Asnaashari, E., & Sagoo, A., (2025). Collaborative Online International Learning: A Catalyst for Advancing Lean Construction Education. In O. Seppänen, L. Koskela, & K. Murata (Eds.), *Proceedings of the 33rd Annual Conference of the International Group for Lean Construction* (IGLC33) (pp. 1516–1527). https://doi.org/10.24928/2025/0186

COLLABORATIVE ONLINE INTERNATIONAL LEARNING: A CATALYST FOR ADVANCING LEAN CONSTRUCTION EDUCATION

Ehsan Asnaashari[1] and Amrit Sagoo[2]

ABSTRACT

This paper explores the implementation and impact of Collaborative Online International Learning (COIL) as a pedagogical approach to enhance Lean construction education. COIL facilitates collaboration between students from geographically diverse institutions through joint projects, promoting international engagement without the need for physical mobility. Two case studies are presented, involving Nottingham Trent University (UK) students collaborating with partner universities in India (2022) and South Africa (2023), to demonstrate how COIL projects were designed and executed to support the global application of Lean principles. Working in international teams, students applied Lean to identify and reduce various forms of waste on live construction sites. Their digital collaboration, captured through Miro boards, along with reflective reports, was analysed to evaluate the learning experience. Findings indicate that the structured COIL approach improved students' understanding of Lean concepts and the UN Sustainable Development Goals (SDGs), while also strengthening key skills such as teamwork, resilience, and digital literacy. Despite challenges, including time zone differences, uneven levels of participation, and technological barriers, the projects highlight COIL's potential to instil a sense of ownership in students' learning and support their personal and professional growth. This paper demonstrates how a do-it-yourself (DIY) learning environment can successfully foster international collaboration and promote Lean Construction education within a globally diverse academic community.

KEYWORDS

Collaboration, pedagogy, sustainability, waste, virtual exchange.

INTRODUCTION

Collaborative Online International Learning (COIL) is an innovative framework that enables students from different countries to engage in structured online interactions, thereby removing traditional travel barriers (Vahed & Rodriguez, 2020; Wood et al., 2022). Developed at the State University of New York (SUNY) COIL Center (2024), the model focuses on equitable partnerships, shared learning outcomes, intercultural competencies, and digital platforms to facilitate meaningful cross-border collaborations. Evidence suggests that COIL improves intercultural awareness, broadens global engagement, and supports both personal and professional development (Vahed & Rodriguez, 2020; Huertas-Abril & Palacios-Hidalgo,

1 Senior Lecturer, Construction Management Department, Chair, ADBE Digital & AI Working Group, Nottingham Trent University, Nottingham, UK, ehsan.asnaashari@ntu.ac.uk, orcid.org/0000-0001-5552-9428
2 Head of Department, Construction Management Department, Nottingham Trent University, Nottingham, UK, amrit.sagoo@ntu.ac.uk, orcid.org/0009-0005-7619-3288

2023), aligning closely with the concept of internationalising curricula and exposing learners to diverse viewpoints (Wihlborg et al., 2018).

COIL projects often focus on global challenges, making sustainability a highly relevant and fitting theme. Tackling issues like climate change demands an international perspective that goes beyond national borders. COIL provides students with the opportunity to collaborate with peers from around the world on real-world problems that impact all of humanity. The construction sector generated 61% of UK waste in 2020 (Department for Environment & Food & Rural Affairs, 2024) and continues to lag behind other industries in terms of productivity (Office for National Statistics, 2021). COIL projects offer students a valuable opportunity to explore these real-world challenges, focusing on enhancing value across the supply chain and promoting long-term sustainability. By simulating the multicultural, cross-border teams typical of large-scale construction projects, COIL also reinforces the importance of collaboration, an essential component of Lean construction.

Despite extensive research on COIL over the past two decades, its potential within Lean construction education remains largely untapped. While successful initiatives like Administering and Playing Lean Simulations Online (APLSO) have fostered a global community of Lean enthusiasts sharing good practices in game-based learning (Rybkowski et al., 2021), a review of the IGLC database shows no recorded use of COIL. This gap underscores the need for Lean educators to adopt COIL to prepare students for international collaboration. This paper aims to promote COIL as a pedagogical tool for sharing Lean construction principles with the wider academic community and with students across different countries and disciplines. Featuring case studies from India and South Africa, the paper highlights practical applications, discusses key challenges, and introduces a do-it-yourself (DIY) learning environment to support international student collaboration.

BENEFITS AND CHALLENGES OF COIL

COIL has gained prominence in higher education for its ability to foster global learning experiences and enrich both students' and academic staff's learning. By enabling international peer interaction, shared online activities, and exposure to diverse cultures, COIL effectively enhances students' intercultural competence (Gutiérrez-González et al., 2023; Huertas-Abril & Palacios-Hidalgo, 2024; Kiegaldie et al., 2022; Vahed & Rodriguez, 2020). Empirical studies show that these COIL significantly improve student performance in project-based tasks and problem-solving (Appiah-Kubi & Annan, 2020; Hackett et al., 2023; Munoz-Escalona et al., 2022; Vahed & Rodriguez, 2020). Moreover, the inclusion of culturally diverse teams broadens students' perspectives, enriching subject matter understanding and boosting their communication and negotiation skills (Appiah-Kubi & Annan, 2020; Soetanto et al., 2015). Consequently, students gain confidence, adaptability, and global awareness—competencies highly valued in modern workplaces (O'Dowd, 2021; Sierra et al., 2022).

Despite its advantages, COIL implementation faces multiple challenges. Securing a suitable institutional partner emerges as one of the most critical hurdles, often demanding alignment of course objectives and learning outcomes (Appiah-Kubi & Annan, 2020). Moreover, time zone differences, varying academic calendars, and language barriers can complicate synchronous interactions, while cultural differences can impede communication and collaboration (Kiegaldie et al., 2022; Rahmawati et al., 2022). Technological limitations, including inadequate internet access or unfamiliarity with digital tools, pose additional constraints, particularly in resource-limited settings (Munoz-Escalona et al., 2022). Effective COIL implementation also requires significant effort from educators, encompassing careful planning, coordination of learning activities, and clear guidelines for assessment (Rahmawati et al., 2022). Institutional commitment plays a pivotal role in integrating COIL into existing curricula, necessitating both top-down support and bottom-up enthusiasm. Buy-in at the departmental and

school levels, as well as professional development opportunities focused on COIL pedagogy, are essential for sustainability and scaling (Wihlborg et al., 2018). Overall, overcoming these obstacles hinges on strategic planning and innovation, with digital technologies creating supportive environments for meaningful cross-border learning. By addressing pedagogical differences, recognising varied communication preferences, and demonstrating strong institutional commitment, COIL can offer transformative, globally oriented education that prepares students for the international job market (Soetanto et al., 2015).

COIL IN THE BUILT ENVIRONMENT DISCIPLINE

The application of COIL within the built environment discipline demonstrates its effectiveness in bridging geographical and cultural gaps while fostering innovation. In one instance, architecture and civil engineering students from diverse universities collaboratively designed a viewing deck roof, blending aesthetic, structural, and durability considerations through virtual whiteboards and 3D modelling software (Rahmawati et al., 2022). Another example paired engineering technology students from the University of Dayton with materials science and engineering students from the University of Ghana, creating a culturally diverse learning environment that facilitated project-based collaboration and interpersonal skill development (Appiah-Kubi & Annan, 2020). A further COIL initiative united architectural science students from Ryerson University with civil engineering students from Coventry University, simulating real-world industry practices through local cost data analysis, building code research, and a BIM-enabled portal (Poh et al., 2018). This experience exposed students to varied architectural, engineering, and construction approaches. Finally, a partnership between An-Najah University in Palestine and Memphis University in the USA focused on designing a sustainable community centre that accounted for cultural context, climate, and international codes (Ryosuke & Kazuma, 2024). Collectively, these studies affirm COIL's capacity to enrich built environment education, promote sustainable design, and enhance students' global competencies.

LEAN AND SUSTAINABILITY AS A THEME FOR COIL

This section explains the rationale for selecting waste as the central theme of the COIL project and explores its connection to sustainability. Waste identification and minimisation are critical in Lean construction because they reveal inefficiencies that consume resources without adding value, thereby undermining productivity and profitability (Dazmiri & Hamzeh, 2023; Koskela et al., 2023). While traditional construction typically focuses on physical waste, expanding the definition to include non-physical factors such as administrative burdens, poor decision-making, and unclear workflows allows Lean practitioners to identify systemic issues more accurately (Sarhan et al., 2019). Although physical waste often takes precedence in construction, conceptualising waste in multifaceted ways creates a more robust framework for improvement (Koskela et al., 2012). A broader perspective fosters a holistic approach to waste reduction and aligns with sustainability goals, yet it remains underutilised in both academic and industrial settings, often treated as a niche rather than a mainstream principle (Koskela et al., 2012). To address this gap, emerging frameworks recommend systematic stages, such as Problem Identification, Value Stream Mapping, Development of Interventions, and Simulation and Validation (Dazmiri & Hamzeh, 2023). This approach was partially implemented in two COIL project case studies, providing a structured workflow that guided students through each task.

Lean waste was selected as the central theme for the COIL projects because it serves as a gateway to understanding other foundational Lean concepts, particularly those related to flow, collaboration, and value. Concepts like just-in-time (JIT) can be more readily understood when connected to transportation and motion waste (Hasan et al., 2024), while tools such as the Last Planner System illustrate the broader principle of flow and provide a structured method for pinpointing the root causes of inefficiencies (Aisyah et al., 2023). Similarly, collaborative

models like Integrated Project Delivery (IPD) encourage shared responsibility for reducing waste (Bølviken & Koskela, 2016), and Lean leadership fosters a deeper understanding of continuous improvement, guiding practitioners away from reactive "firefighting" and toward a more preventative, systematic mindset (Bølviken & Koskela, 2016). Furthermore, Value Stream Mapping (VSM) supports these efforts by visualising the current state, highlighting problem areas such as prolonged lead times and negative iterations (Dazmiri & Hamzeh, 2023). Therefore, selecting waste as a theme enabled educators to guide students in application of Lean construction concepts and tools to address live issues in construction projects.

Focusing on the identification and elimination of Lean waste also establishes a link to sustainability. Sustainability is a fitting theme for COIL, as addressing its challenges requires global collaboration and cross-cultural understanding. Several authors have argued that the synergy between Lean Thinking and sustainability stems from their shared emphasis on resource efficiency and waste minimisation (Francis & Thomas, 2020; Purushothaman et al., 2020; Waheed et al., 2024). Although their interpretation may be somewhat misleading, given that the primary focus of Lean is on flow, the connection between Lean and sustainability remains a valuable argument. While Lean centres on eliminating non-value-adding activities for customers (de Carvalho et al., 2017), sustainability emphasises reducing the environmental, social, and economic impacts of construction processes. While some researchers argued that eliminating Ohno's seven wastes does not necessarily address environmental and social waste (Arroyo & Gonzalez, 2016), others have shown that Lean practices can directly advance environmental sustainability. For instance, Lean can minimise resource consumption by reducing overproduction and overprocessing, decrease emissions by limiting transportation and motion, and lower pollution through defect reduction and inventory control (Francis & Thomas, 2020). Furthermore, Hasan et al. (2024) found that SDGs focused on clean water, sanitation, clean energy, decent work, infrastructure, sustainable cities, responsible production, and ecosystem conservation collectively have 63 "extremely important" linkages and 251 "very important" linkages with Lean construction principles. They discussed that waste minimisation is directly aligned with SDG 12 (Responsible Consumption and Production) and SDG 11 (Sustainable Cities and Communities), underscoring the significant contributions Lean can make to global sustainability objectives. These findings underscore the importance of waste identification and minimisation, laying a solid foundation for the COIL project. By focusing on waste reduction, students can deepen their understanding of Lean concepts and discover how Lean strategies foster sustainable construction outcomes.

OVERVIEW OF THE COIL PROJECTS

This study examines two COIL projects aimed at achieving zero Lean waste in construction. In 2022, students from Nottingham Trent University (NTU) collaborated with their peers from NICMAR University in India over 12 weeks, involving 70 students and 10 staff members from both institutions. The project was replicated in 2023 with the University of Johannesburg in South Africa, engaging 89 students and 5 staff members across the two universities. The projects aimed to deepen students' understanding of Lean principles and the connection between Lean and sustainability through practical DIY learning environment. In each COIL project, students from both institutions formed eight joint teams, with each team focusing on a specific type of Lean waste: Transportation, Inventory, Motion, Waiting, Overproduction, Overprocessing, Defects, or Unused Skills.

Miro, an online collaborative whiteboarding platform, served as the project's virtual workspace, enabling international collaboration. Miro addressed common COIL challenges associated with time zone differences and conflicting academic calendars by providing an accessible space for synchronous and asynchronous teamwork. A dedicated Miro board was created for each team, enabling students to collaborate, upload their materials, and ultimately

present their work. Additionally, to improve accessibility for students at both universities and minimise the challenges of using two separate virtual learning environments, educators created a "Learning Hub" on Miro before initiating the project. This centralised platform provided access to the project brief, learning materials, online sessions recordings, and submission requirements (Figure 1). At NTU, the COIL served as a summative assessment for the Lean Construction MSc module, requiring students to submit a themed Miro board (group submission) and an individual reflective report, collectively contributing 60% of the overall module grade.

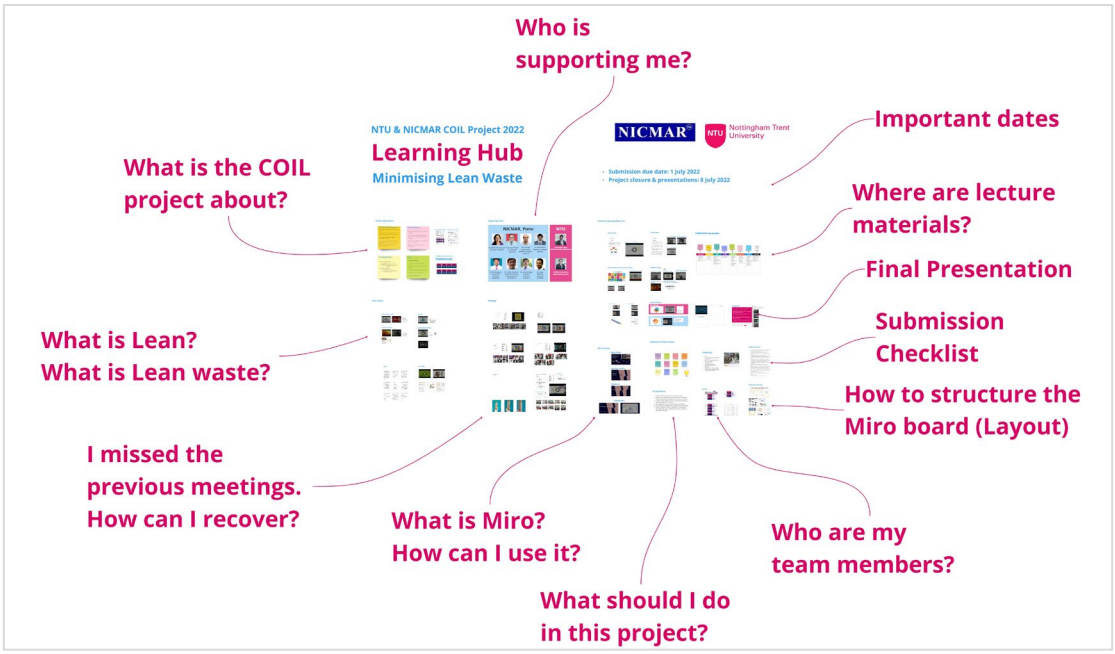

Figure 1: Learning Hub (India Project)

The main project tasks for students included several key stages:

1. Teams conducted a literature review to develop an understanding of their assigned type of Lean waste. Students were required to define both "value" and "waste" in the context of their research. At this stage, students also deepened their understanding of the connection between Lean principles and the UN SDGs by reviewing existing literature.
2. Partner university students collected data from live construction sites, capturing examples of the specific type of waste allocated to their team. These images, along with relevant metadata, were uploaded to the dedicated Miro board for analysis by NTU students. In some cases, students conducted interviews with site staff too.
3. NTU students applied visual analysis techniques to examine the site photos and identify instances of waste. They then used analytical tools such as the Fishbone Diagram and the 5 Whys method to explore the root causes of the problems.
4. Based on their analysis, students developed context-specific solutions aimed at reducing or eliminating the identified waste, applying Lean construction principles throughout.
5. Each group mapped their type of waste to relevant UN SDGs and discussed how their proposed solutions contribute to advancing those goals.
6. As a formative assessment, each team delivered a seven-minute presentation of their solutions, which was evaluated by academics from both universities.

Three online joint sessions were held to support project coordination, covering project startup, progress checkpoints, and final presentations. An additional workshop guided partner students on Lean waste types and effective data collection from live construction sites.

METHOD

To reflect on the effectiveness of the COIL project, student-created Miro boards were analysed using a thematic analysis approach tailored for visual data. This analysis focused on how students visually arranged and structured information to construct a DIY learning environment and how they applied Lean principles and tools to solve real-world problems. Additionally, thematic analysis was conducted on students' individual reflective reports. An inductive coding approach was adopted to capture unique student perspectives and provide deeper insights into the project's impact on learning. In the thematic analysis, six steps were followed: data familiarisation, generation of initial codes, searching for themes, reviewing and refining themes, defining and naming themes, and finally, producing the report.

MIRO BOARDS VISUAL ANALYSIS

Students displayed creativity in their Miro board designs, producing diverse, innovative layouts to examine Lean waste. Despite stylistic variations, a typical board was structured into seven core sections: (1) Team Profile and RACI Matrix, (2) Definition and Examples of Waste, (3) Sustainability Study and SDG Mapping, (4) Visual Assets and Data, (5) Root Cause Analysis, (6) Recommendations and Solutions, and (7) +Delta Table (Figure 2).

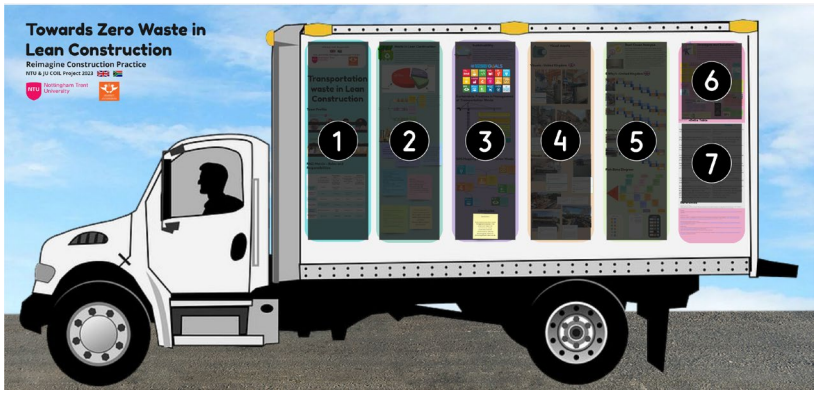

Figure 2: Transportation waste Miro board submitted by students (South Africa project)

Students self-constructed the literature section of their Miro boards, typically beginning with a brief explanation of Mura, Muri, and Muda, before narrowing the focus to their allocated type of Lean waste. A commonly used tool was the mind map, which students used to visually present causes of waste, examples, and potential consequences (Figure 3).

Figure 3: Innovative layout and Learning Ownership - Unused Skills (South Africa project)

Some teams incorporated case studies to support their arguments, while others used external video sources, cartoons, and graphics to help clarify key ideas and communicate their message more effectively. Figure 3 illustrates how students demonstrated ownership of their learning by creatively designing the layout and structure of their learning space, rather than relying solely on instructor-provided resources. However, the depth of the literature review was generally shallow, likely due to a limited understanding of what constitutes a strong academic review. Many students did not adequately evaluate or synthesise high-quality academic sources. Additionally, citation practices were inconsistent, suggesting that students placed greater emphasis on visual representation than on academic content and rigour.

The second task required students to conduct a visual data analysis using photos from live construction sites provided by their partner students, which enhanced their skill to "see waste". As shown in Figure 4, students identified issues such as poor ergonomics and unnecessary movement when analysing photos associated with motion waste. The use of annotated images and the practice of highlighting specific areas within the photos promoted critical thinking and problem-solving, making the task both engaging and highly relevant to real industry challenges.

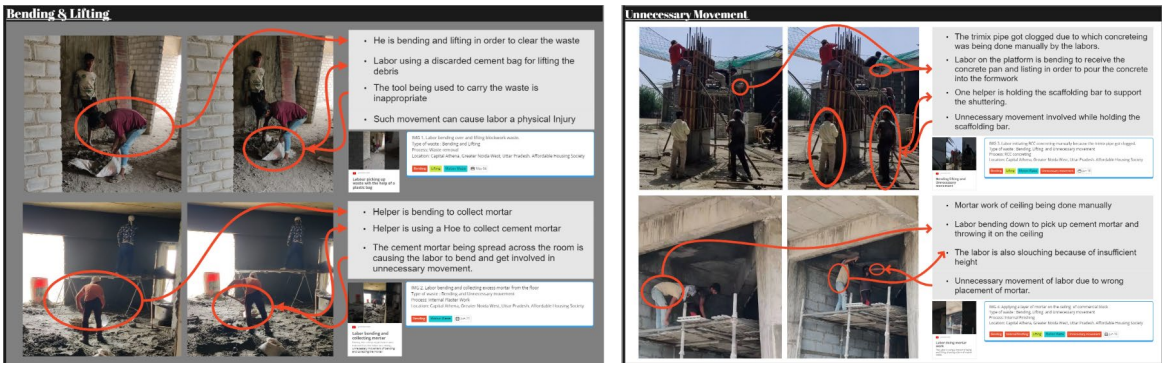

Figure 4: Examples of visual data analysis to identify waste (India project)

The third task focused on root cause analysis, aimed at identifying underlying issues to prevent their recurrence. All teams applied both the Fishbone Diagram and the 5 Whys technique as structured problem-solving tools. The Fishbone Diagram helped categorise potential causes, providing a comprehensive overview of contributing factors, while the 5 Whys technique enabled deeper investigation into core issues. As shown in Figure 5, students identified lack of training and Push Planning as root causes of improper concrete compaction. This exercise encouraged students to move beyond treating symptoms and focus instead on addressing root causes, forming the foundation for continuous improvement in construction.

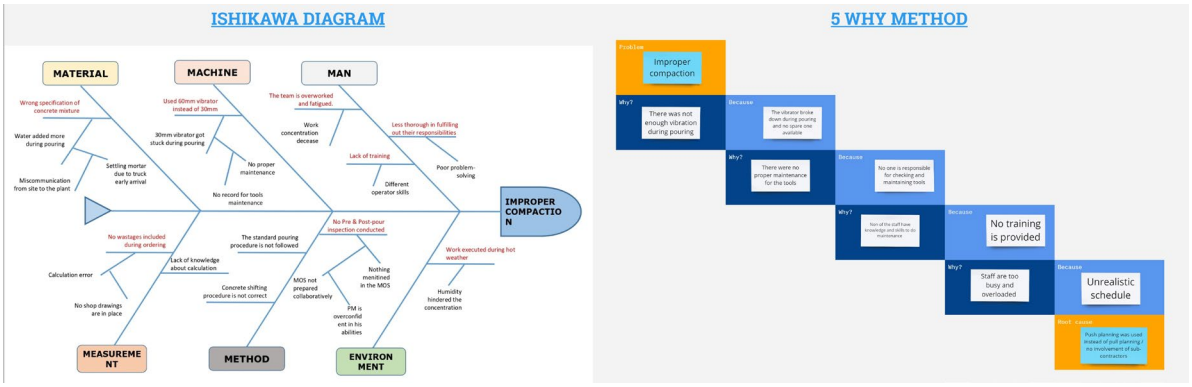

Figure 5: Example of root cause analysis - Defect waste (India project)

An important objective of these two COIL projects was to encourage students to move beyond theory and apply Lean concepts and tools to solve real-world problems. Engaging with

authentic challenges made the learning experience more meaningful, increasing student motivation and ownership of the learning process. As illustrated in Figure 6, students proposed various Lean tools such as the Last Planner System (LPS), Just-in-Time (JIT), visual management, 5S, Poka Yoke, and Kanban to address challenges related to Motion waste and Overproduction. To complete this task, students first explored the theoretical foundations of these tools, then strengthened their understanding by developing actionable strategies and practical solutions, effectively bridging theoretical knowledge with real-world complexities.

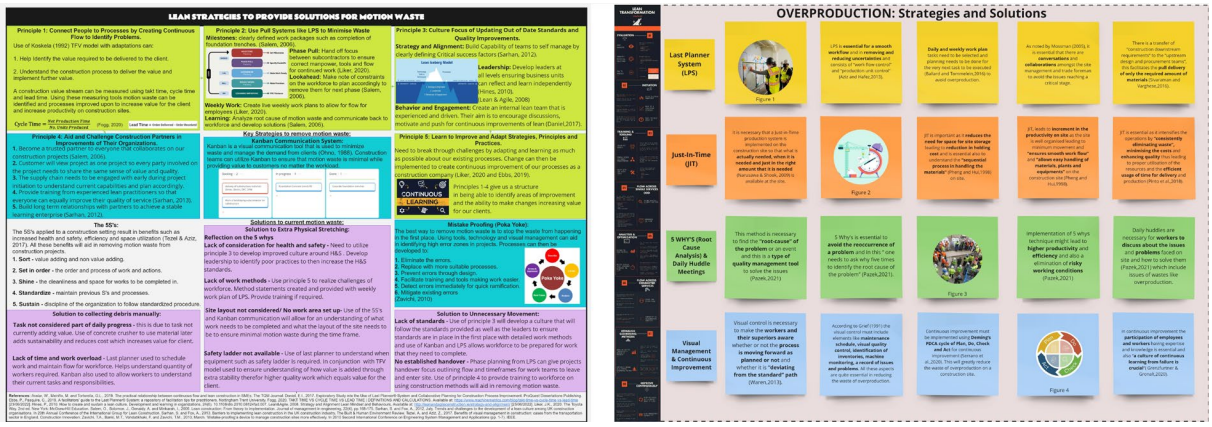

Figure 6: Providing solutions for Motion (India-left) and Overproduction (South Africa-right)

STUDENTS REFLECTION ANALYSIS

A total of 73 reflective reports submitted by NTU students (India: 30 and South Africa: 43) were analysed in this paper. This section summarises students' views on the COIL project. In their reflections, students highlighted several key aspects of the COIL projects, including the use of digital tools, personal growth, project execution challenges, sustainability integration, and emotional experiences.

COLLABORATION WITH INDIA

Students emphasised that Miro played a key role in helping them share and organise complex data. Its intuitive interface and strong visualisation capabilities enhanced communication across culturally diverse teams, easing language barriers and boosting engagement. Nonetheless, students also pointed out Miro's steep learning curve, underlining the importance of early and more targeted digital training, embedded within in-person seminars. They also noted that time zone differences and cultural barriers initially posed challenges; however, structured team-building activities and the project's flexible schedule enabled the development of a meaningful international partnership.

Throughout the project, students reported notable personal growth. Reflection reports commonly highlighted the development of skills such as problem-solving, communication, and adaptability. Students also expressed increased confidence in managing professional challenges within international contexts. In terms of project execution challenges, students noted competing workload, clashing academic deadlines and inconsistent team engagement. However, students viewed these challenges as valuable learning experiences to improve their leadership, communication, and task allocation skills in future.

Students found the Lean waste-sustainability mapping exercise valuable for deepening their understanding of the UN SDGs and recognising how project management practices can negatively impact them. However, they also noted that the 169 targets and over 200 indicators of SDGs can be overwhelming and challenging to grasp fully. Ultimately, students' emotional experience evolved from initial uncertainty to a strong sense of collective achievement, supported by accessible staff guidance and effective teamwork within each group.

COLLABORATION WITH SOUTH AFRICA

Students noted that engaging with South African partners broadened their understanding of diverse work cultures and construction practices, fostering mutual respect and the development of meaningful professional relationships. However, they said communication barriers, such as delayed responses and limited engagement, made collaboration more difficult. Similar to the India project, Miro served as the primary collaboration platform, with students highlighting its role in visually organising ideas and streamlining task management. However, they also noted that complementary tools like WhatsApp and MS Teams were essential for bridging communication gaps and ensuring timely coordination. Despite Miro's overall effectiveness, students encountered technical issues and inconsistent usage, particularly among partner students, pointing to the need for more effective onboarding and training in future projects.

Students reported significant personal and professional development, gaining confidence, adaptability, and leadership skills. They learned to navigate cultural barriers, resolve conflicts, and manage tasks effectively, preparing them for success in global professional settings. Project execution challenges included time zone differences, imbalanced task allocation, and limited engagement of partners, which placed additional burdens on active students. This underscored the value of structured communication protocols and equitable workload distribution.

Students found the integration of sustainability and Lean waste particularly challenging, which was reflected in the relatively lower quality of this section on the Miro boards. Although asynchronous materials were provided and partner students had studied a sustainable construction module, some students expressed the need for more guidance on how specific waste reduction strategies contribute to achieving individual SDGs. Students also shared that the COIL project enhanced their understanding and application of Lean concepts and tools, including Kaizen, workflow optimisation, Collaborative Planning, the Transformation-Flow-Value (TFV) model, and 5s. Students initially expressed feelings of frustration and mental strain as they navigated collaboration and cultural challenges. However, they ultimately viewed the project as a success, noting that their participation in the COIL project strengthened their resilience, perseverance, and adaptability.

COMPARISON OF TWO CASES

The COIL projects in India and South Africa revealed distinct dynamics shaped by cultural contexts, collaboration methods, and resource availability. In India, similarities between UK and Indian participants often facilitated smoother initial interactions, yet this familiarity limited exposure to broader cultural perspectives. In contrast, the South Africa project provided richer cross-cultural insights but faced greater challenges, including delayed responses and inconsistent engagement. Indian students had relatively easier access to construction sites and contributed extensive on-site data, enhancing practical learning. Meanwhile, resource constraints and limited digital infrastructure hindered participation and data sharing in South Africa. Both projects reinforced Lean principles and sustainability; however, India focused more heavily on practical data collection and root cause analysis through tools like the fishbone diagram. South Africa centred on integrating Lean methods with SDGs, though uneven use of digital platforms underscored the need for improved onboarding. Overall, these differing experiences underscore how cultural, logistical, and contextual factors influence collaboration, learning, and the successful application of Lean construction concepts in projects.

DISCUSSION ON ACHIEVEMENTS

The COIL project provided a DIY learning experience that encouraged students to adopt a Lean mindset. This section explores how student-led activities are aligned with principles of the Toyota Production System. It also discusses the paper's pedagogical contributions.

Students examined how their proposed solutions supported the UN SDGs, particularly highlighting the long-term environmental benefits in line with Principle 1. By investigating various forms of waste such as Motion, Overprocessing, and Overproduction, students identified process bottlenecks and worked towards achieving a continuous and efficient workflow, reflecting Principle 2. They employed tools like Value Stream Mapping (VSM) and 5S to visualise and refine processes, while pull systems aligned production with actual demand (Principle 3), exemplified by JIT delivery to minimise Overproduction and Inventory waste. Miro boards facilitated visual management (Principle 7), enabling task tracking and bottleneck identification. Field-based data collection embodied Principle 12, and the 5 Whys provided a structured method for uncovering the root causes of Lean waste (Principle 14).

Beyond these technical aspects, students developed critical professional skills, including communication, problem-solving, resilience, and cross-cultural collaboration. Virtual teamwork using Miro fostered peer learning, cultural awareness, and practical insights into remote working dynamics. Research abilities were also enhanced through literature review, data collection, and qualitative data analysis. Submitting a reflective report created a pathway for continuous improvement by helping students articulate their academic and professional development.

The COIL projects made pedagogical contributions by establishing a globally connected learning environment that emphasised student autonomy, authentic assessment, technological integration, and the internationalisation of the curriculum. Within a DIY framework, students took ownership of their learning, collaboratively constructing knowledge and addressing real-world challenges, thereby deepening their understanding of Lean principles and SDGs. This experiential approach fostered engagement, as students identified discipline-specific problems while simultaneously broadening their views on global environmental and social concerns.

A significant strength of the COIL project was its utility as an authentic assessment method. Students were required to apply knowledge, collaborate with peers worldwide, and propose viable solutions to real construction problems, mirroring genuine professional complexities. By emphasising originality and context-specific problem-solving, COIL projects also met the growing demand for assessments that resist automation (Generative AI). Miro's real-time progress monitoring feature enabled educators to provide timely guidance and ensure alignment with course objectives. However, tracking individual contributions proved challenging when external platforms were used before bulk uploads to Miro.

Furthermore, the project advanced curriculum internationalisation by integrating cross-cultural collaboration and fostering competencies vital for thriving in international work environments. Beyond student learning, the COIL project generated fresh avenues for academic inquiry. The eight detailed Miro boards, focusing on Lean waste types and sustainability, represent a dataset for researching the intersection of these two concepts.

CONCLUSION

This study advocates for COIL as a pedagogical model to advance Lean Construction education. Two international case studies, connecting NTU with partner institutions in India and South Africa, illustrate how digital tools like Miro and DIY learning environments can bridge geographical divides, foster intercultural collaboration, and deepen students' understanding of Lean principles and the UN SDGs. Analysis of Miro boards and reflective reports revealed significant growth in students' problem-solving abilities, resilience, and professional competencies such as communication and leadership. While challenges such as uneven participation and unfamiliar technologies emerged, the findings highlight the value of structured guidance, clearly defined objectives, and supportive digital platforms. Future research should explore the scalability of this model to other institutions and examine the effectiveness of associated assessment strategies.

REFERENCES

Aisyah, R. A., Gunawan, K., & Gazali, A. (2023). Lean Construction Through Waste Register Method: A Case Studies Project in Indonesia. *Proc. 31st Ann. Conf. of the Int'l. Group for Lean Construction*, 1303–1313. https://doi.org/10.24928/2023/0204

Appiah-Kubi, P., & Annan, E. (2020). A Review of a Collaborative Online International Learning. *International Journal of Engineering Pedagogy* (Vol. 10, Issue 1, pp. 109–124). Kassel University Press GmbH. https://doi.org/10.3991/ijep.v10i1.11678

Arroyo, P., & Gonzalez, V. (2016). Rethinking Waste Definition To Account For Environmental And Social Impacts. *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*, www.iglc.net

Bølviken, T., & Koskela, L. (2016). Why Hasn't Waste Reduction Conquered Construction? *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*, 3–12, www.iglc.net

Dazmiri, D. G., & Hamzeh, F. (2023). A Framework for Design Waste Mitigation in Off-Site Construction. *Proc. 31st Ann. Conf. of the Int'l. Group for Lean Construction*, 1025–1036. https://doi.org/10.24928/2023/0119

de Carvalho, A. C. V., Granja, A. D., & da Silva, V. G. (2017). A Systematic Literature Review on Integrative Lean and Sustainability Synergies over a Building's lifecycle. *Sustainability* (Switzerland), 9(7). https://doi.org/10.3390/su9071156

Department for Environment, & Food & Rural Affairs. (2024). *UK Statistics on Waste*. https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste

Francis, A., & Thomas, A. (2020). Exploring the Relationship between Lean Construction and Environmental Sustainability: A Review of Existing Literature to Decipher Broader Dimensions. *Journal of Cleaner Production* (Vol. 252). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.119913

Gutiérrez-González, S., Coello-Torres, C. E., Cuenca-Romero, L. A., Carpintero, V. C., & Bravo, A. R. (2023). Incorporating Collaborative Online International Learning (COIL) into Common Practices for Architects and Building Engineers. A case study in Perú and Spain. *International Journal of Learning, Teaching and Educational Research*, 22(2), 20–36. https://doi.org/10.26803/ijlter.22.2.2

Hackett, S., Janssen, J., Beach, P., Perreault, M., Beelen, J., & van Tartwijk, J. (2023). The Effectiveness of Collaborative Online International Learning (COIL) on Intercultural Competence Development in Higher Education. *International Journal of Educational Technology in Higher Education*, 20(1). https://doi.org/10.1186/s41239-022-00373-3

Hasan, S., Işık, Z., & Demirdöğen, G. (2024). Evaluating the Contribution of Lean Construction to Achieving Sustainable Development Goals. *Sustainability* (Switzerland), 16(8). https://doi.org/10.3390/su16083502

Huertas-Abril, C. A., & Palacios-Hidalgo, F. J. (2024). Collaborative International Online Learning for the Development of Intercultural Awareness: an Experience with Pre-service Language Teachers. *Journal for Multicultural Education*, 18(1–2), 67–80. https://doi.org/10.1108/JME-09-2023-0093

Kiegaldie, D., Pepe, A., Shaw, L., & Evans, T. (2022). Implementation of a Collaborative Online International Learning Program in Nursing Education: Protocol for a Mixed Methods Study. *BMC Nursing*, 21(1). https://doi.org/10.1186/s12912-022-01031-9

Koskela, L., Ballard, G., & Bølviken, T. (2023). Waste: Why Economics Got Is So Wrong, and What Could Be the Remedy? *Proc. 31st Ann. Conf. of the Int'l. Group for Lean Construction*, 1–12. https://doi.org/10.24928/2023/0300

Koskela, L., Sacks, R., & Rooke, J. (2012). A Brief History of the Concept of Waste in Production. *Proc. 20th Ann. Conf. of the Int'l. Group for Lean Construction*. www.iglc.net

Munoz-Escalona, P., de Crespo, Z. C., Marin, M. O., & Dunn, M. (2022). Collaborative Online International Learning: A Way to Develop Students' Engineering Capabilities and

Awareness to Become Global Citizens. *International Journal of Mechanical Engineering Education*, 50(1), 89–104. https://doi.org/10.1177/0306419020934100

O'Dowd, R. (2021). Virtual Exchange: Moving Forward into the Next Decade. In *Computer Assisted Language Learning* (Vol. 34, Issue 3, pp. 209–224). Routledge. https://doi.org/10.1080/09588221.2021.1902201

Office for National Statistics. (2021). Productivity in the Construction Industry, UK: 2021. https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/articles/constructionstatistics/latest

Poh, P., Austin, S., & Soetanto, R. (2018). An International Cross-Disciplinary Student Collaboration: A Retrospective Eight Years. *EDULEARN18 Proc.*, 1, 9398–9404. https://doi.org/10.21125/edulearn.2018.2225

Purushothaman, M. babu, Seadon, J., & Moore, D. (2020). Waste Reduction Using Lean Tools in a Multicultural Environment. *Journal of Cleaner Production*, 265. https://doi.org/10.1016/j.jclepro.2020.121681

Rahmawati, Y., Pradipto, E., Mustaffa, Z., Saputra, A., Mohammed, B. S., & Utomo, C. (2022). Enhancing Students' Competency and Learning Experience in Structural Engineering through Collaborative Building Design Practices. *Buildings*, 12(4). https://doi.org/10.3390/buildings12040501

Rybkowski, Z. K., da Alves, T. C. L., & Liu, M. (2021). The Emergence and Growth of the On-line Serious Games And Participatory Simulation Group "Aplso." *Proc. 29th Ann. Conf. of the Int'l. Group for Lean Construction - Lean Construction in Crisis Times: Responding to the Post-Pandemic AEC Industry Challenges*, 269–278. https://doi.org/10.24928/2021/0135

Ryosuke, O., & Kazuma, S. (2024). Teaching Sustainability in Architecture through Collaborative Online International Learning. *An-Najah University Journal for Research - A (Natural Sciences)*, 38(2), 87–94. https://doi.org/10.35552/anujr.a.38.2.2204

Sarhan, S., Pasquire, C., Mossman, A., & Hayes, A. (2019). The Prevailing Procurement System as a Source of Waste in Construction: A Case Study. *Proc. 27th Ann. Conf. of the Int'l. , IGLC 2019*, 133–144. https://doi.org/10.24928/2019/0270

Sierra, J., Yassim, M., & Suárez-Collado, Á. (2022). Together We Can: Enhancing Key 21st-century Skills with International Virtual Exchange. *Education and Training*, 64(6), 826–843. https://doi.org/10.1108/ET-05-2021-0171

Soetanto, R., Childs, M., Poh, P. S. H., Austin, S., Glass, J., Adamu, Z. A., Isiadinso, C., Tolley, H., & MacKenzie, H. (2015). Key Success Factors and Guidance for International Collaborative Design Projects. *Archnet-IJAR*: 9(3), 6–25.

State University of New York (SUNY) COIL Center. (2024, December). *Collaborative Online International Learning (COIL)*. https://coil.suny.edu/

Vahed, A., & Rodriguez, K. (2020). Enriching Students' Engaged Learning Experiences through the Collaborative Online International Learning Project. *Innovations in Education and Teaching International*, 1–10. https://doi.org/10.1080/14703297.2020.1792331

Waheed, W., Khodier, L., & Fathy, F. (2024). Integrating Lean and Sustainability for Waste Reduction in Construction from the Early Design phase. *HBRC Journal*, 20(1), 337–364. https://doi.org/10.1080/16874048.2024.2318502

Wihlborg, M., Friberg, E. E., Rose, K. M., & Eastham, L. (2018). Facilitating Learning through an International Virtual Collaborative Practice: A Case Study. *Nurse Education Today*, 61, 3–8. https://doi.org/10.1016/j.nedt.2017.10.007

Wood, E. A., Collins, S. L., Mueller, S., Stetten, N. E., & El-Shokry, M. (2022). Transforming Perspectives Through Virtual Exchange: A US-Egypt Partnership Part 1. *Frontiers in Public Health*, 10. https://doi.org/10.3389/fpubh.2022.877547