions were directed at a specific community or targeted beneficiary (e.g., a specific precollege school or district, or a particular center or nonprofit that supports individuals with a particular need). Within program-level interactions, practitioners focused on the following: (1) how a specific CBL approach must be adapted for the intended local context, (2) how and to what extent practitioners can obtain the outcomes that they feel are important, and (3) how to plan and implement the initiative within the specific local context.

These interactions commonly included a practitioner in a leadership role or administrator (i.e., professor, supervisor, leader of a student organization) meeting with practitioners from partner stakeholder groups who would contribute to the initiative. Meetings with the target beneficiaries (i.e., precollege students, local underserved community members, a nonprofit organization) were common as well, although these were mostly directed at capturing the needs of the beneficiaries rather than providing ownership. Repeated meetings were commonly used to plan, organize, and prepare for the implementation of the CBL initiatives. The meetings were generally one stakeholder group at a time. For example, in the STEM Pre-College Research Fair, a continued cycle of meetings was held by Alejandro and the organizing team. These included meetings with just the team (e.g., meeting to discuss the electronic judging platform), as well as meetings with representatives from other stakeholder groups (e.g., meetings with Ivan or Bella). In the Technical Citizen Collaborative, the meetings would involve the board and representatives of each project, first to establish agreement on what the project would be, then several meetings to discuss the implementation of the project itself, and a meeting to debrief around the project. The program-level efforts were generally ongoing but varied around the implementation of the CBL initiatives. Broadly, the interactions at the

program level support achieving programs' educational goals, performing research, and collecting data on the success/impact of the event.

Program-level evaluation was commonly pursued and used to inform the success and impact of the initiatives themselves, typically to justify the contributions of the practitioners or obtain resources. In the STEM Pre-College Research Fair, comprehensive data were collected on the students who participated, their schools, and their results/marks from the judges. Bella and Lourdes use this information to pursue funds; the university team use the data to pursue funds, improve the event, and understand the impact of the event on those who participate. In the Technical Citizen Collaborative, minimal data was collected, but most was oriented toward improving the program, which in turn can improve the learning outcomes of the beneficiaries.

Limitations at the program level involve shaping CBL initiatives to suit the goals of the stakeholder groups that may be involved and the extent to which programming is adapted to the local context. In the STEM Pre-College Research Fair, it is recognized that in some regions, the culture of participating in the fairs has not yet been established. The team hypothesizes that this lack of growth may be due to a lack of alignment between the research fairs and the local precollege context. The Technical Citizen Collaborative struggles with communication and clarity between differing stakeholder groups to ensure that mutual outcomes are obtained in practice and that implementation is handled smoothly. Across both cases, implementing the event(s) requires substantial energy and resources (i.e., person-hours, funding, communication and alignment with stakeholders). Similar to the community level, capturing the voice of targeted beneficiaries, which are often underserved communities, is a challenge and can limit the extent to which nonuniversity outcomes are obtained. In the STEM Pre-College Research Fair, because the event has such extensive infrastructure, it can be difficult to capture the voices of the student participants to shape the event to their needs. In the Technical Citizen Collaborative, the targeted beneficiaries like Vinicius and Amanda are often dispersed individuals with limited unity or power. As a result, capturing their voice and perspectives can be difficult, and their limited education can often preclude their offering expertise in their own lived experience.

**Tier 3: Individual Level**

At the Individual level, focus is placed on the immediate success of those within a CBL initiative. These interactions, which center around the CBL practitioners and beneficiaries, are often the primary platform upon which the goals of CBL efforts are obtained. Here, practitioners negotiate (1) what can be gained from CBL participation and (2) what can be provided to the beneficiaries. Goals and outcomes are directed at individual needs, contributions, and goals of both practitioners and beneficiaries. The outcomes pursued by practitioners commonly include developing a sense of citizenship and making contributions to social needs and/or STEM education. These outcomes are often pursued in parallel to the outcomes intended for the beneficiaries, which generally revolve around supporting their STEM education and development.

Individual-level interactions primarily occur during CBL initiatives but can also take place throughout the planning stages. For example, in the STEM Pre-College Research Fair, nearly all of the practitioners had personal interactions with the precollege students participating in the fairs. These ranged from holding brief conversations to establishing or furthering deep mentoring relationships. For example, Camila, Lourdes, Bella, Ivan, Alejandro, and others often spoke with the fair participants to discuss their research and speak about career ambitions and trajectories. These interactions were personal, involving many smiles and hugs. These interactions often were referenced by the practitioners as what made the hard work and sacrifices for CBL worth it. At this level, student voice is captured by the practitioners, although in these personal moments it appears the practitioners were no longer working toward CBL contributions, but instead were serving in roles as mentors, focused on being present and sharing special moments. In the Technical Citizen Collaborative, the attention and care put forth by the CBL practitioners on behalf of the beneficiaries provided a positive outlet for many in difficult situations. The joy of the youth racing the carts and the custodial staff learning new skills was valued by all involved. These individuals' interactions not only promote the advancement of the

initiative but also establish strong ties between the individuals and produce positive energy that supports sustaining the event and promoting its success.

Evaluation of individual-level outcomes includes collecting data related to how participation impacts the professional development of participating students, the learning outcomes of targeted beneficiaries, and the success of the event in terms of its ability to support the targeted beneficiaries. In the STEM Pre-College Research Fair, the students receive feedback, both informally through the conversations with judges and professionals at the fair, and formally through the scoring and review system of the event. In the events sponsored by the Technical Citizen Collaborative, however, the surveys and questionnaires administered were used for informing the program; results were not relayed to the participants to inform their growth or development within the context of the STEM learning.

Limitations at the individual level include stakeholders not being aware of what can be obtained from or offered to CBL. Many practitioners link CBL to charity, not recognizing the deeper potential for educational or social justice outcomes. Limited awareness of the developmental opportunities possible within CBL prevent many practitioners from pursuing them. Additionally, many individuals can struggle from burnout and exhaustion within these efforts. In both the STEM Pre-College Research Fair and the Technical Citizen Collaborative, the practitioners exhibit a high level of dedication, yet the CBL efforts are a primary responsibility to few. The amount of time and energy provided to the event can commonly require those involved to extend themselves and make personal sacrifices that can have negative implications both personally and professionally.

## Discussion and Implications for Research and Practice

The case study approach to this research establishes observed phenomena that highlight the presence of three levels. Through a further level of abstraction from the individual cases, a model that advances the structural understanding of STEM CBL is proposed. These levels are synthesized in Table 1 to describe how the initiatives, stakeholder characteristics, and outcomes/goals can be manifested in CBL practice. This work contributes to the current CBL literature in two primary ways: (1) introducing empirical evidence showing that three system levels can appropriately describe STEM CBL and (2) illustrating how knowledge of the levels can support STEM CBL research and practice.

### Describing STEM CBL With a Three-Tiered Structure

Hierarchies with the practitioners, their interactions, and the outcomes produced suggests three primary levels are impactful in STEM CBL practice. The practitioners include those in leadership roles who conceptualize efforts; administrators, teachers, and students with high levels of experience who develop and plan initiatives; and a range of novice to experienced individuals who support implementation of the activities. These primary CBL practitioners seek to support the targeted beneficiaries, often individuals from underserved or developing communities. This tiered structure links to prior research, which has suggested that CBL partnership appears to contain several multilayered, multisector partnerships (Bringle & Hatcher, 2002; Mulroy, 2004). The empirical findings of this study provide contextual evidence that as CBL practice shifts from community to program to individual levels, the approaches of the practitioners, their interactions, and their goals become increasingly specific and targeted. Although these levels may not be explicitly considered in practice, the observed phenomena suggest multiple levels are impactful (Bringle & Hatcher, 2002; Mulroy, 2004). The ways in which the three levels describe the two STEM CBL cases, as shown in Figure 2, indicate that this is a valuable approach, yet more levels across the system as well as levels within an individual stakeholder group could be explored in further research.

### Knowledge of the Levels Supports STEM CBL Research and Practice

As illustrated within the cases, as well as through prior descriptions of CBL, STEM CBL practice is inherently complex (Bringle & Hatcher, 2002; Burton et al., 2019; Miller, 2008; Strier, 2010). A three-tiered structure supports navigating the complexity of STEM CBL practice in two ways: (1) promoting clarity for roles, tasks, and outcomes and (2) supporting awareness of how to distribute effort across CBL needs.

**Table 1. Implications of the Three Levels on STEM CBL Practice**

| Level | Stakeholders | CBL Stakeholder Interactions | Outcomes and Goals |
|---|---|---|---|
| Community | • Focus on broad stakeholder categories (i.e., pre-college students, the elderly, or the underserved)<br>• Leadership/select representatives from stakeholder groups provide direction for CBL contributions; some voices may rarely be captured (i.e., the underserved, the youth) | • Conceptual consideration and broad alignment in support of STEM CBL efforts<br>• General approaches that support that advancement of STEM in line with general needs of the stakeolder groups<br>• Alignment of outcomes across stakeholder needs and interests | • Promotion of STEM education and workforce development within and across the stakeholder groups<br>• Social responsibility, market share/ brand loyalty for industry<br>• 3-5 year timelines, difficult to measure, emergent outcomes (i.e., workforce development, access and awareness of STEM) |
| Program | • Focus on specific organizations, institutions, and/or groups (i.e., pre-college students from a single or group of schools, underserved populations from a selected neighborhood)<br>• Leaders, administrative teams, and students provide the needs of specific CBL initiatives | • Organization and implementation of specific initiatives that involve multiple stakeholders and seeks to promote impact through CBL<br>• Debrief, data collection, and refinement for future efforts within specific initiatives | • CBL goals implemented through specific CBL activities (i.e., curricular enhancements, CSR); Supporting the development of innovation and STEM learning; Delivery of engineering/ educational solutions<br>• 0.5-3 year timelines, measurement of outcomes through research, administrative data collection, and aggregate measures of student achievement |
| Individual | • Focus on one-on-one and small group interactions with a high amount of personal involvement<br>• Administrative teams, students, and staff provide for direct implementation of CBL activities seeking success with individual beneficiaries | • Implementation and success of single iterations of CBL activities and programs "on the ground"<br>• Efforts are directed towards impact and development of individual practitioners and targeted beneficiaries of the CBL activities | • Individual outcomes (i.e., educational gains, development/practice of citizenship, individual contributions to STEM education/community needs)<br>• Several hour-6 months timelines, educational outcomes often assessed, community/non-educational outcomes are measured less often |

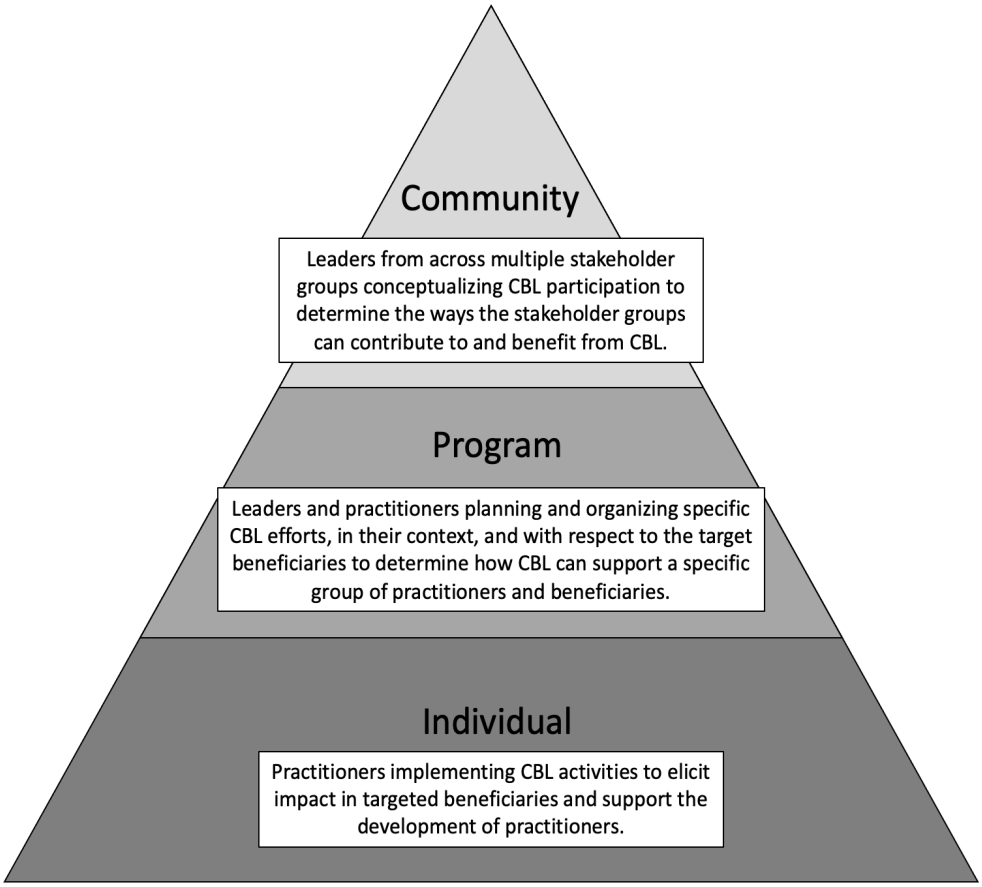


*Figure 2.* Three-Level Model for STEM CBL Practice

### *Promoting Clarity for Roles, Tasks, and Outcomes*

Because a wide variety of stakeholders can make CBL contributions, leveraging the three-tiered model can help practitioners locate a role, approach, and outcome, as identified in Table 1. Practitioner ability to explicitly name and point to these levels, as suggested by Burton et al. (2019) with respect to the phases of service-learning, can enhance alignment and outcomes among stakeholders. Conceptualization and broader impact, planning and program-level outcomes, and implementation toward individual gains are the main contributions to CBL at the community, program, and individual levels respectively. Miller (2008) pointed to community-level actions in recognizing that dispersed leadership can effectively guide joint action across stakeholder groups to overcome the often dispersed, diffused, and unfocused goals within CBL. Furthermore, Miller pointed out that it is easy for leadership across stakeholder groups to become too broadly dispersed to be effective and that strategic action, which takes place at the community level in the proposed model, can alleviate these inefficiencies. At the program level, Mulroy (2004) pointed to awareness of the scope and density of relationships to help leaders better understand how and why programs are complex and labor intensive. Bringle and Hatcher (2002) suggested that relationships at the individual level can support examination of CBL partnerships to promote a better understanding of institutional and personal action steps that can be taken to initiate, develop, maintain, and nurture healthy partnership. Mulroy (2004) has found that the greater the extent to which university practitioners can know and understand the desired outcomes, the beneficiaries, and the organizations that serve the beneficiaries, the more motivated they may be to develop and sustain ties, pointing to effort across program and individual levels.

Practice that seeks connections between the system levels can support stronger alignment and outcomes and thereby promote

a well-rounded approach to CBL. Those who can clearly understand the structure and opportunities for contributions across the levels are able to strongly support CBL practice. Miller (2008) observed that practitioners with in-depth experience and knowledge of multiple university, school, and community positions can be effective guides within partnerships that bring together highly diverse groups with the intention of achieving common goals. These individuals are aided by unique, lived understandings, and they can skillfully unite disparate groups that might otherwise be limited by discrepant conceptualizations of goals, responsibilities, and capacities. This ability is commonly seen in participants who have made long-term contributions as well as those who have made contributions from various roles and various stakeholder groups, pointing to the value of developing and retaining practitioners so they may continue to make increasingly valuable contributions over time.

Additionally, the three-tiered approach can support research through highlighting which phenomena and outcomes are most likely present and where. The consideration of enhancing societal implications of CBL, strengthening programming and curricula within CBL, or maximizing the learning outcomes and positive experiences of the individuals involved should leverage approaches that center the community, program, and individual levels respectively.

### Supporting Awareness of How to Distribute Efforts Across CBL Needs

Emphasis on one CBL level over another can leave gaps in practice. It has been noted that CBL partnerships often neglect communication and trust-building to instead focus on implementation; however, opportunities to pause and reflect at crucial junctures can greatly benefit the outcomes (Bartel et al., 2019). As practice can be unevenly distributed across the levels, with emphasis often at the program and individual levels, additional effort within the community level provides an additional avenue for practitioners and researchers to promote holistic CBL practice. Broad conceptualization allows practitioners to describe how CBL can provide value to those involved. Community-level outcomes are often hard to perceive and measure. Individual-level outcomes feel good to those involved and can provide substantial motivation for CBL practitioners but rarely fill educational achievement gaps or produce substantial change on their own. Further work on the ways in which practitioners can recognize community-level outcomes can perhaps promote increased efforts on this level.

Practitioners from across the stakeholder groups can potentially make valuable contributions across all levels of the system. However, community-level contributions are often confined to those with leadership roles, influence, and substantial CBL experience, while students and targeted beneficiaries are often constrained to contributing at the program or individual level. As a result, STEM CBL as observed within this landscape could be described as a primarily bottom-up phenomenon. This could point to some of the limitations in how CBL is institutionalized, valued, and perceived within universities and the other stakeholder groups. Within this structure, some have substantial voice and others do not, pointing to both limited voice and an imbalance of power commonly described in these partnerships. Stakeholder voice is a critical element for success across stakeholder groups within CBL. Strier (2010) suggested that the strength of CBL partnership depends on the capacity of the leaders to provide a participative organizational structure capable of making room for the supplementing, competing, or conflicting agendas of those involved. Recognizing the levels can help capture voice and promote its value within the power structures more effectively. This finding provides more context to previous research on the imbalances of power within university–community partnerships.

Morton (1995) suggested that CBL partnerships too often rely on charity rather than reciprocity or social justice outcomes. As highlighted by Strier (2010), meaningful university–community partnerships capable of carrying out transformative political agendas can be improved by the equal and lived inclusion of excluded social sectors, suggesting that finding ways to incorporate the voices of the targeted beneficiaries and underserved across the levels can enhance outcomes. An understood goal of CBL is reciprocity (Dostilio, 2017). Thus, the three-tiered model's support for the practitioner's ability to recognize where they fit into the structure can strengthen the potential of benefiting from and contributing to CBL. Community-level conceptualization and

communication across the stakeholder groups can facilitate moving beyond charity.

## Conclusion

STEM CBL is a pedagogical tool that holds substantial promise as a platform upon which contributions can be made and benefits obtained from multiple sectors of society. This promise is often limited in practice, yet increased empirical research can establish knowledge that can strengthen reciprocity amongst stakeholders. Participant observations within two STEM CBL cases provide a nuanced and robust understanding of the CBL relationships and structures, showing that practice in STEM occurs within a diverse, dynamic, and emergent system. It is shown that three levels of practice can provide an appropriate structure for characterizing CBL and limit the negative implications of such complexity.

Although recent efforts within STEM have increasingly called for reciprocity and community-oriented outcomes, much work remains to be done as STEM CBL research is primarily centered on academic outcomes. It is suggested that CBL partnerships must "find ways to preserve the integrity of each partner, and at the same time, honor the purpose of the relationship and growth of each party" (Bringle & Hatcher, 2002, p. 513). Partnerships are most meaningful and lasting when individuals can recognize that the other practitioners and stakeholders are contributing in a meaningful, effective manner to activities that can positively impact important civic and campus outcomes (Bringle & Hatcher, 2002; Zimmerman & Rappaport, 1988).

The proposed model, highlighting three levels of STEM CBL practice, points to the primary behaviors and actions that are relevant to each level to support clarity on roles, actions, and outcomes for differing stakeholders and how these roles, actions, and outcomes change within differing levels of the landscape. Through leveraging this exploratory model, practitioners and researchers can recognize the implications of working within and across system levels in partnership with multiple stakeholders to strengthen CBL approaches and outcomes. Because multiple stakeholder categories and representatives, each performing complementary yet differing roles, often contribute to CBL initiatives, the presence of uneven power dynamics is inevitable. Ensuring that the effort of participating stakeholders is distributed across not only stakeholder groups but also across the community, program, and individual levels can support positive outcomes within CBL practice.

Collectively, recognition of levels of CBL practice, and the corresponding interstakeholder dynamics, can serve practitioners and researchers as a framework to support acknowledging the breadth of stakeholders, roles, and interests possible within CBL. As researchers and practitioners embrace the diverse, dynamic, and emergent system behavior within CBL, further equitable and reciprocal outcomes can be obtained by seeking to actively include the voices of all stakeholders across all levels. Additional attention should be devoted to including, acknowledging, and respecting the voices of community partners/beneficiaries and those often marginalized so that CBL initiatives can more effectively support community need in reciprocal fashion.

## About the Author

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