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Innovation Article

Co-curricular Immersion as a Public–Private Capacity Building Activity

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Abstract—The COVID-19 pandemic exacerbated the already increasing challenge of establishing immersive, co-curricular activities for engineering students, particularly for biomedical-related activities. In the current work, we outline a strategy for co-curricular learning that leverages a private–public partnership in which methods for capacity-building have enabled mutually beneficial outcomes for both organizations. A contemporary issue for many non-profits is identifying effective ways to build capacity for consistent service delivery while at the same time embracing the volunteer activities of students; a challenge is that the lifecycle of a university student is often not aligned (much shorter) with the needs of the non-profit. The public–private partnership simultaneously meets the service motivation of students with the needs of the host. This paper includes two case studies that illustrate the implementation of the methods for capacity-building and related outcomes.

Keywords—Biomedical engineering, Co-curricular, Immersion, Community-based learning, Undergraduate education, Capacity building, Pedagogy, Device design.

INTRODUCTION

Capacity Building is an integral concept for any organization to effectively serve stakeholder needs over the long term. The United Nations defines capacity building "as the process of developing and strengthening the skills, instincts, abilities, processes and resources that organizations and communities need to survive, adapt, and thrive in a fast-changing world".[32]

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According to Century,[6] there are four types of capacity to consider as drivers of systemic educational reform: human capacity, organizational capacity, structural capacity, and material capacity. There is an interdependence in these aspects of capacity building to promote continuous change and improvement over the long term. Human capacity includes both knowledge and interest in a specific area. Material capacity involves the financial resources and other material supports available for systems reform, including those resources from inside and outside the system. Organizational capacity describes the culture of collaboration, communication, and willingness for change among the people involved in the organizational system. Structural capacity includes the system components used by the people for system function. This includes items such as policies, procedures, curriculum frameworks, and formal partnerships between universities and an educational organization. There is a need to assess the quality of structural components to understand the prospect for long-term sustainability. Century[6] notes "there is a limit to the extent to which any single capacity can contribute to the overall capacity of a system without depending on, and building on, the other capacities." The optimization and alignment of all four capacities could lead to greater benefits and opportunities for continuous growth. This topic is of relevance given the recent position paper released by Rehabilitation Engineering and Assistive Technology Society of Northern America (RESNA) advocating for capacity building to increase access to assistive technology (AT) for learners with disabilities. Barriers for those with the most profound needs include the misunderstanding of complexities surrounding those with the most significant needs, misperceptions of people disabilities, poorly designed assessments and a missing person-centered approach.[19] This creates a critical need to build capacity within school teams for AT services.

Community-based learning (CBL) has been an integral part of engineering education for over a century, spanning a multitude of co-curricular and extracurricular out-of-the-classroom applied learning activities.[39] Of particular interest are complementary co-curricular activities which are not directly tied to the course of study (in contrast to extra-curricular activities that are not linked to a major program of study). In comparison to unengaged peers, students pursuing CBL activities have increased satisfaction with their college experience, have enhanced academic success and are more likely to persist to graduation.[27] Applied learning also provides leadership development,[16] civic mindedness,[5] psychosocial development,[12] practical skills attainment, and fosters an entrepreneurial mindset.[25] Higher education support for co-curricular learning not only provides student intellectual benefit but also reflects an institution's strategic emphasis on campus-community activity.[30] Building capacity for CBL is inherent to the sustainability of this approach to learning. This includes capacities within all four domains of capacity building in areas such as financial resources, communication, skill development, collaboration frameworks, and the structural capacity of the program

While the literature predominantly explores CBL's positive outcomes and benefits to engineering students and universities, less research has undertaken the need for reciprocal benefit to the host organization. During the pandemic, some host sites restricted student access, given that the student CBL activity was not part of the essential services the organization sponsored. Scenarios whereby capacity-building is mutually beneficial for both the host organization and the students tips the balance favorably to CBL as mainstream and not peripheral to the host services. Segeve *et al*.[29] explored the concept of mutual capacity building, reporting benefits to a rural tribal community and an urban university through long term relationships. Jones and colleagues identified the importance for the university to ensure actual benefit vs. burden to the community organization.[20] It is mutually beneficial partnerships that garner an environment conducive to long-term relationships which serve the mission of the NPO as well as the University program.

Relationships must be robust enough to embrace the likelihood the partners operate on different program time scales and to address the problems (or expectation issues) that may be created. For instance, a university that is on a semester cycle—with the possibility of students having a diminished presence or absence at a host site over the summer—may present challenges if the CBL becomes "mainstream" to the host organization. This parallels the realization that the life cycle of collaboration is dynamic and needs to be adaptive. With these issues in mind, we emphasize the importance of the project management function to manage stakeholder expectations.

In the projects described within this paper, the engineering students and the NPO's maintained a focus on the equipment needs of end-users which organically contributed to the overall realization of mutual capacity building. This concept envelops user-centered design (UCD) to where end-users influence development of a design over time.[2] For optimal device utilization, the tools or products provided to the host must be cost-effective, reliable, and of ample quality in design to serve the intended purpose.[35] A unique problem arises when ATs or medical devices are of insufficient quality or do not serve a need of the individual or group.[11,13]

This paper explores the deepened benefits experienced through "mutual capacity building" where two organizations work together on a common project with different goals for building capacity. Specifically, this project involved building capacity through CBL with biomedical engineering students and two different non-profit organizations (NPO) serving niche, high-need populations. The first NPO provided programming, including ATs, through an alternative education program for children with severe disabilities. The second NPO repurposed donated medical devices for humanitarian aid. Over time, each program developed a reciprocal and complementary understanding of the capacity building needs unique to each entity within the partnership. The method we pursued is a derivative of existing models and has been tested through multi-year CBL engagements that have resulted in long-term partnership and mutual capacity building for all participants. We believe the method is extensible and scalable.

METHODS

Strategies for capacity-building frequently recite organizational, human and material capacity-building components to consider when building an educational program.[9,24,26,32] We evolve those basic ideas through a three-step method aligned with a co-curricular educational framework. In short, we build:

1. organizational capacity, by establishing a mutually beneficial collaborative setting,

2. human capacity, to ensure student growth though immersion, and
3. material capacity, from which project work produces value-added outcomes.

Figure 1 illustrates the capacity-building framework; we have learned from experience that the sequence in which the steps are executed is important. Each of the steps of the method in the context of the co-curricular framework have important sub-elements that are important to expand upon and are predicates for subsequent steps.

Organizational Capacity

As indicated earlier, organizational capacity describes the culture of collaboration, communication, and willingness for change among the people involved in the organizational system. Three aspects critical to the current model are: (a) defining partnership roles, (b) establishing the organizational accountability structure, and (c) underscoring the SETT model for needs identification. Prior to setting partnership roles, we need to first identify a partner interested in capacity-building. Not every organization is interested in long-term activity. In our case, the Biomedical Engineering Department's year-round outreach effort to recruit translational research and design projects builds a network where host organizations favorably view CBL activity. Once a candidate organization seems receptive, a series of meetings ensues in which an interdisciplinary team identifies integral team players, common goals, the needs of each organization, materials, timelines, *etc*. and begins iterating an outline and basis of the partnership and how it will work. This activity sets the stage for the next step involving exploration of the accountability structure (formally or informally).

Establishing the accountability structure is a unique aspect of our method and the second step in the organizational capacity-building process. As suggested earlier, many CBL activities are relatively short-term engagements where the activity is more beneficial to the student than the host. Limited follow-up and follow-through phase of activity may be intentional due to the nature of the engagement though reduces potential long-term impact. In the current method for capacity building, we seek *professional accountability*, not *mandated accountability*, governing, say, a service organization requirement for student volunteer hours. Different types of accountabilities are shown in Fig. 2, drawn from the work of Romzek and Dubnick.[28] To illustrate, consider at one extreme a CBL activity that is part of a one-semester senior design project whereby there is a requirement, faculty assessments, and design process are all external (prescribed) to the student. Figure 2 categorizes the nature of such accountability as that of a "mandate." In comparison, consider the

Degree of external control over collaborator activities		Source of control of collaborator expectations: Internal	External
	High	1. Bureaucratic	2. Mandate
	Low	3. Professional	4. Political

FIGURE 2. Source of accountability, from Romzek and Dubnick (1987).

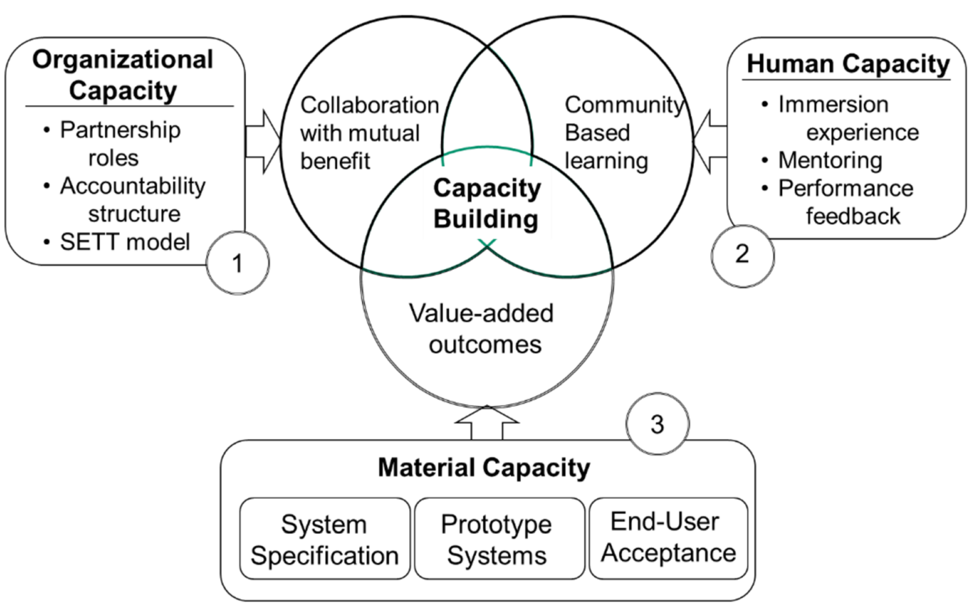

FIGURE 1. Three-component capacity-building model.

situation where the team is highly self-directed and the immersive experience can disconfirm a student's preconceived notion of what the host need is, and so the students must reorganize thinking to adapt to innovative ideas or a new frame-of-reference. The sources of control are internal to the student and behavior entirely different then when sources of control are external. The situation implies that "..learners are seen as … actively responsible for their learning as active constructors of their knowledge…".[18] Professional accountability leads to a decision-making mindset pertinent to a collective capacity-building goal that supports a long-term collaborative mindset. Interdisciplinary processes take time to carry out and herein lies a challenge when working with a university: the lifecycle of student activity is frequently not aligned (much shorter) with that needed for capacity-building.

The third component is establishing the process of identifying "need," and we cannot overstate this as a critical step in the collaborative project process. In the current work, our method relies on a hybrid model formed by blending the basic BioDesign process[37] and the SETT framework.[38] as shown in Fig. 3. The Stanford BioDesign method for device design divides the innovation process into three main steps: "Identify, Invent, Implement" that has the well-known benefit of centering attention on need analysis. Many designers rush through the "Identify" first step, compromising the identification of need and thus compromising the ultimate solution available to the end-user. By not addressing the root "needs analysis" at the start, the result is the creation of products or systems that often are left unused due to their inability to address the end-user need. This will compromise the value to the host organization and make achieving long term capacity-building more difficult.

Including the SETT (Student, Environment, Task, Tools) framework[38] as part of the Needs Analysis is a logical predicate to the BioDesign process, as SETT frames thinking relevant to capacity-building. SETT is cast in the language of educators and this lens promotes a collaborative discussion of critical factors such as the target audience, the setting, and the desired tasks from the NGO perspective; this start to the innovation process enhances the root need exploration process before ideation on concepts is launched. We have experienced many projects over the years where device concepts or problem solutions were prematurely introduced and heavily advocated by students, only to find the host was polite in not objecting to the students' development, but never ultimately embraced the project outcomes.

In summary, our method for developing organizational capacity derives from an alignment with partner roles. This ensures professional accountability and due diligence, underpinning end-user needs.

Human Capacity

Building human capacity for students follows once the organizational scaffold is in place. Human capacity has multiple interpretations,[6,29] but in the current work we center primarily on the skills, knowledge and abilities of biomedical students interested in translating their emerging engineering competencies into practice. Host organization staff capacity expands commensurate with student competencies as the student team becomes aligned and fits within the host organization; more than the students benefit from building human capacity. In that context, the three components of human capacity we explore here are: (a) immersion, (b) mentoring, and (c) performance feedback. In aggregate, these three components ensure the students' CBL experience aligns with the host institution with mutual benefits.

Immersion

Immersion for biomedical students is often thought as synonymous with clinical immersion. There are beneficial outcomes associated with clinical immersion programs[3,15,21] as the focus of clinical immersion provides unique exposure to the practice of medicine (Fig. 4). For that trajectory, the "host is the teacher", and students gain first-hand knowledge of standard-of-care medical procedures. A reciprocal benefit to the medical host is less likely an outcome, though certainly some formalized advanced stage and graduate programs have demonstrated clinical immersion fellow-

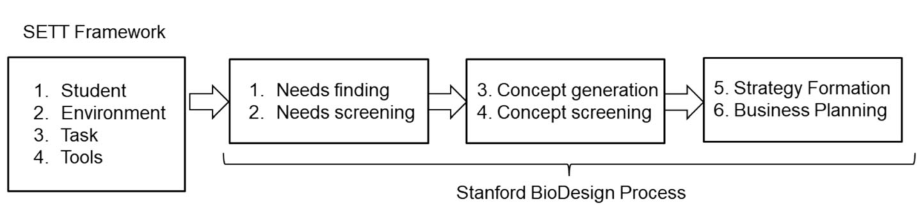

FIGURE 3. The need-based approach to innovation and design is embodied in the 3-phase "identify, invent, and implement" design process. The SETT framework is a four-part model that enhances need identification through a unique collaborative process.

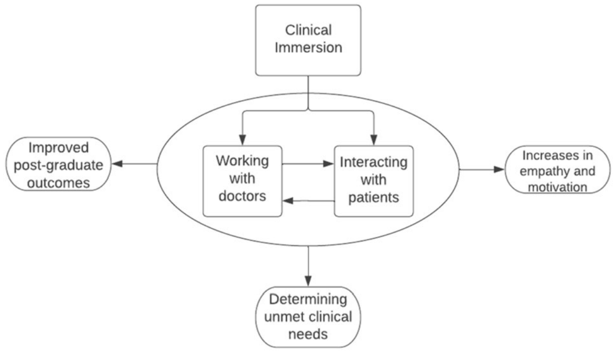

FIGURE 4. Potential outcomes associated with clinical immersion programs.

ships as a pathway to identifying new needs and bringing innovative ideas into medical practice with great success.[23,33,36] Scalability of such programs can be a financial challenge to expand beyond a handful of students annually, notwithstanding the challenge of including undergraduates. Further, the COVID-19 pandemic clinical site facility access restrictions exacerbated the already increasing challenge of establishing immersive activities for engineering students at any level. We recently conducted a pilot study whereby we trained two undergraduates in specific sensor and data analytics competencies, and because the clinicians were seeking this type of support, the result was clinical access and a shadowing opportunity for the students that would not have otherwise been possible.

There is much less literature available on the impact of non-clinical immersion, especially regarding partnerships between universities and NGOs, on student development and educational outcomes. We argue that experiential, co-curricular, non-clinical immersion is an untapped opportunity for enhancing student education in biomedical engineering and encouraging, for instance, sustainable design. For instance, the non-clinical immersion experience through the CWRU MedWish project (described later) has the unique potential to expose students to common medical device end-of-life issues and practical ways to design for sustainability, offering real world hands-on work experience. Collaborating with volunteer clinical engineers on-site provides a view into the field of clinical engineering in the hospital environment. This knowledge is not typically gained through clinical immersion programs. It also provides opportunities for strong peer-to-peer interactions, which has been shown to enhance undergraduate student education and promote changes in outlook.[7]

Both non-clinical and clinical immersion have value in student learning, but for the process of capacity-building, mentorship and performance feedback are vital components of the immersion experience. Feedback in the group setting (including the host) provides memorable "teaching moments" when it is clear the end-user need has been misunderstood, underestimated, or ignored. These are excellent times for students to remember the focus should be on the mission and seeking to better understand end-user need.

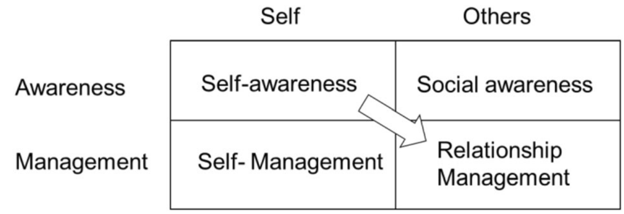

FIGURE 5. Emotional intelligence model of Goleman *et al.* (2013).

Mentoring and Performance Feedback. At some point every student will interact with an academic advisor, someone who offers specific curriculum advice or input on navigating complex issues; students may not meet with them frequently and the relationship is generally informal. Mentoring is quite different, with the mentor being a person experienced in the field with tacit knowledge that is shared with the student for character and career development as well as the tools needed to socialize into a field. A mentor has more of a long-term role in student development guiding a student to reach their goals.

Students immersed in capacity building situations may need mentoring more than advising, given the need for self-directed activity that may be new, as well as the ability to be active constructors of new knowledge. Observation and performance feedback are integral activities of the mentor, and the student's ability to be constructive with feedback is an acquired skill. Mentors are particularly helpful in the journey students may need to make in developing emotional intelligence, an essential component of those learning engage in and manage projects with increasing complexity.[14] Figure 5, based on the work of Goleman (2013), suggests a role for mentoring is to help students and teams make the transition from the very limiting "self-awareness" quadrant to the "relationship management" quadrant: operating from this new quadrant positions students to be on par as collaborative leaders when interacting with the host organization. Students will find the transition easier with a healthy perspective on performance feedback.

Identifying faculty to serve as mentors in capacity-building projects may be challenging if other University service demands are present, and this may require calling upon alumni to jump in. In one of our projects the alumni network was an effective solution to finding a mentor for the student group.

Material Capacity

Biomedical engineering readership will likely be well-versed in the classic model for the design process and there is no intent to describe the process well documented in many conventional biomedical engineering textbooks. Figure 6 will be recognized as a derivative of the classic FDA waterfall process used for teaching medical device design,[22] modified here for more generality and fit to capacity-building.

Aspects of the process that warrant special attention are the way specifications are made, design reviews are worked in complete collaboration with the host organization, and the assessment of end-user validation is primarily the province of end-user feedback. Often frustrating is the highly iterative nature of the design process. As the host becomes more aware of the end-user needs, there is potential for idea generation of new products or service ideas. It may seem like the process is not converging—this is where the ''discipline of innovation'' steps in and a design freeze is implemented.

Summary

The material capacity building process is iterative and team based. Indeed, the peer-to-peer aspect of the effort reflects ''equal privilege'' at every step of the way. There are essentially five major steps in the process:

1. Identify the end-user need,
2. Identify a stakeholder within each organization as a point person for communication,
3. Create an action plan for prototyping,
4. Develop, demonstrate and assess the prototype within the context of Fig. 5.
5. Revise as needed, going back to any of the steps *over and over*, as needed!

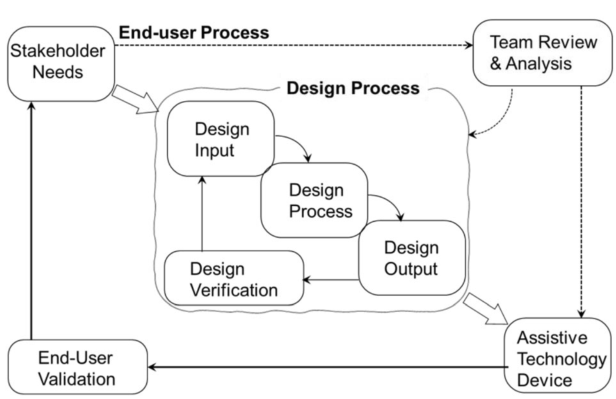

FIGURE 6. FDA waterfall process as a roadmap for collaborative design.

The notion of ''identify, collaborate, execute'' surrounds the philosophy of an interdisciplinary approach where multiple skill sets come together to achieve a common goal. The overall roadmap of this activity is depicted in Fig. 7. Identifying need provides an overarching foundation of action steps for the interdisciplinary team, it is viewed as the soul of the partnership as it cultivates structural and organization capacity among all organizational entities involved. Collaboration emphasizes cooperative immersion experiences for the engineering students that involves observing and on-site interaction with the AT users. Finally, the execute phase encompasses the tangible outcomes of the partnership like the development of robust AT. The process is continuous in nature and phases often overlap allowing for continuous growth and capacity building within the interdisciplinary team.

The co-curricular activity produces significant value primarily on the front-end of the design process and rapidly producing prototypes through the five-step process outlined above. This enables the need of the host to be articulated, and a set of functional specifications to be created. Rapid prototyping and engagement with the host is to assure ''we got the fundamental need right.'' Like most design efforts, the process is iterative, and to further enhance capacity building, the co-curricular activity sets the stage for a follow-on curricular activity through the Senior Design Capstone. When launched as a specific project within the Capstone, product design benefits from the rigor of a conventional academic design process that includes creating a more comprehensive set of technical specifications, conducting a risk and hazard analysis, a verification analysis and then validation with the host to ensure the design meets the needs of the host. Recent experience is that the co-curricular activity enhances the senior design curricular activity; within the time-scale of a semester the co-curricular ''pre-work'' expedites the capstone effort. This leverages capstone instructor effort in terms of having a ''vetted'' project available for detailed design. Additionally, the co-curricular team members provide peer support that enhances the capstone experience.

RESULTS

The co-curricular immersion program based on the capacity-building method for mutual benefit in CBL has been explored on three different projects. Only two of the projects will be discussed here as they have been underway long enough for meaningful results to be obtained. The MedWish project is the inaugural project and in its current form has been in place for almost 4 years. The LeafBridge project has been underway for

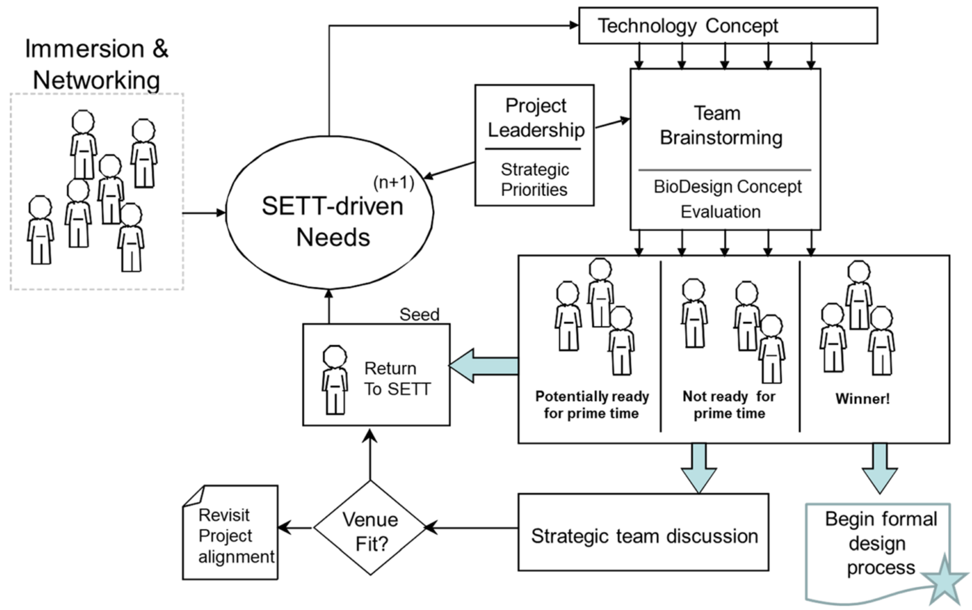

FIGURE 7. Process flowchart for identifying projects that support capacity building in a mutually beneficial fashion.

TABLE 1. Capacity building outcomes for the LeafBridge and MedWish Projects.

	Build human capacity	Build material capacity	Build organizational capacity	Build structural capacity
CWRU	Students receive highly applicable cross-training *via* immersion with non-profit partners	Leverage institutional and Agency investment in Senior Design	Highly collaborative meetings result in higher-level learning for University Students	Pathway for outreach and immersion experiences
LeafBridge	Staff receive cross-training through collaboration with University Partners	Assistive technology developed for unique un-met client need	Highly collaborative weekly meetings lead to more effective AT solutions	Equity and Inclusion supported through multi-system collaboration
MedWish	Organization leverages limited clinical engineering staff though student immersion program	Medical products and devices repurposed for un-met emerging economy hospital needs	Immersion experience enhances MedWish capability to support higher level medical device recycling	Patient needs supported through multi-system collaboration

approximately 2 years. The third project is a collaboration with a hospital and remains relatively new (less than 1 year) with preliminary outcomes that are promising, but more time is needed to develop outcomes that enable comment on the impact of the CBL method. Table 1 highlights the main capacity-building components for each project.

Capacity-Building with LeafBridge

Scenario

This project involved high school students with severe disabilities who attended a specialized alternative education program through LeafBridge at United Cerebral Palsy of Greater Cleveland. Most of the participants used speech devices and wheelchairs, with extremely limited abilities with moving or controlling their bodies. The project surrounded the creation one-of-a-kind artwork on drink coasters using alcohol inks as part of a larger goal to develop vocational skills through marketing and selling the artwork. At first, the students used basic ATs such as Environmental Control Units and head, foot, or hand switches to operate a standard blow dryer to move the paint on the surface of the coasters. While this offered a unique means of participation with AT, the NPO team could not identify a way for the participants to place a signature on their artwork. Individuals with the most profound disabilities typically require more intense AT tools.

Through exploration of community resources, the team reached out to the Biomedical Engineering Department at Case Western Reserve University (CWRU) to gauge interest in helping with this problem as it was beyond the capacities of the NPO. University staff and students met with the LeafBridge program coordinators, toured the learning space, and met the students (end-users) to gain a broad perspective prior to engaging in the collaborative process.

An emphasis on SETT principles—illustrated previously in Fig. 3—are central to success. Classroom observations are at the core of the process, followed by a formalized approach to ''need analysis.'' Subsequently, the team creates a notion of the AT concept including brainstorming device/design options. With development of a prototype, the entire team evaluates the concept for ''readiness for use.'' This is often an enlightening period of the project, as innovative ideas arise during the demonstration process. The peer-to-peer strategy for collaboration led to a robust partnership with the creation of a switch accessible robotic arm for a student to stamp their name on the back of the artwork.

As a specific example of this ''need analysis'' in action, team members observed students with Cerebral Palsy exhibiting decreased fine and gross motor functionality following the steps of the SETT framework. In line with the BioDesign process, our design effort was launched with observations regarding the student's general concerns relating to movement quality along with special accommodations and learning environments the students were exposed to in the classroom setting. The decomposition of creative art activities led to tractable design sub-elements that could be more easily managed and amenable to iterative design efforts. Analysis of SETT framework report revealed the need for AT capable of providing independence to students regarding stamping signatures, logos, and in completing daily art projects. In the absence of SETT considerations, the initial solution appeared to be a single generalized complex robot. By breaking down the necessary responsibilities through the SETT framework, the team revised specifications to design and construct simpler task-specific robots to successfully place in service.

Results

When an identified need surpassed the human capacity within the NPO organization, the circumstances allowed for progressive and collaborative communications with university personnel. In essence, all stakeholders experienced growth in terms of human and organizational capacity given the intricate and unique nature of collaboration and communication.

As a direct result of the partnership between LeafBridge and CWRU, LeafBridge demonstrated growth in all four capacity domains, especially human capacity and material capacity. Even though human capacity was an original strength of LeafBridge, the complexity of the AT available often led to staff not using it with the students. Because of the simplicity of the AT designed by the engineering students and the customizations for the needs of LeafBridge students, the number of staff who could effectively set up the AT for the end-user on a regular basis increased significantly. Furthermore, the transferable knowledge and expertise of the engineers not only made it possible for the LeafBridge team members to fix minor damages caused by daily wear and tear in a timely manner, but it eliminated the need to wait until the engineers were on site. LeafBridge staff also acquired the knowledge to create additional parts for the AT like simple button switches and interchangeable stamps. Growth in material capacity exists with the development of robust AT (stamper, apple slicer, art spinner) that meets the needs of the end-users at LeafBridge. LeafBridge also lacked the means of funding for developing the necessary AT, whereas CWRU was able to meet that need through various grants. Both CWRU and LeafBridge experienced meaningful change with structural capacity through partnership, as demonstrated by persistence of the program despite changes in staff and students. Furthermore, the direct observations of and interviews with device end-users revealed that the AT designed and built by CWRU students led to improved quality of daily life and experiences of the LeafBridge students with complex disabilities.

Capacity-Building at MedWish

Scenario

Stakeholders in the biomedical engineering education field may overlook the understanding of the medical device lifecycle. Traditional biomedical engineering education focuses on innovative device design and theory, with little focus on understanding the maintenance and problem solving associated with devices as they age.[17]

Reports, relating to both academic studies and written experiences by nonprofits, have revealed that hospitals in the US collectively discard millions of dollars' worth of equipment annually, ranging from basic supplies to complex medical devices.[4,34] This results in large hospital expenses as hospitals purchase more devices, and in e-waste pollution, particularly in developing countries where e-waste disposal is concentrated.[1] Regarding the latter, many devices are donated, but studies have shown that a large portion of these donated devices break down shortly after arrival.[10]

Hospitals frequently discard older device models for newer, higher-end devices to maintain efficiency and safety. One priority of hospitals is an increase in speed of operation, often resulting in discarding or donating older devices for a more efficient model. To retain assurance of safety, hospitals will discard models after a set time of use or rather than pay for repairs and risk further problems, they will purchase a new device. Hence, to combat the speed of e-waste produced from hospitals, a solution will lie in sustainable design. The training of engineers and technicians with an emphasis on sustainable design would help to impede the e-waste pollution from the health industry, save hospitals millions of dollars, and prolong the device lifecycle such that donated devices can more often be repurposed and reused. Access to organizations such as MedWish International (''MedWish'') exposes the end-of-life design issues of devices, a crucial area of knowledge if the sustainability initiative is to succeed.

MedWish International is a 501(c)(3) nonprofit organization located in Cleveland, Ohio promotes environmental sustainability by repurposing surplus medical supplies and equipment to provide humanitarian aid to people in need. MedWish receives donations from local hospitals, clinics, and private practices of medical devices and disposable supplies that would have otherwise been discarded. The goal of this organization is to repurpose medical devices and supplies and ship them to under-equipped hospitals around the world. At CWRU the Student Club CWRU/MedWish was formed to work with MedWish in testing, refurbishing, and repairing medical devices. The club provides an avenue for students to work with a variety of medical devices facing end-of-life issues. Volunteers work with MedWish throughout the academic school year on-site but continue some project work offsite. The on-site experience is highly self-directed but mentored. In order to support student engagement during summers, CWRU/MedWish receives funding through CWRU's undergraduate student government, alumni association, and an NIH R25 grant for an internship program.

Results

CWRU/MedWish hosts biweekly volunteer trips to the MedWish warehouse, in which students work with different devices under the guidance of two retired biomedical engineers. These trips occur over the academic school year (September to May) and contain large diversity in student majors and interests. Aside from these trips, CWRU/MedWish recently created a training area run by students for students. The training area teaches students much of the basics needed to start testing and fixing medical devices. When there is a surplus of students or when it is the first time a student is working with a device, they will be sent to the training area. Within the training area are a set of stations with instructions on how to either test equipment or learn a repair technique. A student can learn how to solder wires to one another or how to utilize a digital multimeter to test battery life or fuse continuity. These skills are often required as a large portion of broken donated devices have dead batteries or missing chargers. The students are then capable of identifying said end-of-life issues as well as applying abilities to attach new batteries, fuses, or chargers. Along with skills, there are stations to teach testing procedures for the most donated devices. These devices include pulse oximeters, EKGs, blood pressure cuffs, and an infusion pump. This training is crucial for the standardization of testing and maintaining the quality of outgoing devices. Lastly, there is a medical based educational component to each station that informs students when a device would be utilized in a clinical setting, what range of vitals is considered healthy, how to read certain results or signals, and what medical conditions correspond to those results.

The project at MedWish is unique in that formalized plans for immersion that were developed and initially launched in 2019 required re-structuring due to the COVID-19 pandemic. The summer 2020 eight-week internship consisted of three components: (1) remote manual condensing and clinic write-ups, (2) limited on-site work at the MedWish warehouse, and (3) remote database development.

Manual condensing consisted of reading medical device manuals for common devices at the MedWish warehouse and making one-page summaries of functions, common issues, and troubleshooting advice. Clinic write-ups consisted of writing a brief description of items sent to each clinic, a brief description of the country, and a brief description of local health conditions, along with photos if possible. Remote database development refers to an effort to build a database that will effectively track work that CWRU/MedWish has conducted at the host site and track where devices are being delivered. While MedWish tracks this type of data through their own systems, a database specifically for club activities will provide more quantitative assessment of immersion impact as well as related club activities, including volunteer opportunities that subsequently occurred off-site. The on-site, in-person work at the warehouse centered on two products: Quantum wheelchairs and automated external defibrillators (AEDs).

During year two, the immersion experience was enhanced through increased engagement with the experienced biomedical engineers that helped interns in identifying and troubleshooting issues. Reduced device donation inflow to MedWish due to the pandemic afforded students the opportunity to focus on reorganization of the on-site experience.

Also, the influx of unique design ideas was showcased throughout the summer internships. An example of a design idea includes interns that worked on designing Quantum wheelchair charging cables. Some wheelchair models only have an automated, battery-powered method of lifting the seat up to change the battery. When these wheelchairs run out of battery, it is difficult to lift the seat up, hence why companies also sell charging cables with these wheelchairs. Many of the donated wheelchairs, however, did not get donated with these cables, and many of these models/associated cables have been discontinued in production and/or not sold separately and this was the catalyst for self-directed activity. Two students created their own charging cable design for these wheelchairs to charge them. Members of CWRU/MedWish sent the necessary components along with instructions if interested to build these cables remotely. Another example includes interns that worked with AEDs; this work involved efforts to develop either alternate connections (through wall outlets) or reusable batteries to prevent the use of expensive single-use batteries which often require replacement.

CWRU/MedWish have worked on over $300,000 worth of devices over the past 4 years through hundreds of hours of student volunteering. Once the database for performance metrics come is finalized, important metrics of performance can be reported. To date, projects including pulse oximeters, electric wheelchairs, EKGs, patient beds, and patient monitors, have established an adequately diverse product base on which to base future organizational activity; these devices have been shipped to over 90 countries demonstrating that students can ''act locally with impact globally.''

It is important to recognize the structural shift in operations at MedWish as a result of project activity. Previously, MedWish did not have knowledgeable staff or volunteers to test, troubleshoot, or repair medical devices donated to the organization. As the student club evolved. As the student club evolved to become an integral part of the organization, a renewed focus on medical devices took place. In this way, CWRU/MedWish adds to the human capacity of MedWish by complementing the limited existing clinical engineering staff with student volunteers through CBL. A reciprocal benefit is that MedWish adds to the human capacity of CWRU/MedWish members by providing them an opportunity to increase their knowledge and develop their skills relating to working with various devices and learning from the clinical engineers. MedWish's material capacity was greatly enhanced by CWRU/MedWish members' expertise and investment, as measured by MedWish capability to ship and deliver thousands of dollars' worth of devices to emerging economies. MedWish highly leverages donated devices, space, and human resources needed for CWRU/MedWish to function on-site. Organizational capacity-building has become evident through collaboration between and among CWRU/MedWish and MedWish staff, leading to higher-level learning for CWRU students and enhanced recycling output for MedWish. Finally, structural capacity-building enabled both organizations to successfully meet their goals—-MedWish with supporting the global need of patients for medical devices, and CWRU MedWish with providing immersion opportunities for its members. The MedWish project successfully enhanced organizational capacity-building through a CBL experience. Figure 8 illustrates the infrastructure components with potential for replication in other settings.

DISCUSSION

Several benefits arise from the implementation of a public–private partnership. Students learn from and collaborate with their peers, helping to foster interpersonal and team building skills. Through this approach, mentors ''guide from the side'', facilitating the project rather than controlling it. This allows students the ability to gain a sense of autonomy over both the project's successes and failures. Additionally, effective capacity building is seen to be enhanced through the merger of two frameworks: The Stanford BioDesign Method and the SETT (Student, Environment, Task, Tools) Framework. While these steps provide a clear roadmap to users, rushing of the ''identify'' step may compromise the final solution. By including the SETT Framework at the start, the team collaboratively addresses the root need at the beginning through enhanced need identification. An unintended benefit is that when the need is refined this way, the handoff between the co-curricular work and the curricular work is streamlined.

Despite the benefits of co-curricular activities between public and private entities, there are factors to consider before engaging in an immersive partnership. Managing scope and expectation is an important aspect to address early on in order to produce a mutually benefiting relationship. Differences in each party's time scale can be a point of concern. There may be differences in opinion regarding delivery speed. This division

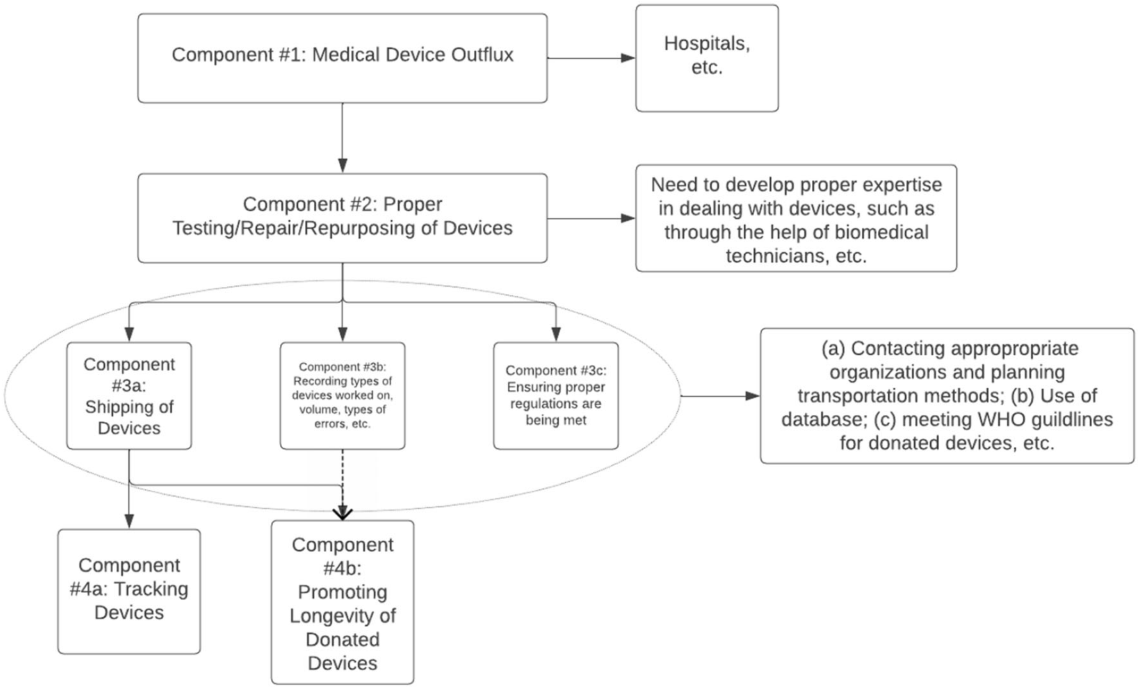

FIGURE 8. Diagram representing different infrastructure components necessary for minimal replication of the medical device component of the MedWish workflow.

in time frames can lead to one party feeling as though no work is getting completed. Along with managing scope and expectations of the partnership, it is important to protect the end user. Safety and privacy are of the upmost importance when dealing with products used with human subjects. With partnership development, it is imperative to follow all IRB, HIPPA, and safety guidelines.

In the present paper, the SETT Framework allows a similar approach in a school setting to help build an understanding of specialized needs for AT with students who rely on adults to observe and anticipate their needs due to extraordinarily complex disabilities. In the absence of SETT considerations, team members initially thought the solution surrounded a single generalized complex robot. By breaking down the necessary responsibilities through the SETT framework, the specifications were revised to design simpler task-specific robots that were constructed and placed successfully in service. This set the stage for a more realistic (iterative) strategy for development and launch of AT. This was not a case of ''one-and-done'' in which external volunteers ''jump in'' to create a device or system that only partially meets the educational needs of the staff, left with a refreshed but non-optimal project execution. Interdisciplinary processes take time to carry out; herein lies a challenge when working with a university in which the lifecycle of student activity is not aligned (much shorter) that of the project for the alternative education program. A disciplined approach to the partnership enables students to engage over short periods and create value, but without taxing the nonprofit staff more easily. One perspective on the value of the co-curricular activity is to extend project activity outside the typical semester framework, and when the co-curricular and curricular phases are aligned, the span of university activity is now more closely aligned with that of the host.

Often, partnerships represent a pathway that—-when mutually beneficial—are sustainable over an extended period. Research demonstrates a number of benefits from a team-based approach including appropriate goal development, advancement of knowledge and AT skills, team confidence, effective decision making processes, and improved service coordination for AT.[8] Through the implementation of the collaborative process, both the university and the nonprofit organization reaped many benefits, including the development of robust AT. Less obvious benefits included opportunities for co-curricular and peer-to-peer pedagogy. Due to the perceived complexity of the individuals served by the nonprofit, the university students had the opportunity to fully immerse themselves within the program to better understand the unique challenges the individuals faced when accessing the curriculum. This co-curricular approach not only allowed for the university students to discuss biomedical engineering theory, but to take the theory and apply it in real time. The university students engaged in peer-to-peer instruction which encouraged constructive feedback on failed developments within the design process and created opportunities for students to analyze each other's work and apply a new strategy to the design. When students have the opportunity to learn from one another, student engagement and conceptual learning is increased which directly impacts a student's ability to solve novel problems.[31]

The non-profit alternative educational program team members benefited immensely from regular opportunities to interact with university students and professors with a knowledge base in robotics and engineering. This helped to build internal capacity for identifying needs and articulating those needs to university students charged with building the tools. The individuals served within the non-profit alternative education program have directly benefited from the collaborative process due to the tangible outcome of AT designed specifically to meet their needs. With the AT developed by the university team, the individuals within the alternative education program have demonstrated increased engagement with greater independence across the curriculum.

The CWRU/MedWish initiative has been very productive across multiple aspects. First, the number and cost of devices worked on by club members were significant with relation to both medical device recycling and global health impact, clearly highlighting the influence of the rise in material capacity of MedWish due to club activities. Additionally, this experiential immersion opportunity provided CWRU students with exposure to a large variety of medical devices and promoted the development of design ideas and sustainable thought. This highlights the mutual benefits for both CWRU and MedWish. While our current discussion primarily focuses on qualitative factors, there is room for further analysis regarding key statistics. Two unexpected qualitative outcomes are noteworthy. First, the co-curricular activity involved students that were non-BME majors, and this interprofessional experience provided informal networking that caused students to "raise their gaze" and see their degree activity from another perspective—in one case a cognitive science major provided a perspective entirely new to the BME students. Second, a majority of the students who participated were not being paid; they were involved and committed to the projects since they were not only learning but having fun! Students who were "seasoned" and served as role models learned that leadership can be rewarding when you realize you influence how people spend their spare time.

CONCLUSIONS

Evident in both the CWRU/MedWish and LeafBridge/UCP Programs are signs that the methods we have developed for the immersive experience involving capacity-building activities have encouraging initial outcomes. The work further suggests that non-clinical immersion opportunities can be impactful—equally but in diverse ways—for biomedical students.

Over the past 2 years, a non-profit alternative education program for children with complex disabilities and a biomedical engineering department in a higher education institution explored a collaborative relationship based on developing AT for students with moderate to severe disabilities. By utilizing the well-known SETT framework (Student, Environment, Task, Tools) as a prelude to the Needs Analysis for design based on the Stanford BioDesign process, the team established a pathway between the entities which directly contributed to the success of service delivery and student engagement. The strategic significance of the SETT-BioDesign framework is the identification of specific roles for each of the partners. This can be thought of as a "matching strategy" in which the demands of the alternative education program for specific project activity are matched with the competencies of the biomedical engineering team. We have found that when bringing together different (but complementary) communities of thought, a "disciplined approach" to interdisciplinary project activity leads to collective expectation settings and reduced frustration on long-term project activity.

We also detailed the inner workings and outcomes of the CWRU MedWish Initiative, highlighting the benefits of this initiative with regards to capacity-building, increasing knowledge of device design issues, and promoting sustainable design thought. We then provided a brief analysis of the infrastructure necessary to sustain a minimal version of this initiative.

A focus of future efforts will be to collect specific statistics about work volunteers perform. Collecting this data will allow us to build a much better understanding of how this initiative can be optimized to both meet the goals of each organization and enhance the student immersion experience. While the current work has largely been descriptive, adequate qualitative evidence highlights the numerous benefits of co-curricular immersion as public–private capacity building activity.

AUTHOR CONTRIBUTIONS

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