The Process of Developing an International Engineering Education Collaboration in the United States and United Kingdom

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Abstract

This paper describes the collaborative inquiry process of developing an international collaboration between Cornell University, a Northeastern U.S. institution, and University College London (UCL), a UK institution, to share evidence-based practices, develop collaborations, share resources, and develop new tools and approaches to support engineering workforce development. The rapidly growing field of engineering education research (EER) is recognized as a crucial resource for research to advance engineering workforce development during this period of increasingly complex, global engineering problems. Despite this potential, EER currently comprises of many strong (but largely unconnected) international networks, and there is no unified platform from which large-scale engineering workforce development strategies and findings can be shared and leveraged. Collaborative inquiry is a process in which individuals come together to identify common challenges, analyze relevant data, and develop potential interventions for testing. Each workshop focused on a discussion of two themes: 1) broadening access and participation in engineering pathways and 2) experiential learning in engineering education. Each workshop was advertised broadly to all engineering faculty, student support staff, engineering administrators, and centers for teaching and learning. A total of 20 individuals came to the workshop at UCL, which was held in June 2024, and 19 individuals came to the workshop at Cornell, which was held in August 2024. Each workshop was guided by collaborative inquiry to develop a shared understanding of the challenges and shared opportunities for education innovations. We led off with short presentations to share contextual differences between the two educational contexts and to share challenges encountered, what has been done on these topics, and engage a larger discussion. Field notes and artifacts were collected from these groups and themed to identify shared challenges, supports, and opportunities for future collaborations that included, as examples rather than an exhaustive list, resources for team formation and evaluation, mathematics preparation and onboarding courses, and resources for first-year students, faculty professional development challenges and opportunities, and use of reflection as a tool in courses. Findings and implications for supporting international hubs for engineering education research and workforce development partnerships will be discussed.

Introduction

Current engineering undergraduate enrollment and job placement trends indicate slow progress in increasing gender and racial/ethnic diversity in the United States and United Kingdom. This project brings together engineering education research across two institutions with emerging engineering education research expertise—one U.S. Northeastern private institution and one UK metropolitan Russell Group institution—to build capacity for cross-national research to aid student development of knowledge, skills, and attitudes to support a diverse and well-prepared engineering workforce. As engineering education emerges as a research field capable of creating solutions to these pressing problems, the growing expertise at these institutions provides an opportunity to develop cutting-edge scholarship to support these essential student outcomes.

As society faces increasingly urgent contemporary challenges around climate change, energy provision, food security, local and regional economic sustainability, global migration, and cybersecurity, there is no question about the important role engineers play in addressing these challenges. Additionally, employers often cite professional skills as an area for student development over technical aspects of engineering education [1]. Finally, rapid shifts in technology demand an engineering workforce prepared to leverage large amounts of data for evidence-based decision-making. However, many engineering programs have not kept pace with the skills needed [2]. The rapidly growing field of engineering education research (EER) is recognized as a crucial resource for research to advance engineering workforce development. EER can provide evidence-based solutions for several challenges related to workforce development, including student recruitment and retention; effective pedagogies and practices to support the development of relevant knowledge, skills, and abilities; broadening pathways for engineering careers; and upskilling the current engineering workforce. Despite this potential, EER currently comprises many strong but largely unconnected international networks, and there is no unified consortium from which large-scale engineering workforce development strategies and findings can be shared and leveraged. Thus, this Global Strategic Collaboration aimed to build research networks across two institutions with emerging engineering education excellence to address this need.

- Aim 1: enable a global community of EER researchers to evaluate the effectiveness of current practices to share resources, knowledge, and expertise to support the development of a diverse and highly skilled engineering workforce prepared for 21st-century challenges
- Aim 2: provide a platform for launching international multi-team research projects

Addressing these aims will identify research priorities for engineering workforce development and lay the groundwork for establishing an international consortium (a global network of EER networks) to address those priorities. Creating this network is a timely and pressing need as the U.S. education system lags international peers in mathematics and science assessments, particularly for low-income, Black, Latino/a/x, and Indigenous (BLI) students. Additionally, while undergraduate engineering enrollments, which translate into engineering employment, have grown, the percentage of women and BLI people has not dramatically changed [3]. Between 2011 and 2021, the STEM workforce grew by 5.9 million, from 29.0 million to 34.9 million, representing a 20% increase [4], and yet the development of individuals prepared to fill this growth demand is insufficient. Similar trends exist in the United Kingdom as well. Only 14% of engineers are women, even though women hold engineering degrees at higher rates [5]. People from Black, Asian, and Minority Ethnic (BAME) backgrounds in engineering comprise an estimated 7.8% of the workforce [6]. It should be noted that the UK government is moving away from the term BAME and instead recommends, wherever possible, that specific ethnic classifications of the Census should be used [7]. Additionally, for engineering to reduce its talent shortage, the United Kingdom needs 186,000 skilled recruits each year [8]. These realities result in a skills and labor shortage that needs novel research solutions to continuously adapt and improve the educational and career pathways of engineers across the United States and the United Kingdom [9], [10]. A consortium across national and international boundaries can create

opportunities to accelerate and broaden EER beyond the current capacity of siloed national networks.

Collaborative Inquiry

Collaborative inquiry is a research approach that emphasizes real-time learning and dialogue among participants, enabling them to reflect on shared experiences and develop strategies for improving future practices [11]. Traditionally, this method has been employed in educational contexts, allowing teachers to refine their methods through reflective discussions and evaluations of proposed adjustments. More recently, collaborative inquiry has been adopted in research focused on guiding specific actions or practices. For example, it has been utilized in engineering education research (EER) to evaluate the quality of diverse qualitative methods [12], to explore the development and negotiations of first-year faculty [13], and to probe methodological choices in interpretive phenomenological analysis [14]. In this context, collaborative inquiry served as a structured framework to enhance our understanding and application of interpretative phenomenological analysis (IPA) in EER. It also facilitated the systematic and intentional formulation of our guiding question, anchoring our formal reflection process.

Collaborative inquiry consists of a set of key steps in an iterative and flexible cycle, including 1) orientation/question to center the phenomenon of interest, 2) hypothesis generation of shared challenges and opportunities, 3) planning for change, 4) investigation into how planned activities will or do work in context, 5) analysis/interpretation, 6) evaluation of the implementation of the efforts, and 7) communication of effort and results with stakeholders and research community [9]. Orientation/question involves creating a shared understanding of the phenomenon of interest and posing questions of it. Hypothesis generation is the formulation of relations between the constructs of interest based on the starting understandings. We did this step by presenting data about the topic of discussion to the group. This effort grounded the assembled team in important aspects of the topics we explored for engagement across our communities. Planning involves the design of a process to investigate the questions and hypotheses developed. We spent time during the workshop exploring the different ongoing efforts at each of our institutions and generating new ideas for how we could collaborate on common shared problems in supporting a broad representation of students in engineering, authentic learning experiences, and larger questions of workforce development. Investigation carries out the development of an understanding of the phenomenon. We continued this work after each workshop session by taking data generated by the group through discussion and field notes and synthesizing the core ideas of the conversation and presenting them back to the group. Analysis and interpretation use the generated data from the discussion to develop a model or answers to the particular questions. Based on the synthesis of the core ideas in the workshops, we have begun to engage small groups in implementing efforts. This aspect of the project is ongoing. In evaluation activities, the team extracted the results to make sense of how the results can be practically used. Finally, in communication, the results are shared more broadly with the community. This paper is the progress to date on our efforts. Although not all collaborative inquiry models or practice reports incorporated every one of these characteristics, most examples included a majority of them. Furthermore, while certain characteristics tend to occur earlier or later in the process, they do not follow a strictly linear progression.

Institutional Contexts

EER is more established at UCL with the founding of the Centre for Engineering Education, focused on both research and innovation, which improved the process of engineering education locally and more broadly in the 2010s. The efforts span research, outreach and programs, program review and evaluation, and interdisciplinary teaching and student experiences in the curricula.

EER is a new strategic research area for the College of Engineering at Cornell University. This effort started with hiring one EER tenured/tenure-track faculty member in recent years and has grown to three current faculty members with plans for additional growth in the next five years. While the faculty hired have training and experience in EER, the efforts on campus and engagement of the larger College and University are nascent. The collaboration with a more established Centre in the UK context is facilitating the growth of efforts at this institution.

Developing Shared Understanding and Language

One significant challenge in developing this international collaboration was developing a shared understanding of the differences and similarities of the education systems across the United States and United Kingdom, and the language used in these contexts. This shared understanding was an essential step in the first part of the collaborative inquiry for orientation to the unique contexts involved in the work. For example, while issues of representation in engineering in the United States and United Kingdom have similar histories of oppression and challenges today, how representation in engineering is discussed is nuanced and distinct. This shared understanding of differences and similarities was addressed not only at the start of the collaborative inquiry but also throughout as different people joined discussions and workshops

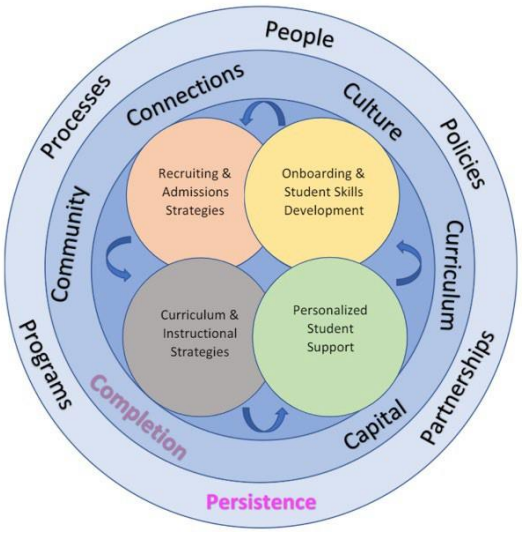
Two main efforts supported this development: 1) the core project team had worked together on various small projects over seven years, and 2) the collaboration workshops developed (described more below) included level-setting efforts to bridge the contextual gaps between the United States and United Kingdom contexts.

Starting Framework for Student-Focused Efforts

To provide a starting point for collaborative inquiry, we leveraged the “Weaving In, Not Out” framework developed by Carpenter [15]. This framework was developed to address persistent equity issues in who becomes an engineer, an issue directly connected to the future workforce. Through a series of four brainstorming sessions with national experts and stakeholders across engineering (i.e., from K-12 education through industry) in Spring 2022, including a U.S. National Academy of Engineering and American Society for Engineering Education conference, this framework addresses major areas for realizing meaningful improvement in the number and diversity of engineering graduations with a focus on practices that make effective changes in recruiting, admissions, and retention practices.

The framework from [15] is shown in Figure 1. The outer circle represents larger institutional, often outward-facing aspects of an engineering program that either draw students in or filter out/exclude students, both before they arrive on campus and while they are pursuing their degree. The inner circle represents student-facing or more internal aspects of an engineering program that can serve as either a system to support student success or a system to drive them away. Finally, within the center, there are mutually reinforcing practices that can shape student experiences and for which there are existing evidence-based practices: 1) recruiting and admissions strategies, 2) onboarding and student skills development, 3) curriculum and instruction strategies, and 4) personalized student support. These four topics were the starting areas for collaborative inquiry of what the participants cared about, what was already happening on our campuses, and how we might collaborate internationally on shared efforts.

Figure 1. Weaving In, Not Out framework [15].



We used this framework as a guide in our hypothesis generation and planning. It provided generative areas for discussion in which we could explore how we might address our collaboration Aims and consider various aspects of the student experience that are nested within departments/schools, Colleges of Engineering, and university contexts

Collaboration Workshops

To commence the project, two 3-hour in-person workshops at UCL were organized in June 2024. An academic from Cornell, Godwin, visited the United Kingdom and participated in both workshops. The two workshops each focused on a different theme:

1. Access to Engineering Education – to investigate widening participation in engineering from ethnic and gender minorities, and those whose education has been disrupted by personal or socioeconomic circumstances, exploring opportunities to support students' education experience and continued workplace success.

2. Experiential Learning & Teamwork – to explore the opportunities and challenges of the process of learning by doing, examining best practice of teamwork, exploring communication, conflict resolution, and intercultural teams.

Each workshop started with two topic motivation presentations before moving on to an open discussion amongst all workshop participants, facilitated by project leads. To promote diversity of perspectives covered, the two topic motivational presentations were delivered by academics from different academic institutions—Cornell, UCL, and an additional UK metropolitan non-Russell Group institution, Queen Mary University of London. In addition to presentation speakers, workshop participants were, in the majority, teaching-focused academics in the Faculty of Engineering Sciences, UCL. Other participants included academics from UCL's Centre for Engineering Education and learning technologists. Furthermore, a teaching-focused academic from another UK metropolitan Russell Group institution, Imperial College, and an engineer education academic from a U.S. public Midwest institution, Purdue University, were also in attendance. In total, five academic institutions—2 United States and 3 United Kingdom—were represented. Attendance at only one or both workshops was permitted to promote maximum participation, and in total, 20 attendees attended the workshops, with 10-14 participants present at each workshop.

A follow-up workshop and meetings were arranged at Cornell during a visit by one of the UK-based project leads, Pollock, in August 2024. The themes from the two UK workshops were further explored in a 1.5-hour workshop with 19 faculty and staff from Cornell. Each theme discussed within the UK workshops was also discussed in the United States. The main outcomes from the UK workshop discussions, actions taken since the "Access to Engineering Education" workshop, and how challenges identified in the "Experiential Learning and Teamwork" workshop have been addressed to date in a capstone engineering design project course at the UK institution were presented to the U.S. group. Then, further discussion and opportunities for collaboration, other similar activities, and new ideas were solicited. The workshop was further supported by individual and small group meetings with 12 faculty and staff members representing five units, including two engineering schools, one science school, a College-level institute for teaching and learning, and a student-facing group focused on hands-on project-based student experiences.

We synthesized the discussions to share back with the larger teams in attendance and to facilitate smaller group efforts in implementation and evaluation of the efforts. These implementation efforts are ongoing. In this paper, we present the emerging themes developed through collaborative inquiry guided by the "Weaving In, Not Out" framework and the specific aspects of the two institutional contexts.

Emerging Themes

Following discussions amongst participants at both the UK and U.S. workshops and meetings, common themes and initial ideas on areas to investigate or evaluate further were identified, as discussed below.

i. Promote open and inclusive environment to support students and peer-to-peer learning

In the “Access to Engineering Education” workshop, the importance of supporting students from ethnic and gender minoritized groups, first-to-university students or first-generation college students, was identified as paramount. Ideas were shared on how this support could take various forms, ranging from considering team formation to encouraging students to talk about their experiences to address issues of isolation, academic confidence, and actions to support student belonging. Workshop participants shared their experiences. For example, author [16] designed an ecological belonging intervention in a first-year engineering program implemented with 691 students. The targeted belonging intervention for BLI engineering students was designed to normalize the struggle, address threats to belonging, and close equity gaps in student academic outcomes (these are called “equity gaps” as they emerge from the context versus something about the students). Findings showed that the targeted intervention can help address issues of isolation and academic confidence. Further interventions to encourage students in higher years to share their experiences and support current students through panel events were also discussed. A participant shared an effort to have students share stories of their experiences within their degree programs [17]. Emphasis was placed on involving students in the organization of student panel events and diversifying discussions to allow incoming students to ask a panel of higher year students not only about their experiences of the program but also more practical questions about student accommodation, societies, student mentors, or next study or career steps.

Reflecting on this discussion further, this form of peer-to-peer learning was considered important to share among all students as they transition into engineering education. While some students may be dealing with belonging issues related to gender, race/ethnicity, and access, others could be dealing with issues related to cultural differences, studying away from home in the same or different countries, and changing mindsets focused on solving open-ended problems.

ii. Diversity in assessment

Workshop participants and discussions highlighted significant diversity in student cohorts in different academic institutions and programs. One key point of discussion was centered around the idea that to address diversity in cohorts, diversity in assessment should also be considered. This is further supported when considering accreditation guidance. For example, ABET’s criteria in the United States for accrediting engineering programs [18] mentions a range of student outcomes including the ability to function effectively on a team and the ability to communicate effectively with a range of audiences together with curriculum outcomes including mathematics, engineering topics and completion of a major engineering design experience.

This discussion directly links to preparing a highly skilled engineering workforce prepared for 21st-century challenges, where there could be significant diversity in future job roles, careers, and teams. Reflecting on this, further evaluation of the success and suitability of different forms of assessment is an area for further investigation.

iii. Teamwork, formation and engagement

There is a significant amount of teamwork in engineering education, and in workshop discussions, many challenges associated with teamwork and solutions devised by participants to

overcome the challenges identified were discussed. Firstly, the importance of building diverse and inclusive teams, where students from marginalized genders and racial/ethnic groups are not isolated, was stressed. While it was clear that all participants worked towards creating diverse and inclusive teams, further investigation into student perception of these teams, their roles within their team, and the success of their team could be investigated further.

Another significant challenge identified in teamwork was the issue of dealing with lack of engagement among team members. Various ideas were shared on how to tackle this ranging from formative or summative peer feedback, external mediation and team contracts. The importance of reflection, not only of technical work but also of teamwork, was discussed to address engagement in teamwork. From discussions it was clear that all engineering education academics work towards attempting to deal with this, following various options depending on project, course and experience. Again, future work into examining how efforts that have been made by academics to address lack of engagement have been received is an area for further investigation.

iv. Technical and professional skills development

Following on from the themes addressed in previous sub-sections, the importance of both technical and professional skills was acknowledged by all participants and yet the vast scope of what is considered under these themes is a challenge continually being addressed by educators. As already outlined, accreditation guidance addresses not only technical, but also professional skill development [18]. Workshop discussions focused significantly on professional skills, such as teamwork, as already identified, as well as communication and project management. In addition, the challenges of solving open-ended problems, what is recognized as a "successful" solution, and the value of learning from "unsuccessful" solutions in engineering were considered.

An extensive scoping review [19] was shared amongst participants, which illustrates the growing focus on professional skills in literature, particularly since the year 2000, not only on communication, teamwork, and project management but also leadership, problem-solving, and entrepreneurship. The review also examined trends in strategies for professional skill development with specific programs or courses, interactive learning strategies (such as co-operative learning and project-based learning), and use of technology being adopted with significantly increased frequency since 2010. These themes, together with diversity of assessment, are key to developing graduates prepared to go into diverse industries and job roles that they may encounter in the future and effectiveness of different strategies employed is an area for further investigation.

v. Navigating challenges at scale

Many participants mentioned a significant challenge dealing with large cohorts of students in courses, particularly in project and lab work settings. The challenges can range from ensuring valuable student-academic interaction occurs amongst large cohorts, developing diverse and scalable projects and labs, delivering effective feedback, which is manageable from an academic perspective, or simply a consideration of physical space limitations. The importance of investigating scaling of learning and good practice techniques from small to medium and large-scale student cohorts was of interest among many participants. The use of technology,

particularly AI, as a means of developing personalized feedback and learning opportunities, as a means of supporting large cohorts, was of significant interest. From participant discussions, it was clear that some AI tools to promote teamwork and large cohorts are under development [20]. The use of technology was identified as an area of further investigation with collaboration amongst engineering education academics with different specializations, from assessment, professional skill development, and technology skills needed to develop effective tools to address the challenges of large cohorts.

vi. Concluding thoughts

In summary, from workshop discussions, it was clear that there are many challenges in engineering education delivery that many of us are trying to address, developing different solutions based on our program, module, and experience. It was also acknowledged that there is no definitive approach and that we must learn from different situations to anticipate and address issues. Significant overlaps in areas of interest to investigate further in both locations, motivated by cross-institutional similarities and differences (refer to Table 1), that would be beneficial for further engagement. Overall, the importance of reflection of technical and professional skill development for academics and students, the use of AI to develop relevant tools, and the continued shared learning of teaching experience amongst engineering and education-focused academics were identified as significant areas to follow in future collaborations.

Starting Initiatives

As a result of these workshops, a few of the participating faculty and staff have begun to implement and develop ideas discussed further. For example, interventions of previous students sharing their experiences, comparable to those discussed in [14], were further developed thanks to the workshop best practice sharing. These interventions were included, not only at the start of the course, but were repeated at a significant turning point in the course where it has previously been observed that students struggle with course expectations. Furthermore, efforts to support incoming students through the opportunity to discuss with student panels of higher year students about their experiences of the program as well as more practical questions as discussed in [15] was initiated and further developed in another department. Student feedback indicated initial events were very successful amongst attending students and that repetition of such peer-to-peer learning events should be repeated. It is hoped that these initial actions to adopt and develop best practices shared amongst workshop participants have been replicated by other participants as relevant to their teaching and experience.

Future Work

This unique cross-institution collaboration was facilitated by shared interests in improving engineering education to meet the demands of a future workforce and this international funding source. More funding that facilitates networking and cross-country collaborations for engineering education innovations and translations across contexts is needed.

The next steps in this effort will continue to build on the momentum from this effort. First, we will continue to share these results with the communities who participated in the collaborative

inquiry workshops as well as the broader engineering communities at Cornell and UCL. Next, we plan to develop smaller working groups focused on developing shared resources, implementing shared ideas across contexts, and investigating what works, for whom, and why across the cultural and institutional contexts. This evaluation effort will take the form of a follow-up hybrid workshop at the UK institution where U.S. and UK project leads will meet in

Table 1: Contrasting similarities and differences observed by project leads and in workshop discussions.

Category	Cornell University	University College London
Focus of Efforts	Emphasis on broadening participation, experiential learning, and workforce development with an emerging10) EER focus.	Emphasis on access and retention, experiential learning, teamwork and assessment with aim to develop further EER presence and cross-institutional collaborations.
Typical student cohorts	DEI frameworks are guided by federal initiatives and legal frameworks; use of BLI (Black, Latino/a/x, Indigenous) terminology. The College of Engineering has ~50% women, which is much higher than U.S. undergraduate engineering enrollment nationally. BLI student enrollment is ~20% of undergraduates.	Up to ~50% overseas student cohort, approximately 10-40% women representation in different undergraduate engineering degree programs. Significant minority ethnic group representation and growing focus on widening access to higher education.
Class sizes	Medium cohorts of students (~80) within engineering majors with variation by engineering discipline.	Typically, large cohorts of students within departments (~150+),with some variation dependent on engineering discipline. Some faculty wide classes ~800+ students.
Teaching Track Academics and Differences in Role	Teaching faculty have defined roles with limited research expectations; tenure-track faculty in EER are relatively new and growing. A centralized teaching and learning center within the College of Engineering supports faculty development.	Teaching-focused faculty have well-defined career tracks with focus on teaching, assessment and student support leading to some efforts in EER. Centre for Engineering Education (CEE) focuses on EER and supports wider Faculty teaching-focused academics.
Funding Mechanisms and History of EER	Heavily dependent on competitive federal funding (e.g., NSF, NIH); relatively newer focus on EER, growing in prominence.	Faculty teaching-focused academics typically rely on small seeding grants, CEE academics involved in larger scale funding grants.
Accreditation	ABET accreditation focuses on defined student outcomes, including teamwork, communication, and problem-solving. Programs must demonstrate continuous improvement.	UK accreditation bodies (e.g., Engineering Council, IET, IChemE) emphasize evidence-based assessment of learning outcomes covering technical, practical and professional skills.
Professional Skills for Engineers focus	Communication, leadership, ethics, and entrepreneurship all emphasized across the curriculum through specific Centers and programs supported at the College-level.	Integrated Engineering Program at UCL focuses on project-based learning to enable students to graduate with not only technical skills but also advanced professional skills, an understanding of engineering design, context, impact and a shared identity.

small groups to discuss idea development and will conclude with a virtual seminar. Ideas will be further developed in a series of virtual focus group meetings to identify potential future pathways and further funding opportunities with the aim to develop cross-institutional and cultural collaborations further by expanding themes of interests and academics involved. The results of these efforts can lead to additional insights on international education collaborations as well as future opportunities to engage in efforts focused on developing the next generation of engineers.

Acknowledgements

The authors would like to thank the Cornell-UCL Global Strategic Collaboration Awards and the UCL Centre for Engineering Education for funding to support this effort. We also thank the workshop participants for their engagement and efforts to improve engineering education.

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