Making engineering education more sustainable through community-based learning and teaching

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KEY WORDS: Community-based Learning; Partnerships; Sustainable Education; Curriculum Design; Engineering Education

ABSTRACT

Community-based learning and teaching offers engineering students a transformative educational experience that extends beyond textbooks, labs and classrooms by engaging students in co-creation activities with local community as part of their formal learning. By immersing themselves in real-world community contexts, engineering students develop practical skills, cultivate a sense of social responsibility, and become well-rounded professionals prepared to tackle the intricate challenges of our ever-evolving world.

Community-based learning and teaching takes engineering education beyond the confines of 'in-house' produced project proposal briefs, leads to better opportunities for interdisciplinary learning (beyond engineering 'subdisciplines') and more opportunities for creativity and flexibility in how engineering problems are approached and solved.

As part of an institution-wide study, in this paper we share specific findings from engineering educators, as well as university-wide engagement professionals and those supporting teaching and learning (24 in total), on the barriers and opportunities to community-based learning and teaching approaches. Using semi-structured interviews, we used thematic analysis to generate a series of themes which aligned with four key beneficiaries within engineering education: academics, students and community partners and university.

Our findings reveal the values and expectations, employability benefits and infrastructural considerations to implement this type of learning as part of future-facing and sustainable curricula in engineering. This includes areas such as motivation, role of the community, partnership building, development of leadership skills and networking and financial planning and relationship management.

The findings also provide useful context-specific recommendations for educators seeking to develop their own sustainable approaches towards facilitating community-based learning and teaching in engineering disciplines.

INTRODUCTION

Global challenges that call for environmental, social and innovative solutions have consistently pushed us to be open to the changes and challenges to engineering education (Graham, 2012; Graham, 2018; Crawley et al., 2014; Lawlor, 2013; The Royal Academy of Engineering, 2007). Alongside this, as engineering educators and researchers in higher education, there is no doubt we continue to share a commitment to innovation in our teaching and learning practices.

Sometimes, called Community Engaged Learning (CEL), community-based learning and teaching (CBLT, henceforth) describes an educational experience in which students engage in organised activities that benefit the local community as part of their academic curriculum (Bringle and Hatcher, 2000). CBLT for engineering education innovation is a form of culturally responsive pedagogy to make engineering more sustainable. Culturally responsive pedagogy is a student-centred teaching approach which emphasises the importance of recognizing and valuing diverse cultural backgrounds, experiences, and perspectives within educational settings. Culturally responsive pedagogy helps highlight that engineering education does not exist in a vacuum nor is it distinct from other disciplines such as arts and humanities which are traditionally associated with community engaged research and teaching (Sleeter, 2012; Howard, 2021).

Universities across the world are growing more committed to forming strong regional partnerships with local community partners and businesses (Betts et al., 2022; Shah et al., 2023). In engineering education in particular, placements, are increasingly embedded in the curriculum as they provide students with an opportunity to develop transferable and employability-related skills in a real-world setting (Swan et al., 2014; IET, 2017). While most engineering placements are traditionally performed with industry partners, research from recent years highlights the value of community engagement in engineering education, which could take the form of community-based placements and other forms of projects and interventions (Natarajarathinam et al., 2021).

LITERATURE REVIEW / RATIONALE

The field of engineering is typically seen as highly technical and lacking direct involvement with local communities (Cheryan et al., 2015), which accounts for the increasing preference for partnerships with industry partners, instead of community organisations. On the flip side, however, engineering is also regarded as a "profession with a societal context leading to social responsibility" (Natarajarathinam et al., 2021), which indicates a necessity for the involvement of engineers with their local communities.

Swan et al. (2014, p. 362) defines community engagement in engineering education as a "form of active, experiential learning where students, instructors, and the community partners work collaboratively on projects that benefit a real community need and provide a rich learning experience for all participants. The projects must be properly planned, implemented, and assessed with expected outcomes, educational and others, in mind. Critical reflection is part of this assessment effort".

Furthermore, community engagement in engineering education offers a platform for mutually beneficial exchange of knowledge and resources between all key stakeholders: academics, students, community partners and universities as higher education institutions (Farner, 2019; Bielefeldt and Lima, 2019). Participation in community-engagement among engineering students is associated with higher academic achievement and greater reported satisfaction with their academic course (Bielefeldt and Lima, 2019). Students also showcase improved critical thinking skills and strengthened abilities to apply academic concepts in real-world scenarios (Bielefeldt and Lima, 2019). Students also develop several soft skills from community-engaged activities; For example, they not only learn how to be effective leaders, but also good team players, while also developing a level of cultural competence and awareness (Keshwani and Adams, 2017).

Community-engaged projects within engineering education have several key features, as explained by Swan et al. (2014). First and foremost, there should be an authentic and clear connection between serving the needs of the community and those of discipline-specific academic learning (Swan et al., 2014). Therefore, it is crucial for the relevant community stakeholders to collaborate with academic stakeholders in the design of the interventions to ensure that both their needs and the academic learning outcomes are met (Swan et al., 2014). The academic learning aspects of the project should be well-planned, structured and assessed, with a reflective component incorporated, whereas for the needs of the community to be met, it is of great significance for academic stakeholders to keep seeking the input and direction of community partners throughout the whole duration of the project (Swan et al., 2014). Nevertheless, the logistics and documentation involved in executing a community-based intervention with multiple key stakeholders usually involve issues with liability, regulations, and local constraints (Swan et al., 2014). Moreover, long-

lasting sustainable partnerships between HEIs and community partners are hard to sustain throughout the years (Swan et al., 2014).

Despite all the challenges involved in executing community-engaged learning and teaching, the effort for implementing community engagement in engineering education across UK universities is growing. One notable example is the Manchester Leadership Programme (MLP) at the University of Manchester, which is a credit-bearing community-based placement program for undergraduate students coming from a variety disciplines, including engineering (MLP (the University of Manchester), n.d.). The programme consists of academic units, during which students learn about community-engagement, and an experiential element, in which students are matched with a community partner or organisation, based on their preferences and experience, and together, they work to design and implement projects that address the community's needs (MLP (the University of Manchester), n.d.). An engineering student who undertook the programme reflects on the value of their experiences:

"I've had six interviews with a range of companies and have been asked about the MLP every time. Employers want graduates with technical abilities who also have the potential to become managers. The MLP helped me to show that I have the leadership skills recruiters want". (Why take the MLP (the University of Manchester), n.d.)

Another notable example of community-engaged learning and teaching in practice is the UCL Engineering Tutoring Programme, which aims to reduce the attainment gap in East London (UCL, 2021). In this programme, UCL teamed up with London Legacy Development Corporation (LLDC), as part of East Education, to devise a tailored tutoring intervention (UCL, 2021). UCL undergraduate and postgraduate engineering students were tutored students in schools and community centres in East London in STEM subjects (UCL, 2021). The UCL students who expressed interest in the programme received training prior to becoming tutors (UCL, 2021), which ensured that students could deliver a high-quality service to meet the community's needs. While the programme is not credit-bearing (UCL, 2021) (which means that no learning outcomes were established) through the act of tutoring itself, students were actively strengthening academic knowledge relevant for their discipline. Moreover, they strengthened their soft, hard-to learn skills in the areas of communication and critical thinking, which were crucial for devising and offering personalised interventions to meet the needs of each student.

There are therefore a range of examples of excellent practice in CBLT and attempts to develop frameworks for engineering education. But how does the field move from pockets of practice to broader scale activities? To help frame our research, we considered two ways in which CBLT links to developing a more sustainable engineering education. The first, is as

an approach to teaching and learning, by enabling engineering students to experience learning along a continuum of the following dimensions:

1) engineering education about sustainable development
2) engineering education for sustainable development
3) engineering education as sustainable development

The first dimension 1) refers to the integration of sustainability principles and practices into the curriculum and pedagogy of engineering programs, learning about the environmental, social, and economic dimensions of sustainable development and equipping them with the knowledge and skills to address sustainability challenges in their professional practice. The second dimension 2) refers to the integration of sustainability issues, possession of the necessary technical knowledge and skills and demonstration of ethical and responsible behaviour for students' engineering practice. The final dimension 3) considers engineering education itself as a vehicle for addressing education for sustainability regarding how it integrates sustainability principles, ethics, and social responsibility into the culture and values of engineering education institutions. CBLT can be viewed from the lens of all three conceptualisations and in doing so, is one way in which educators can ensure that education approaches are pushed to be open to the changes and challenges to engineering education.

Secondly, as previously mentioned, it is as a form of culturally responsive pedagogy where students' unique cultural strengths are identified and nurtured to promote student achievement and a sense of well-being about their cultural place in the world (Howard, 2021). The CBLT experiences of engineering students move them beyond the discipline-specific curriculum content to consider the multidimensional aspects of learning of what it means to be engineer through, for example, context, classroom climate, student-community relationships and non-traditional instruction and assessment. In doing so, engineering students can begin to recognise diverse knowledge systems, including the indigenous and local knowledge systems, and those of students.

RESEARCH QUESTIONS

Our research with engineering educators grew out of previous work which examined the values and expectations, graduate outcomes and employability and infrastructural considerations of designing and implementing CBLT. Our work (Shah et al., 2023) sought to extend the discussion of CBLT beyond components of learning outcomes, syllabi and assessment to areas which were repeatedly highlighted by university stakeholders as presenting challenges to students, educators, community organisations and universities. In

the context of engineering education, we further identified the following through conversations with our peers:

1. Complexity of definitions of CBLT in the context of engineering education
2. What universities can do to support engineering educators to implement CBLT
3. A need to better listen, identify and respond to engineering educators
4. Developing approaches to investment of time, nurturing proactive and productive relationships, partnership work support and vision building and sharing
5. Unexplored conversations about what community stakeholders themselves would see as beneficial to their involvement with engineering disciplines

These initial discussions helped us refine our own motivations and methodological approach to the research. We formulated and designed the following research questions based on a grounded approach to support reflection and learning and to give voice to those working within the engineering education ecosystem:

RQ 1. According to university stakeholders, what do engineering academics, students and community partners expect from CBLT and what benefits do each of them hope to obtain?

RQ2: What do stakeholders in the university ecosystem think are the employability-related skills to be gained from CBLT for engineering students?

RQ3: What logistical processes and documentation does a university require to effectively implement CBLT in engineering education?

METHODOLOGICAL APPROACH

We used a 'students-as partners' approach, where research students interested in CBLT took a leading role. Current research students with an interest, but little knowledge or experience in institutional-level CBLT were key partners and invited to collaborate as part of a paid internship. The concept of 'students-as-partners' (SaP) is a well-known concept which permeates particularly in higher education in the UK, US, Canadian and Australian contexts (Healey et al., 2014). It is an approach which aims to develop practices of involving students as co-producers and co-designers, within contexts directly relating to their education and learning.

We used qualitative methods namely semi-structured online interviews (Newcomer et al., 2015) to gather data on university stakeholder perspectives on the implementation of CBLT. These were designed to focus the research focus on the key thematic areas (corresponding to each of our research questions) and to enable new related sub-themes to emerge based on what the participants raised with the interviewer (Edwards and Holland, 2013). Our thematic areas were broadly grouped into three categories respectively:

- Values and expectations (RQ1)
- Graduate outcomes and employability (RQ2)
- Infrastructure (RQ3)

The questions used with different stakeholders varied a little according to their role and interaction with community-based learning and teaching, however the interviews generally used the following guide, as shown in Table 1 below:

Table 1. Thematic Guide to Interview Questions

Common question themes:	**Current role, key activities** **Experience and knowledge of CBLT** **Current challenges in the planning and delivery of CBLT** **Improving planning and delivery** **Benefits to graduate outcomes**
For specific participants	Academic student support: skills and employability Engineering academic: educational design, planning and preparation Engagement professional: community benefits and public engagement

Each interview lasted for up to an hour and was recorded with permission of the participants using MS Teams. We used interview recordings as well as accompanying automatic transcriptions to create our growing corpus. Ethical consent was granted by all participants and procedures adopted used BERA standards.

We invited a range of stakeholders working within the engineering faculty at the university to participate in the research, as shown below in Table 2. The participants were identified through role, job title and based on existing connections with members of the research team. Student partners also highlighted specific stakeholders they felt were important and on the basis on web-based research and recommendations. As research which sought to 'look within' in terms of scrutinising current practices from an institutional perspective, we did not engage the participation of external community partners on this occasion.

Table 2. Stakeholder participants in the university ecosystem

Stakeholder Group	Number of participants (Total 24)
Engineering academics	11
Engagement professional	8
Academic student support	5

KEY FINDINGS

Our findings are presented in terms of research questions and address the themes revealed in the analysis of our university-based stakeholders' views and perspectives. Themes aligned with four key beneficiaries within engineering education: academics, students and community partners and the university:

1. engineering academics who provide the opportunities for learning
2. engineering students who are recipients of the teaching opportunities afforded by community-based learning and teaching
3. community partners, who play a diverse role as both recipients and providers of the affordances of community-based learning and teaching
4. the university.

RQ 1. Values and expectations: According to university stakeholders, what do engineering academics, students and community partners expect from CBLT and what benefits do each of them hope to obtain?

Figure 1 below shows the key themes linked to values and expectations pertaining to CBLT.

Figure 1. CBLT themes for values and expectations (RQ1)

Key to icons:

Impact: inspiring everyone involved

All the stakeholders emphasised the multifaceted impact of CBLT, which ensures "learning and growth for everyone involved" (Participant 1). On the one hand, engineering academics reported that community-engaged learning and teaching drives students to become "socially aware engineers with perspective" (Participant 8). Consequently, this would enable students to exercise their disciplinary knowledge and have a tangible impact in the local communities. From the community's perspective, our stakeholders noted that community partners are eager to see academic expertise and innovation being shared with them and applied through projects involving intragenerational groups of people. Moreover, the stakeholders hoped that the intragenerational work in CBLT would inspire the younger generation within local communities to enter STEM fields.

Reciprocal Skills: community as change agents

Each of our stakeholders also commented on the expectations of engineering academics, students and community partners centred around the development of community-specific skills occurring as an offshoot of CBLT. Apart from students developing a set of transferable, disciplinary and employability-specific skills, they also recognised the importance of skillset building within the local communities. They highlighted the growing "positive attitude towards change" (Participant 3) amongst community members, however,

they also noted the general lack of knowledge and skills needed to create that change. Through collaborative work between universities, students and community partners, the members of the local communities could also develop the much-needed skillset to inspire and lead more community-based work to generate measurable impact.

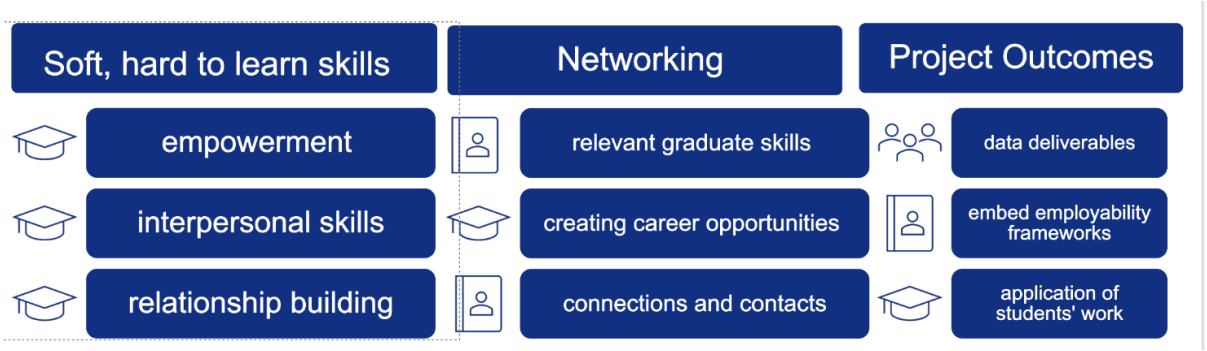
Promotion: creating sustainable partnerships

Our stakeholders also stressed the importance of establishing long-lasting sustainable partnerships between universities and community partners to sustain engagement of all key groups throughout time for engineering education. An effective promotion of community-based work and its impact, for example, would not only boost each the motivation of engineering academics and community partners, but it would also help with the work's scalability and its impact in the community.

RQ2: Graduate outcomes and employability: What do stakeholders in the university ecosystem think are the employability-related skills to be gained from CBLT for engineering students?

Figure 2 below shows the key themes linked to graduate outcomes and employability pertaining to CBLT.

Figure 2. CBLT themes for graduate outcomes and employability (RQ2)



Key to icons:

Leadership skills: real-world problems

All our stakeholders reflected on the "gap between practical scenarios and real-world problems" (Participant 11) in engineering education, implying that students were "technically proficient, but not equipped with transferable real-life skills" (Participant 14). The stakeholders acknowledged that CBLT encourages the development of soft, hard to learn skills, such as problem-solving, effective communication, teamwork, time management etc. which are crucial for a successful career in engineering. Moreover, they stressed how CBLT helps students acquire empathy and social awareness, which are essential to empower the leaders of the future. These qualities will also "allow new leaders to better understand who they are designing for and encourage them to bring different voices in the development of engineering projects" (Participant 20), while also including members of underrepresented groups.

Networking: discipline-specific skills needed for the workplace

Many of our stakeholders also identified CBLT as an excellent platform for networking. Based on student feedback, they noted how many students can build invaluable connections and contacts during their community-based experiences, which subsequently offer them several routes in their career paths. Additionally, it also provided engineering academics with the opportunity to "gain valuable feedback regarding discipline-specific skills required of recent graduates moving to the workplace" (Participant 5).

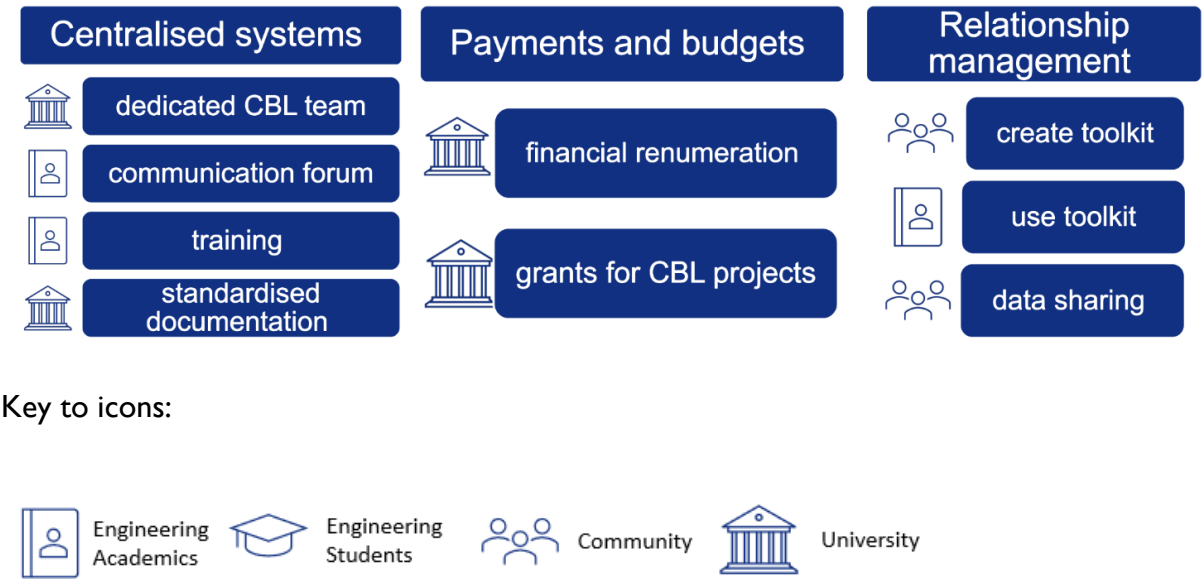
Project outcomes: making a difference

While students gained valuable employability skills from CBLT, we also found that engineering academics valued the pragmatic thinking and the emphasis on applicability which students developed from their CBLT experiences. Our stakeholders mentioned the importance of project outcomes fostered by CBLT, for example, through the application of students' work within local communities, which can empower young engineers to work on projects that make a difference. Furthermore, with the diverse skillset profile which students develop through CBLT, many of the students also get "scooped up by important companies like Google later on" (Participant 9).

RQ3: Infrastructure: What logistical processes and documentation does a university require to effectively implement CBLT in engineering education?

Figure 3 below shows the key themes linked to infrastructure pertaining to CBLT.

Figure 3. CBLT themes for infrastructure (RQ3)



Centralised systems: get people listening

Each of our stakeholders identified the need to "establish a central communication platform between academics and university engagement professionals" (Participant 16) within the university to manage CBLT activities. They envisioned a dedicated CBLT team that would create a framework for defining CBLT and subsequently implementing it in the curriculum, for example, in the form of a dedicated CBLT module or a community-based placement as part of the degree. Such a team would standardise the language used to communicate about CBLT and clarify the logistics and documentation needed for CBLT activities to allow for smoother implementation. In this way the team "can really keep track of what is going on, report about it to university staff in an efficient way. This will really get people listening" (Participant 7).

Payments and budgets: based on financial need

The issue of whether payments were to be made to community organisations for their work on partnership projects was found to be handled differently by members of each of our stakeholder groups, primarily stemming from their varying budgetary constraints. While engineering academics highlighted the fact that communities recognised the impact created by the partnership projects and therefore had no expectations of receiving any financial payment for their work, the engagement professionals stated that community organisations usually received some form of financial or non-financial remuneration. This emphasises the need for "adopting a more standardised procedure as set by the university with regard to payments made to communities" (Participant 18), in line with the budgetary allocations available for each project. Some of our academic stakeholders also highlighted the need for increasing the grants available for community-based projects to encourage the involvement of engineering academics in community-based work.

Relationship management: supporting sustainable partnerships

Finally, stakeholders highlighted the importance of relationship management to ensure long-term sustainable partnerships between the university and the community partners. They stated that everyone would benefit from an established partnership toolkit, which would include a framework for carrying out engineering community-based projects. This framework could ensure that effort and resources are split fairly and equitably across all stakeholders. Moreover, stakeholders also reported the need for "effective data sharing between universities and community partners in terms of past and current projects' impact" (Participant 22), as well as new project opportunities. They expressed interest in establishing communication platforms, which could be in the form of conferences dedicated to CBLT, for instance, where community partners could come learn about students' engineering projects and seek to establish partnerships, as well as learn about previous projects' outcomes.

DISCUSSION

The analysis reveals themes and perspectives that underpin community-based learning and teaching within engineering education. The insights derived align with existing literature in engineering education (Swan et al., 2014; IET, 2017) and showcase the resonance between engineering educators and practical stakeholder perspectives.

Before moving on to a broader discussion, it is worth noting the strength of themes across our key groups. Our analysis indicated that for academics and teaching professionals, the most significant themes were in the impact of disciplinary knowledge, which included the application and development of employability skills and frameworks as well as professional skills such as networking and social capital. A further key area identified was the need to develop more training, resources and toolkits. This stands in contrast to the strength of themes for the student group which highlighted the development of soft skills and personal development. This suggests that although our stakeholders share similar perspectives on educators and students, there could still be a gap in terms of the current benefits to students and the potential for many more employability and professional outcomes if academics are supported enough and in the right ways.

For community partners, themes were focused primarily on the overarching benefits of organisational promotion and the affiliations that community organisations stand to gain from their involvement in CBLT. Less prevalent as a theme were aspects related to the skills development brought into organisations as a result of engaging with universities through CBLT. This is potentially an area of development.

Finally, for universities, themes lay exclusively in the areas of financial support, suggesting that as a beneficiary, there is less emphasis on what universities stand to gain institutionally.

Our stakeholders also shared the reciprocal nature of CBLT for engineering such as supporting community agency to address problems and issues, the impact on skills development in the community and the creation of sustainable partnerships.

Values and Expectations

The themes that emerged from the analysis highlight the profound impact that CBLT has on all stakeholders involved. Inspiring everyone, promoting the community as change agents and creating sustainable partnerships emphasizes the transformative potential of community-engaged learning. The emphasis on inspiring change and empowering communities mirrors educational theories on transformative learning (Boyd and Myers, 1988), which assert that education should facilitate personal, social, and structural transformation.

Graduate Outcomes and Employability

Our stakeholders' perspectives also map on to literature about the pivotal role of CBLT in shaping engineering graduate outcomes and employability skills. The emphasis on leadership, problem-solving, communication, and networking mirrors the industry demand for well-rounded engineers who possess both technical acumen and the soft skills needed to navigate multidisciplinary teams and diverse environments (see for example, The American Association of Mechanical Engineers, 2023) (ASME, 2023).

Infrastructure

The themes related to infrastructure underscore the need for effective communication, streamlined processes, and sustainable partnerships. This echoes the literature on the importance of institutional support and robust frameworks for implementing CBLT (Shah et al., 2023).

CONCLUSIONS & RECOMMENDATIONS

As engineering education continues to evolve, our research seeks to underscore the potential of CBLT to empower students, educators, community partners, and universities towards a shared vision of sustainable engineering education and practice. In this paper, building on work which investigated institutional approaches to the role and contribution of community-based learning and teaching, we undertook qualitative research to extend understandings of how engineering education could become more sustainable through adopting more culturally responsive pedagogical approaches.

Our aim was to build on the ongoing calls to design university programmes for future engineers who can address innovations to global challenges drawing on technical and scientific knowledge alongside creativity, ethical, professional and leadership skills. A key

takeaway from this is that the success of making engineering education more sustainable and culturally responsive depends on activities to raise awareness of the approach both within engineering education and our own universities and to provide tools to support it.

A lot of what is shared by our stakeholders provides useful guidelines for practitioners, which can help in developing new curricula and assessments and convince others to adopt more local CBLT practices and set up new partnerships:

- Impact: inspire everyone involved
- Reciprocal Skills: support the community as change agents
- Promotion: Create sustainable partnerships
- Leadership skills: address real-world problems
- Networking: encounter discipline-specific skills needed for the workplace
- Project outcomes: make a difference
- Centralised systems: get people listening
- Payments and budgets: base on financial need
- Relationship management: support sustainable partnerships

Our overarching goal is to contribute to a broader shift about what the core business of a 21st century university should and could be and engineering education has an important part to play in this. Studies such as ours which look to marry engineering education approaches with methods already taking off in other disciplines to enhance the sustainability of those areas, are a valuable activity for building evidence-based institutional practice and we encourage others to do the same. We are currently expanding our work in engineering education and participating in a cross-institutional-led research into UK-wide approaches to community-based placements in engineering and are always happy for anyone interested to get in touch for more information on this project or any other related area of CBLT.

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