CONNECTING ACROSS DIFFERENCES TO DEVELOP ENGINEERING SOLUTIONS TO SUSTAINABILITY CHALLENGES

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ABSTRACT

Study abroad has long been promoted to aid the development of intercultural confidence, adaptability, and context awareness, necessary to work cross-culturally and in different environments. International travel, however, is increasingly at odds with the broader objectives of sustainability due to its climate impacts and uneven global availability. Collaborative online international learning (COIL) offers a potential solution to this issue, creating opportunities for students to engage with peers in a wide diversity of locations, increasingly reflective of contemporary team-based engineering environments. To provide students with an opportunity to collaborate globally, the Department of Engineering at Nottingham Trent University introduced a virtual Engineering Research Online Summer School (EROS International) in 2021. EROS International connected engineering undergraduate students across different disciplinary backgrounds from Canada, Malaysia, India, Taiwan, and the UK, to collaboratively complete a one-week sustainability challenge on energy consumption and energy management. Students worked in multi-cultural groups across different time zones supported by an academic mentor. This paper explored the outcomes of this project by drawing on evidence from students' pre- and post-activity self-assessments. At the beginning, students had little or no prior experience of sustainability in their engineering curriculum and limited understanding of engineering challenges associated with sustainable development. EROS International helped participants to increase their knowledge of sustainability and to recognise the importance of international collaboration for developing engineering solutions to sustainability problems. Students experienced challenges related to online and distributed workspaces but were also able to recognise the opportunities for sharing complementary knowledge, contextualising technical knowledge, and building strong communication skills.

KEYWORDS

Collaborative Online International Learning, Online International Learning, Connecting Globally, Sustainability, Standards: 1, 7, 8, 10

INTRODUCTION

In this paper we examine the potential for models of collaborative online international learning (COIL) to enhance Engineering education and facilitate the embedding of CDIO standards into the Engineering curriculum. Working in internationally and in culturally diverse teams has long been a feature of the work of Engineers, but connectivity has intensified and increasingly takes

place online, in remote offices and digitised workspaces, particularly since the start of the COVID-19 pandemic in 2020. Working in such environments requires confident intercultural communication skills, and this is reflected in the inclusion of such skills in the recommendations of accreditation agencies, such as the CDIO (Standards 7 and 8) and the Accreditation Board for Engineering and Technology (ABET). Collaborating in virtual environments also requires additional skills to navigate cultural differences through verbal and on-screen communication, while also managing time differences, varied levels of connectivity, and access to online communication platforms (Zaugg, and Davies, 2013).

Virtual Exchanges, such as those enabled by COIL initiatives, provide opportunities for students to gain international experience, develop intercultural awareness and global citizenship skills, as well as improving digital literacy (King de Ramirez, 2021; de Wit, 2016; Guth, 2013). The global pandemic has increased interest in this type of activity. Additionally, the need to address climate change and the carbon footprint of higher education institutions, and a continued desire to improve equity in access to international experiences, will likely sustain interest in the possibilities of international learning independent of mobility in the longer-term (Ward 2017; Leask and Green, 2020; Kahn, 2020; Munoz de Escalona et al., 2019). While there is a growing body of evidence to indicate the possibilities for intercultural learning via virtual exchanges, there has been much less attention to the benefits of online international collaboration for knowledge development in specific disciplinary fields, such as engineering.

Evidence from studies of collaborative learning highlights that collaborative settings create opportunities for students to develop effective communication skills as well as richer understandings of engineering problems, as students are encouraged to listen, learn, reflect, and critically appraise new and established knowledges. CDIO Standard 8 recognises the importance of such active learning styles that mimic the engineering workplace, requiring students to develop and apply knowledge with the goal of solving a specific problem.

In this paper, we explore the outcomes of EROS International, an optional study module developed by the Department of Engineering at Nottingham Trent University to provide opportunities for NTU students to experience international collaboration and for partnership students to experience teaching and learning at NTU before engaging in longer-term exchange or study abroad. EROS International was first introduced in Summer of 2021 and brought together students in five countries to work collaboratively to complete a one-week sustainability challenge on energy consumption and energy management. This focus on sustainability provided participating students opportunity to use the collaborative mode to share and exchange knowledge but also to consider responses some of the challenges future engineers will be required to address. Drawing on evidence from student pre- and post-activity self-assessments and a faculty focus group, we reflect on if collaborative online international learning can enhance engineering students' knowledge of sustainability in national and global contexts, whilst also building confidence to design and test engineering solutions in culturally diverse and geographically distant locations, characteristics that are in alignment with a CDIO-based education.

METHODS

The Project

In 2021, the Department of Engineering (DoE) at Nottingham Trent University (NTU) established a virtual Engineering Research Online Summer School (EROS International) to connect engineering undergraduate students with different disciplinary backgrounds from across the globe to collaboratively complete a one-week sustainability challenge. The aim of the activity was to provide an opportunity for NTU students to connect with partner students to develop their international perspectives on engineering, to enhance their intercultural communication skills, and to use the opportunity to enthuse engineering students in the topic of sustainability. Although the activity was not co-designed with teaching staff at partner institutions, as is typical of COIL projects, it was developed by NTU staff from multiple engineering backgrounds and involved academics at partner institutions in the delivery of guest lectures. A total number of 45 students participated in EROS International. Participating students came from five different partner institutions in five countries, which enhanced the opportunity for each student to collaborate with peers from a wider range of backgrounds than is normally possible with bi-lateral COIL projects. To encourage collaboration and active learning from diversity, students from the United Kingdom (NTU), Malaysia, Canada, India, and Taiwan were separated into groups of five. Each group contained representatives from different participating countries and different disciplinary backgrounds (Table 1). Hence, students worked in both multi-cultural and multi-disciplinary groups across different time zones.

Table 1: Participants for EROS International in 2021.

Country	**Participants [#]**
Taiwan	2
Malaysia	6
India	1
Canada	11
United Kingdom	25
Academic Background	**Participants [#]**
Mechanical Engineering	7
Biomedical Engineering	11
Electronic Engineering	3
Sport Engineering	4
Aerospace Engineering	6
Computer Engineering	7
Polymer Engineering	2
Electrical Engineering	1
Engineering	2
Intelligent Systems and Automation Engineering	2

During this one-week sustainability challenge, each group was supported by an academic mentor who met with the group daily to discuss the groups' progress and to guide students through the tasks they were given. Through NTU's Blackboard-based virtual learning platform, groups were provided with a range of sustainability problems around energy management and energy consumption from which they had to choose one topic. This topic was then researched

by the teams to identify the background of the current problem, current solutions, and their limitations; to then develop a novel engineering solution. Students researched on energy storage technologies for future power grid, the potential of artificial photosynthesis as a sustainable energy source, nuclear energy as a sustainable energy source for future generation, space-based power stations for renewable/non-renewable energy, among others. Students' research and learning were underpinned through international guest speakers (synchronous and asynchronous), a carbon literacy training and energy management game (both synchronous) spread over the weeks' programme. The group's findings were then presented as power point presentation at the "EROS International Showcase" on the final day to share and discuss findings and innovative solutions with all peers and academic mentors (synchronous). Students completing the required work were awarded a digital badge that they could share on social media platforms, including LinkedIn. All interaction between academic mentors, students and guest speakers took place on MS TEAMS. Channels were set up in the EROS International MS TEAMS team to facilitate communication among group members. Students also chose to communicate via social media platforms and email.

EROS International coincided with NTU's Global Summer School, which in 2021 was offered exclusively online. Hence, EROS International participants were able to join over 400 students from 44 countries in a comprehensive social and cultural programme, which included an intercultural communication workshop.

The evaluation methods

Pre-and post-activity self-assessments were carried out via MS Forms, where students were asked to answer several graded, non-graded and open-ended questions to reflect on their own knowledge and understanding of sustainability in Engineering, prior and post EROS International. Additionally, students were asked to provide feedback about their experience after completion of the sustainability challenge. Completion of the pre-and post-activity questionnaires was voluntary and had no influence on participation in EROS International. All contributions were anonymised to ensure confidentiality of responses. Approximately 53% of participants took part in the pre-activity and around 29% in the post-activity self-assessment (Table 2).

Table 2: Responses of participants who completed pre-and post-activity questionnaires.

Country	Pre-Activity (# Responses)	Post-Activity (# Responses)
Malaysia	6	5
India	1	1
Taiwan	2	0
Canada	6	2
United Kingdom	9	2
Unknown	0	3
Total (Number)	**24**	**13**

PROJECT OUTCOME

Integrated learning experiences through COIL

Most virtual exchanges focus on the development of intercultural competencies and other non-discipline specific knowledges such as those associated with global citizenship, though it is acknowledged that COIL projects have the capacity to broaden and deepen understanding of course content (Guth, 2013). Ramírez's (2019) study of a COIL project involving second language students at institutions on both sides of the US-Mexico border, for instance, reports how students who initially knew very little about their neighbouring countries increased their intercultural confidence; and developed knowledge of each other's countries and the past and present socioeconomic connections between them. While this type of knowledge was an important part of the ambition for EROS International, the aim was to also use collaborative international working to deepen students' specific understandings of the significance of sustainability for engineers and engineering. As set out in CDIO Standard 7, the intention was to achieve personal development in tandem with knowledge development. The intention was further that students should not simply use the activity to learn more about other places but to also use their encounters with other places to reflect on their own contexts for engaging with sustainability.

When students were asked about how knowledgeable they were about general sustainability issues and sustainability issues relating Engineering prior to EROS International, most participants replied, "not at all", "slightly" or "somewhat", though this varied by country (Figure 1). Around 66% (16/24) of students reported being "not at all knowledgeable" or only "slightly knowledgeable" of the specific issues of energy management in their home country, with much less variation by region observable. Despite their lack of confidence in their knowledge, students appeared to have good general understanding about sustainability. Students reported having studied polymer degradation, plastic recycling/reuse; clean energy sources and materials; carbon footprint and the United Nations (UN) Sustainable Development Goals (SDGs), in both core and elective modules. Results from the pre-activity survey revealed that 58% of all participating students did not have prior knowledge of sustainability through their engineering curriculum, which may help explain a lack of confidence in some students (Table 3). Most students from the UK were exposed to general sustainability issues through their undergraduate studies, followed by Canada and Malaysia.

Table 3: Assessment of understanding and knowledge of Sustainability through the Engineering Curriculum.

Country	Positive Responses [#]	Negative Responses [#]	Positive Responses [%]
Malaysia	2	4	33
India	0	1	0.0
Taiwan	0	2	0.0
Canada	2	4	33
UK	6	3	67
Overall	**10**	**14**	**42**

Despite the short duration of the course, students reported feeling much more knowledgeable about sustainability issues, both in general and as related to engineering after their week of

study (Figure 1). After the activity, around 90% of participants reported a “moderate” or “extreme” level of knowledge for each general and engineering sustainability, no students reported this level of confidence in their knowledge in the pre-activity survey.

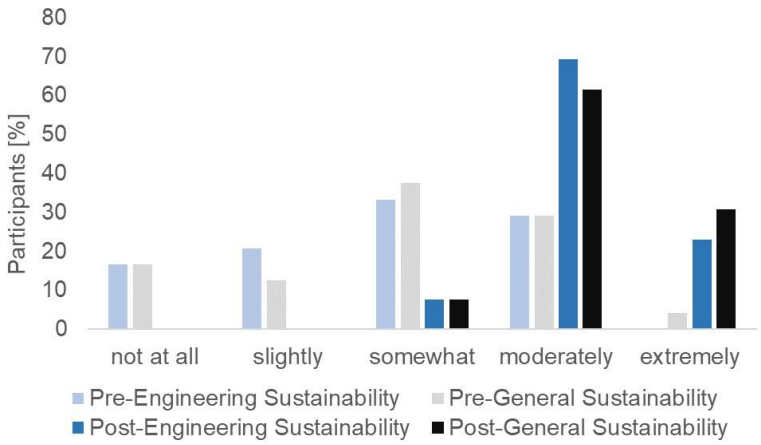

Figure 1: Knowledge level of participants. Knowledge and understanding of general and engineering sustainability issues prior and post EROS International.

One example that helped students increase their sustainability knowledge was the energy management game. During the game, students within their groups were tasked to build a 24-hour energy profile using price information from a Smart Meter. Students had to discuss within their groups the use of base loads (e.g., TV), cooking loads (e.g., rice cooker), wet loads (e.g., washing machine), heating loads (e.g., radiators) and cold loads (e.g., fridge) based on their own energy consumption behavior throughout the day (Figure 2). Energy profiles from all groups were compared and the team with the lowest overall energy price and carbon footprint won.

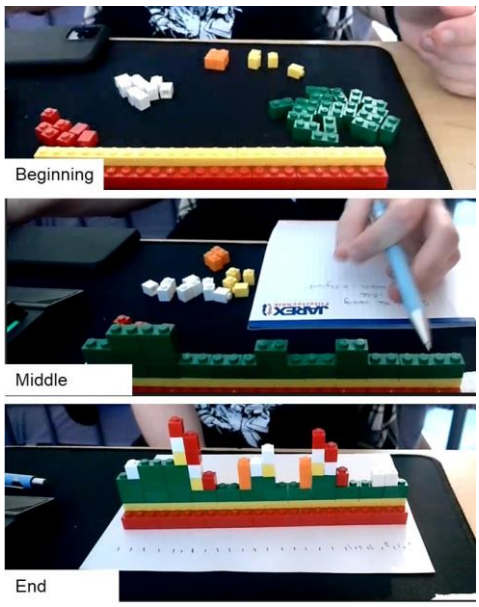

Figure 2: Energy management game. Students within their groups build energy profiles based on their own energy consumption behavior. Students used building bricks as energy units.

To provide insight into how students understood sustainable engineering problems, participating students were asked pre- and post-activity to reflect on what they thought an engineer should consider when working on sustainability challenges (Figure 3). Pre-activity, 58% of students reported that non-Engineering knowledge should be considered “Often” or “Always” in Engineering projects but 42% suggested this was necessary only ‘Rarely’ or ‘Sometimes’. Post-activity 92% of students felt it was ‘Often’ or ‘Always’ necessary for engineers to consider non-Engineering knowledge when considering engineering solutions to sustainability challenges. A similar pattern was evident in views on the importance of non-technical issues, with students being more aware of the value of taking account of non-technical issues post-activity. These findings suggest an increased acknowledgement amongst students for the need for engineers to take account of a breadth of information when seeking solutions to complex and integrated problems. This openness to multiple knowledges and sources of knowledge is a feature of global citizenship but also associated with contextualizing the work of engineers. This broadening of student understanding of what constitutes relevant engineering knowledge is further reinforced by shifts in student evaluation of the importance of both local and global contexts to engineers working on sustainability challenges, both of which students reported as more important post-activity than they had before they joined the programme. Potential features of the external contexts in which engineering challenges are situated include political and social issues, factors that STEM disciplines have traditionally excluded or downplayed in relevance. Yet, having competed EROS International, student views moved significantly on the relative importance of political and social issues, indicating, as Mejtoft, et al (2021) suggest “that international online collaboration between engineering students "addresses issues as cultural differences, the roles of the engineer in a larger context and also touches upon the impact of engineering on other parts of the economic and societal system” (203).

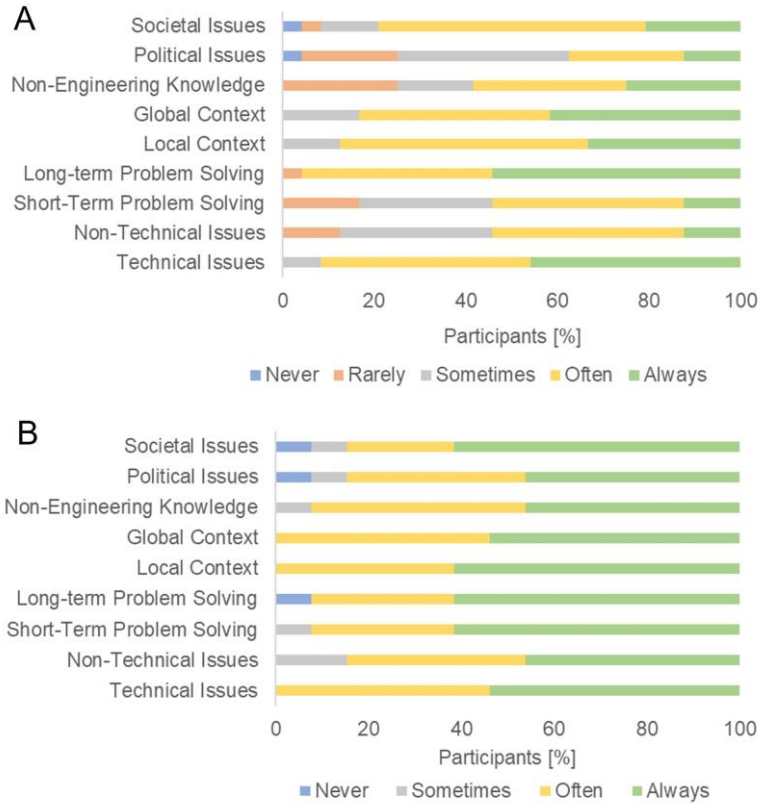

Figure 3: When working on solutions for sustainability problems, engineers should consider a variety of areas. Responses of students before (A) and after (B) participation in the activity.

Awareness of benefits and challenges of international collaboration

The evidence to suggest students were more open to contextualising engineering practice was also complemented by a shift in the perceived importance of collaboration to solve engineering problems. Prior to the activity, students felt that engineers should collaborate internationally "sometimes "(~8%), "often" (~54%) or "always" (~38%). A clear shift was observed post-activity when more than 50% of participants recognised the need to "always" collaborate (Figure 4).

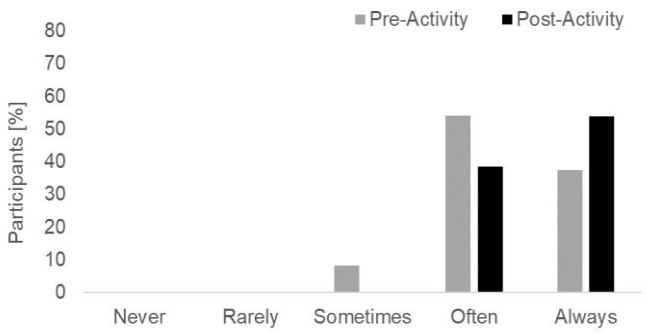

Figure 4: The need for Engineers to collaborate internationally to solve sustainability problems.

One of the key benefits of engaging with cultural diversity through Virtual Exchanges and COIL projects is that they provide opportunities for students to learn from different perspectives, to have previously held knowledge qualified in relation to both the challenge under consideration and the different contexts in which it is being explored. Even pre-activity students from all countries were aware of the benefits of international collaboration for sharing resources, knowledge, data, capabilities and perspectives. They also suggested collaboration was key to longer-term solutions and effective problem solving. Some of the benefits to collaboration that students noted, such as cultural and country differences, also appeared in responses to the question regarding the challenges of collaboration. This suggests students were aware of the benefits of working across different cultures and contexts to better understanding engineering challenges but recognised that working across different knowledge systems was not always easy, particularly with additional challenges around the practicalities of communication – of time zones, communication technology, language etc. (Figure 5). The post-activity survey did not include questions designed to encourage students to explore the issue of collaboration in relation to their own experience though EROS International. This would have been a useful insight for evaluating the success of the programme and will be included in future post-course evaluations.

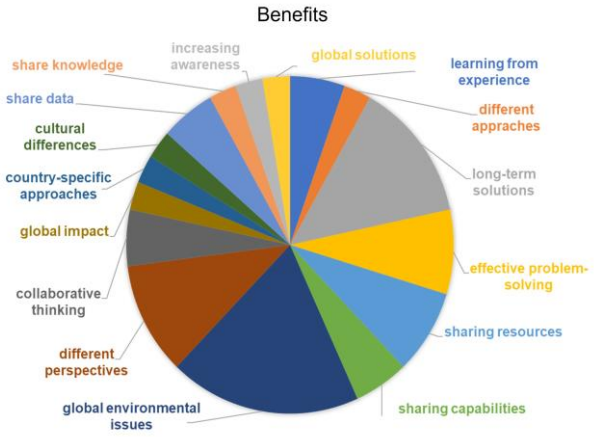

Figure 5: Benefits of engineers collaborating internationally on sustainability problems. Combined responses of students from the pre-and post-activity survey.

In addition to understanding the significance of international collaboration for engineers as professionals, working on sustainability, findings also pointed to students increased appreciation of the importance of taking account of sustainability issues in their daily life. Sustainability impacted decisions for daily life in almost all participants either “often” or “always” prior (~53%) and post (~99%) EROS International (Figure 6).

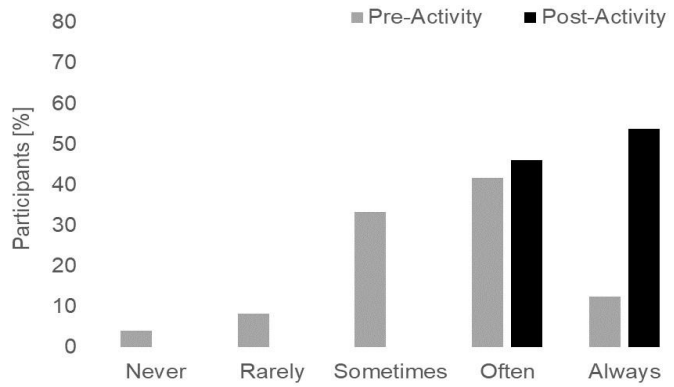

Figure 6: Impact of sustainability on decisions of daily life.

Enhancing faculty competencies in providing integrated learning experiences

CDIO Standard 10 recognizes the specific importance of opportunities for engineering staff to develop and improve competencies in new approaches to integrated and active learning. The shift to online delivery necessitated by responses to COVID-19 has required staff to rapidly develop confidence in navigating online communication platforms and to employ new approaches to content delivery and student engagement. COIL projects, however, require staff to have competence in digital, collaborative, and international pedagogies.

The organisation and delivery of EROS International brought together a team of academics from different engineering disciplines, namely Biomedical, Mechanical, Electronic and Electrical Engineering, many with different cultural backgrounds e.g., German, Sri Lankan, Pakistani, Iranian and British. This facilitated collaboration, as well as cross-disciplinary and intercultural communication among staff.

Since students were experiencing similar situations and challenges within their groups, staff members were able to better relate to students and guide them during the daily mentor meetings. Since different activities were led by different academics, staff were able to take responsibility and gaining leadership creating a sense of belonging. Additionally, one of the main challenges experienced by staff, was to timetable synchronous sessions, e.g., guest lectures, games and the showcase, so that students' attendance and staffs' session delivery was possible at reasonable times. On the other hand, daily mentor sessions and the showcase on the final day proved to be some of the highlights of the activity. These sessions provided opportunities for staff and students to learn from each other about engineering concepts, solutions, but also about cultural differences and customs.

EROS International provided a virtual field trip for students and staff alike. It enhanced staff's ability to communicate across differences, sharpened the awareness for different educational needs and backgrounds, and provided the opportunity to hone skills for navigating challenging situations in the virtual classroom.

CONCLUSIONS

The EROS International activity discussed in this paper was short in duration and limited to a small number of participants (<50 students), however, it provided a valuable pilot for exploring the potential of online international learning pedagogies for developing specific skills and aptitudes required by professional engineers. Combing collaboration with online and international engagement creates scope for enhancing group-working skills, developing intercultural confidence and building digital literacy in a context of multiple practical challenges. In addition, as this project demonstrates, with its focus on sustainable engineering challenges, such activities also have the potential to create opportunities for students to develop their knowledge and their ability to apply it in different contexts.

The Engineering Department at NTU plans to develop their online international programme with a continued focus on sustainability challenges. To deepen the international collaborative dimensions, faculty at international partners will be more actively involved in design and delivery, further embedding comparative and diverse content and perspectives. The pre- and post-activity surveys will also be developed to better enable students to reflect on their own learning through the programme, support them to articulate their skills to future employers.

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