IDENTIFYING THE FOUR CORE BENEFICIARIES OF INDUSTRY-DRIVEN CDIO PROJECTS

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ABSTRACT

Industry sourced and supported CDIO projects achieve beneficial outputs for all internal and external stakeholders including students, higher education institutions (HEI), industry partners, and society. For students, these projects provide exposure to authentic, real-world challenges rather than purely academic or hypothetical problems. In addition, to the standard learning outcomes and critical-analysis skills developed through CDIO projects, students gain technical and work-related skills experience in project management, market analysis, budgeting, quality assessment, and working with industry standards. Engagement with industry professionals, enhance their graduate employability through interactive and presentation skills. HEIs benefit in teaching and learning frameworks, research impact, knowledge exchange and networking with local commercial sectors. These activities support institutions in achieving professional accreditations, quality benchmarks and contributing to regional developments as civic anchor institutions. Industry partners gain access to academic knowledge, development of local workforce, new business ideas, collaborative funding opportunities, and expanded professional networks. Society ultimately gains from positive regional economic impact on businesses, socioeconomic improving and students' future through enhanced career opportunities, production of skilled professionals, and development of sustainable relationships between all four beneficiary groups. At Canterbury Christ Church University, students have completed more than 25 industry-sourced CDIO projects across various engineering courses from foundation year to final year supported by a diverse range of industries, including manufacturing, design, healthcare, shipping, and construction etc. The projects have not only strengthened students' learning and technical skills but also supported employability, with an average of 75% securing graduate jobs, placements, or internships. Participation in these projects has enriched students' academic and professional portfolio. Overall. this paper analyses how such industry-sourced CDIO projects generate multidimensional benefits across key stakeholder groups.

KEYWORDS

Industry-source projects, quality assessment, industry standards, professional accreditation, graduate employability, Standards – 2-8,11,12

INTRODUCTION

CDIO projects have been very effective in implementing project-based learning (PJBL), problem-solving, with experimental analysis in higher education sectors. PJBL (Ramírez de Dampierre, 2024) aims to improve learning outcomes and competencies in technical and non-technical areas (De Dampierre *et al.*, 2024). The CDIO model adopted globally in engineering education but covers wider curricula frameworks (Lingling *et al.*, 2012). The multi-stakeholder approach (Armstrong *et al.*, 2005) that the CDIO framework leads to varying impacts on various entities. This study identifies four core beneficiaries: students, HEIs, industry, and society. Through imitating the lifecycle of real-life engineering projects, CDIO provides unique exposure through which learners familiarise themselves with industry standards and access wider network pools. They acquire hands-on experience with industry practice (Rigden, 2022).

Applying PJBL through CDIO enables engineering students to learn from reality "rather than generalisation" (Hong *et al.*, 2024). Teaching through CDIO aims to train students comprehensively in terms of knowledge, skills, attitudes, and core competencies linked to their profession. This emerging practice also enhances curriculum relevance and supports the alignment of programs with professional accreditation requirements, including the development of industry-standard competencies in quality assurance, sustainability, and regulatory practice.

Canterbury Christ Church University is among the HEIs that actively use the CDIO framework as a structured approach that encompass the entire life cycle of engineering projects, from conception, design, implement to operation, (Edström & Kolmos, 2014). The institution emphasises the need for early students' exposure to industry-sourced projects and collaboration. In addition to student-centred benefits, the institution reports experiencing positive CDIO impacts in the form of improved pedagogy, enhanced knowledge exchange capacity, strengthened accreditation readiness, and research and outreach potential. Industry partners and society also benefit from better innovation and more sustainable relationships.

The primary aim of this article is to identify the key beneficiaries of industry-supported CDIO project-based curriculum and to evaluate its impact beyond the educational domain. In particular, the study examines its broader socio-economic and environmental contributions. The outcomes are intended to demonstrate the significance of the CDIO approach not only in advancing technological capability but also in fostering responsiveness to evolving industry demands and promoting environmental sustainability.

Based on these premises, the present study explores the impact of CDIO projects on students, HEIs, industry, and society. The mixed-methods study sources information from an array of sources, including documentation from the 25 projects, student artefacts, staff and industry partner feedback, and project key outcome artefacts, among others. A thematic analysis pattern helps identify recurrent benefits to various stakeholders of interest in the study. By considering each stakeholder separately, the study distinguishes the unique benefits that the CDIO-PJBL approach brings to each of the stakeholders considered.

METHODOLOGY

This study employs a mixed-methods approach grounded in project records, stakeholder reflections, and institutional performance indicators. Evidence was gathered from:

- Documentation from 25 industry-sourced CDIO projects.
- Student reflective reports, presentations, and assessments.

- Staff and industry partner feedback.
- Graduate Outcomes and progression data from CCCU.

IMPLEMENTATION OF INDUSTRY-SOURCED CDIO PROJECTS

To enhance graduate employability and adapt to real-world engineering problems, CDIO projects in our curriculum are sourced from local industry partners. A robust process (Figure 1) has been created to transform those real-world engineering problems into CDIO projects (Manna *et al.*, 2023). Those engineering problems from local industries have been obtained through various channels and converted into student projects integrated with modules.

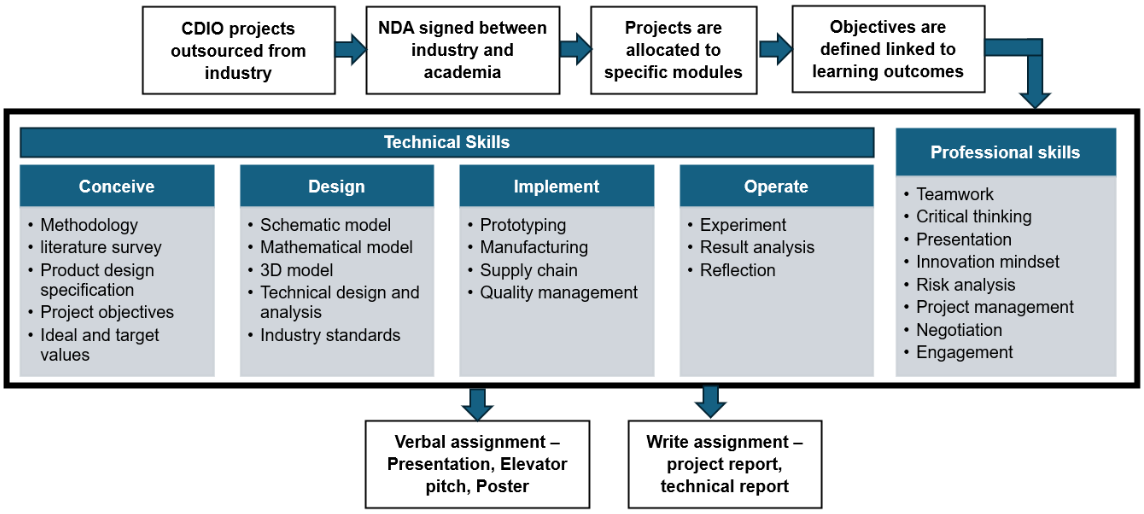


Figure 1. Industry sourced CDIO projects

Project allocation is determined by the complexity and technical demands of the problem, the level of the students, and the expertise of tutors and technical staff. Based on these factors, each project is assigned to an appropriate cohort within a specific course and year group.

Tasks in conceive stage

In this stage, students develop the methodology for the industry-defined projects, including the Product Design Specification (PDS) sheet and the Bill of Materials (BoM). They determine the technical specifications of the proposed solutions along with their structural components. The specifications for the CDIO project are defined using three metrics: ideal, target, and achieved values. The ideal values are derived from the literature review, the target values are set based on business factors such as cost and time, and the achieved values are established after the prototype has been developed.

Tasks in the design stage

In this stage, students design the foundational framework of the CDIO project, including the schematic model, mathematical model, and 3D model. They also explore various technical designs such as electronic circuits and virtual prototypes. To develop these designs, students use several software tools. For example, Fusion 360 was used to create the 3D model; Arduino IDE for programming the Arduino board; Tinkercad for designing electronic circuits and virtually embedding and verifying the programmed logic; MATLAB for developing the mathematical model of the proposed solution; and ANSYS for conducting finite element analysis and computational fluid dynamics when required. Depending on the complexity of the project, the types of software used may vary. Throughout this process, students conduct risk assessments and comply with relevant industry standards.

Tasks in Implementation stage

In this stage, students manufacture the models using various processes such as 3D printing, laser cutting, and machining in the mechanical workshop; develop electronic circuitry by soldering discrete electronic components and programmable modules. Throughout this phase, they also follow quality management procedures.

Tasks in Operate stage

In this stage, students execute the project and reflect on the outcomes. They create a controlled environment and conduct real-time experiments to evaluate the performance and effectiveness of the prototype. A critical analysis is carried out by comparing the experimental results with the theoretical predictions, and the findings are documented in a comprehensive report. Finally, students present their work, either individually or as a group, to an academic and industrial panel and submit the final reports for assessment.

The objectives of the project have been transformed into various assessments (coursework, lab and presentations) of the associated module so that students can achieve the module learning outcomes while meeting the project objectives. As part of their assessments, students prepared both written and visual outputs, including technical and business reports, risk assessments, posters, and elevator pitches to present their findings. Beyond developing technical competencies, students strengthened key professional and soft skills such as teamwork, critical thinking, creativity, innovation, and active engagement.

FOUR BENEFICIARIES OF CDIO PROJECTS

Since 2019/20, engineering students at Canterbury Christ Church University have already worked with more than 25 industry-sourced CDIO projects, mostly from small and medium-scale industries. In this process, students have liaised with internal and external stakeholders, including academics, technical team, industry personnel and sponsors. There are mainly four stakeholders who have benefited from these projects (Figure 1). Through delivering real-world CDIO projects, the team have explored good academic practices to reduce the complexity of industry-standard processes for adaptive learning and graduate employability. Besides, students gained familiarity with current industry standards (Figure 2).

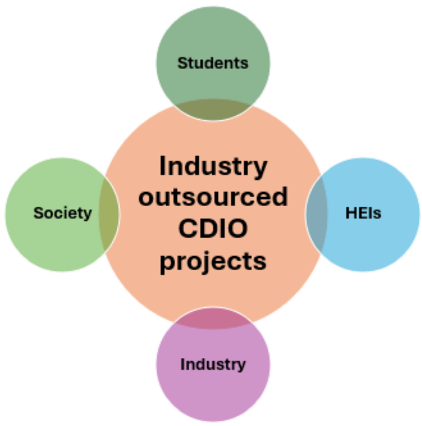


Figure 1. Four core beneficiaries

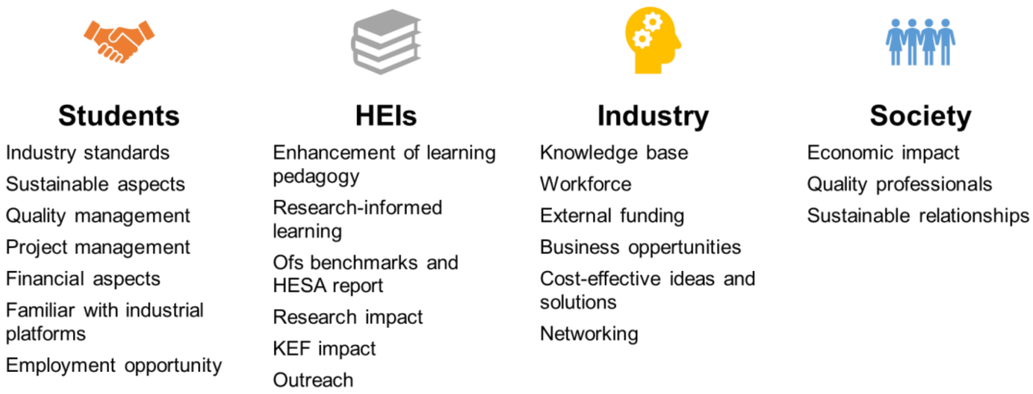


Figure 2. List of benefits

BENEFITS FOR STUDENTS

Industry standards

While working on the industry-sourced CDIO projects, the prospective solutions will aim to achieve industry standards and regulations such as BSI and ISO. This approach would make the solution closer towards the market standard while students' perspective. Keeping the objectives of projects aligned with industry standards, students will continue their design, implementation and operation process.

Sustainable aspects

To reduce environmental impact and carbon footprint, students are encouraged to design and implement sustainable elements in their CDIO projects (Steuer-Dankert, 2023). This has also become a learning requirement set by professional accreditation and regulatory bodies across the UK HEIs. Wherever possible, project solutions (Jaca *et al*., 2021) should align with the UN Sustainable Development Goals (SDGs). As part of this effort, students calculate the carbon footprint of the overall development and manufacturing process, design for sustainable end of life, make use of recyclable materials and design environmentally friendly products or systems.

Quality management

While completing industry-sourced CDIO projects, students have also followed the QMS (quality management system) since it is required by the industry for further investigation, testing and launching the products/systems. During the QMS process, students will study the quality of the solutions, robust testing, risk assessments, and sustainable supply chain etc.

Project management

Most of the projects are group work with 3-4 students and the role of each usually possesses a significant contribution while supporting each other, like an industrial platform. A Gantt chart is produced with a timeline of completion for each task and students also reflect on the issues they faced and how they overcame them. In this process, they coordinate with peers while liaising with academics and industry personnel, enlightening their multi-team working model.

Financial aspects

To understand the market compatibility of their proposed and developed solution, students will do a comparative cost analysis of existing products. At the beginning of the project, students were allocated a specific budget for the project. They also complete a thorough costing of the solution, starting with designing, building, testing and production. The costing will include the cost of components, manpower, supply chain, manufacturing etc. This kind of analysis is helpful to maintain the cost-effectiveness of the proposed solutions.

Familiar with industrial platforms

While pursuing CDIO projects, students interact with industry personnel, visit their platforms and are continuously guided by their expert advice. Sometimes, students also approached prospective industries to secure sponsorship for project finance. In this process, they learn how to professionally communicate with the industry both verbally and in writing and how to present their ideas and solutions in a more convincing way.

Employment opportunity

The outcome of CDIO projects leads to both direct and indirect impact on student employment. Completing the CDIO projects boosts their confidence and portfolio while applying for jobs. These industry sourced projects enriched their industrial experience, CVs and fulfilled the industry expectations. Sometimes, they also receive recommendations from industry personnel. Pleased by the performance of students, the industry sometimes offers internships, placement and contractual job roles. So far, the collaboration opportunities with eXroid have supported five interns, two KTP associates and one full-time and one part-time role and are currently supporting one part-time contractual role. In a few scenarios, students also received with monetary contributions from industry as a token of appreciation.

BENEFITS FOR HEIS

Enhancement of teaching and learning pedagogy

Through collaborative work with academics, technical team, learning skills team and industry partners, students can practice most of the required learning methods such as problem-based learning, project-based learning and experimental learning. Therefore, having those projects onboard supports their teaching and learning framework as required for professional accreditation and quality framework (Penttila and Kontio, 2016), thus helped students to realise how complex, industry-standard engineering products can be designed from a simple idea with appropriate technical expertise and hands-on skill. Through this process, students can use their previously gained knowledge and skills, which also help them to retain the knowledge, one of the major concerns for current education.

Research-informed learning

Transforming the best practices of teaching and learning into research can show strong evidence of its impact. Following the CDIO projects, the developed research mindset may drive students to pursue research in future rather than going for traditional jobs, eventually getting them in a research and development organisation or academics. Sometimes, it also fosters their entrepreneurial mindset for startups and spinouts (Norrman *et al.*, 2014).

Ofs benchmarks

There are certain measures defined by Office for Students (Ofs, 2022) to measure outcomes of HEI providers for example, Continuation and Completion measure the percentage of students who remain on their course and successfully achieve their qualification, while Progression captures graduate outcomes such as employment, further study etc.

Industry-sourced CDIO project supports the students to enhance their graduate employability, which also has a direct impact on progression statistics of Ofs benchmark in the UK. It also appears that the performance of the students is much better in project-based modules when they are industry-sourced. For biomedical engineering, the course continuation rate is high (91.7%), the retention rate is 84% and progression rate is 100% with graduate employment in NHS, eXroid, BAE etc whereas average progression rate for engineering courses is 75%.

Research impact

The research-oriented CDIO project can also contribute to the research framework in UK HEIs. With appropriate support, those student-based CDIO projects can be transformed into large-scale, impactful research projects supported by internal or external funders. One of our student-based CDIO projects supported by eXroid in 2020, which eventually led to a mini-KTP project and later an accelerated KTP project funded by Innovate UK. The outcomes from CDIO projects will be used a REF (research excellence framework) impact case study.

Knowledge exchange

Liaising with local industry as a part of CDIO projects, universities will deliver knowledge transfer to local businesses, which has a direct impact on local economy and society in terms of value and workforce. This approach will also build a sustainable relationship with HEIs. In the current scenario, universities need to build courses to support the industry expectations; therefore, the local industry always play a major role in developing industry-oriented courses, eventually contribute in the UK-wide knowledge-exchange framework.

Outreach

Through collaboration with industries, even at the academic level, the outreach of HEIs can be expanded, especially in commercial sectors. This, in turn, enhances institutional reputation and rankings. In addition to establishing national and international footprints, such engagement can also help to increase student recruitment.

BENEFITS FOR INDUSTRY

Knowledge base

Since industry partners typically do not allocate funding for student-based CDIO projects, these initiatives are primarily supported by academic institutions. On the other hand, industries receive new ideas, prospective solutions and working prototypes for their proposed engineering problems. Industries are open to taking those ideas to implement in their platform. At the beginning of collaboration, a Non-disclosure Agreement (NDA) is signed between industry and institutions to preserve any developed ideas or solutions.

Workforce

The local industry, which is mainly small and medium scale, engagement in the CDIO projects enable them to develop their future workforce in collaboration with HEI without going through the extensive and costly recruitment process. In one of our previous projects, students from the project have been recruited by the industry.

Business opportunities

It has been found that while working on CDIO projects, there are new ideas and product concepts that have evolved and developed, which have also led to new business opportunities for industries. Usually, students are not familiar with the current market scenario; sometimes, those ideas are not biased and affected by pre-existing information. For example, while working on the CDIO project on electrotherapy, students managed to build a software solution for tracking and monitoring the tissues, which has led to a new product.

Cost-effective ideas and solutions

CDIO projects do not incur any financial liability on industries. The only commitment for them is to make a few engagements with the students to clear their queries and provide guidance along with academic team. On the other hand, it would enable industry to crowd source new potential viable new ideas, feasibility studies or a working prototype of their engineering problems, which will result a huge cost savings on their research and development.

Networking

Through engagement with CDIO projects, industries can network and collaborate with world-class academia to support their continuous professional training and development in both technical and business areas from manufacturing to supply chain management. Industry personnel can receive Institutional training as a form of CPD (Continuous Professional Development) for growing their business model and product market fit. Sometimes, researchers from academia can work as consultants in industry to provide support.

External funding

Building on the outcome of the CDIO project, the industry can pursue external funding (InnovateUK, NIAB, British Council etc) to support its projects. Having a track record of working with CDIO projects helps the industries to provide evidence of their achievements.

BENEFITS FOR SOCIETY

Economic impact

The local economy of the society is indirectly influenced by the growth in education and industry sectors. Additional income through a rise in recruitment numbers and in the industry through sources of income from products could lead to more investment in society. Besides, by securing graduate-level jobs at the end of their course, the quality of life for graduates will be improved and they will further contribute to society through taxes, benefits etc.

Quality professionals

Early training and interaction with industry from the start of their course make students industry-ready professionals. Since the industry has certain expectations where skills in both technical and professional sectors are equally important, CDIO projects provide the scope of learning from an early stage. This will further reduce the wastage of resources in society.

Sustainable relationships

Building sustainable relationships between industry and academia through CDIO projects has long-term implications for society since it keeps current education aligned with industry requirements to reduce the gap between the real-world challenges and academic world for long term goals in education and industry.

RESULTS

Since 2019/20, the engineering courses (Biomedical, Product Design, Mechanical and Chemical) at Canterbury Christ Church University have incorporated approximately 25 CDIO projects (Figure 3), typically sourced from industry (healthcare, real estate, construction, shipping, sport, manufacturing, education, agricultural technologies and so on) to all levels, including Foundation Year to Final Year. Figure 4 shows the distribution of these projects across the various engineering disciplines and academic levels.

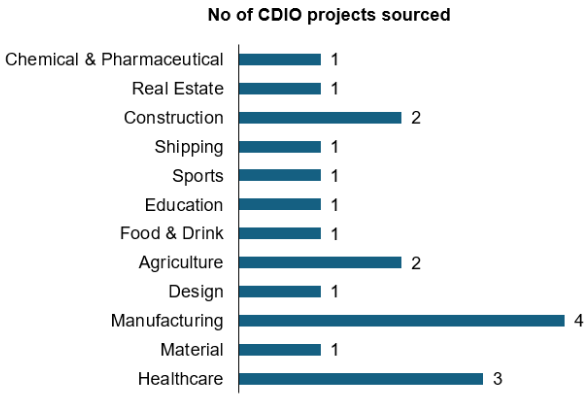


Figure 3. Types of industries supported by CDIO projects

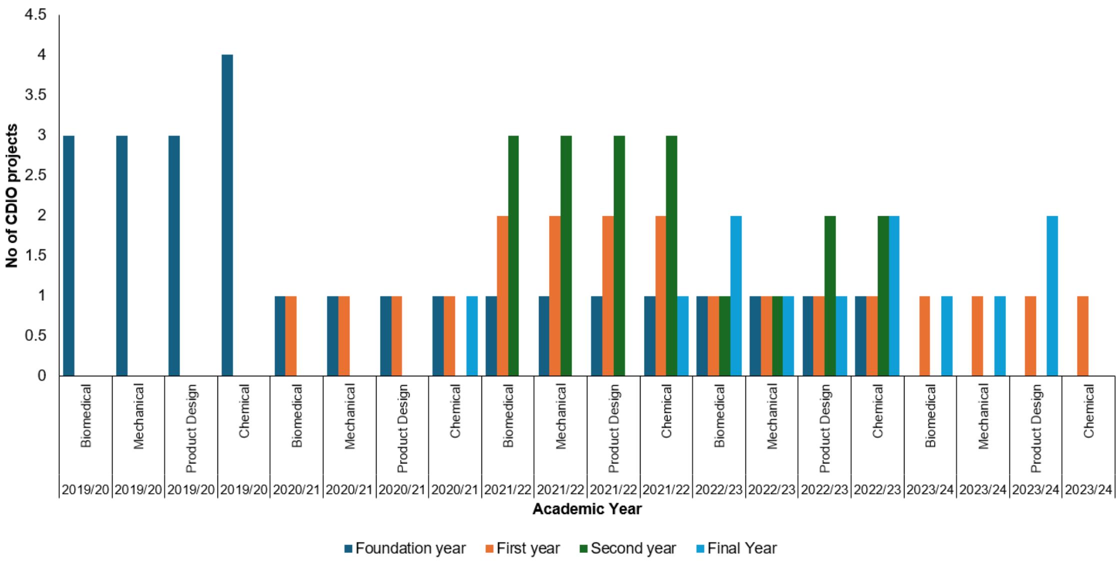
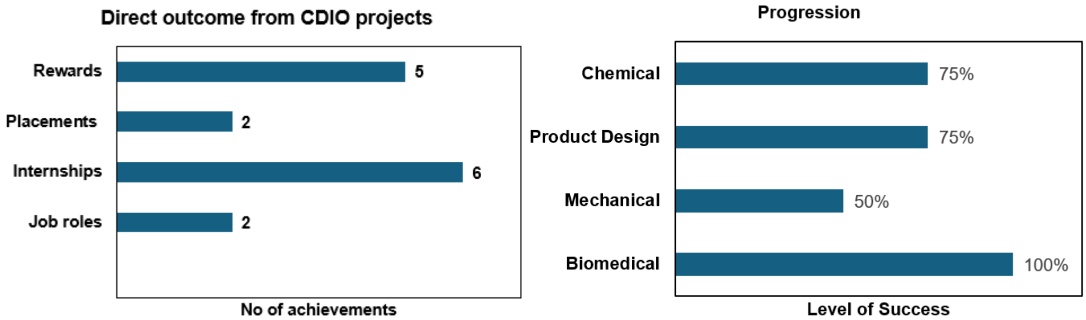


Figure 4. Project allocation across courses and Years

Both short-term and long-term opportunities are shown in Figure. 5a. For example, a manufacturing company awarded £3,000 to the best first-year student group working on a SLAM lock project for delivery vans and has incorporated their innovative ideas into the next version of its product. Another organisation awarded £1,500 to the top Foundation Year group for an inclusive, flexible easel design. Students have also received individual awards; for instance, one Product Design student was awarded £500 for a Pickleball racket project.

Furthermore, several students have secured internships through these industry-funded projects. In terms of long-term goals, some students have obtained commercial employment with partner organisations. For example, one graduate is currently employed by a healthcare company after working with them on a project. Overall graduate employability (Figure 5b) has also improved and is reflected in national graduate outcomes data for UK students. The data was collected from university platforms such as Power BI and the Careers and Enterprise team, the average progression rate across all four engineering courses is approximately 75%, with Biomedical Engineering achieving the highest rate at 100%.

The analysis adopts a structured and systematic approach to evaluating CDIO project activity and its impact on graduate employability. Data relating to the number of CDIO projects is first collected and organised on a course-specific, year-wise basis. Each project is then categorised according to its thematic focus, area of research, and associated industry or provider company, enabling a coherent mapping of academic activity to industry engagement and research domains. In parallel, project outcomes are analysed using defined employability indicators. These include student progression rates as a primary measure, alongside short-term success metrics such as awards and recognitions, internships secured, placement achievements, and the nature of job roles obtained. This dual-layered analysis facilitates a more comprehensive understanding of how CDIO project participation contributes to both immediate student success and longer-term graduate employability outcomes.



a. Short-term and long-term opportunities b. Progression of graduate students

Figure 5. Impacts of CDIO projects on student employment

Students and industry partners have also shared their personal experience while working on the industry-sourced CDIO projects.

Quotes from students

Student 1 - 'While doing the CDIO project I've been able to improve upon my CAD (computer-aided design) skills. For these two subjects I've gained a lot of self-confidence and the ability to speak with confidence during team presentations'.

Student 2 - 'I feel that as a future professional engineer I have gained a lot of new skills as well as helped contribute to my team'.

Quotes from industry partners

'The talent and resources at Canterbury Christ Church University are very impressive. It's been an absolute pleasure to work with both the students and lecturing staff on innovations that will continue to transform our potential, as well as the University management for their approach to partnerships with industry.'- Managing Director, healthcare company

'The CDIO framework is acknowledged by WBCL as being effective in both education and the design of real-world products and systems in due course hopes to benefit from the investment through recruitment of CCCU graduates.' - UK manufacturing company

CONCLUSION

The study demonstrates that CDIO projects are not only impactful to students, but their impact radiates across HEIs, society, and industry partners. Integrating real-life engineering problems into the framework imparts technical and critical employability capabilities such as project management, communication, sustainability analysis, quality assurance and professional engagement. In summary, the study reports multi-stakeholder benefits emerging from CDIO projects. HEIs like Canterbury Christ Church University should continuously improve their PJBL by integrating emerging industry trends into CDIO to prepare students for current and future industry trends. Integrating emerging trends and techniques would also lead to more innovative solutions across disciplines. The multi-stakeholder approach to this PJBL method helps address any challenges that emerge in the profession. Students become part of the solution while still in their training and learning stages. Industry-sourced CDIO projects are, therefore, an ideal approach through which the goals of PJBL are achieved.

The main challenge lies in identifying appropriate industry projects. Most partner organisations are SMEs, and they have their own business operations. As a result, the projects they offer are often non-commercial in nature, with little or no financial support available. This means that HEIs have to rely on their own internal funding and resources to deliver such projects. Another limitation is maintaining the quality of projects to meet industry expectations. This is often constrained by students' limited knowledge and the restricted resources available within the institution. Consequently, many projects result in working models or conceptual designs rather than fully developed commercial prototypes. Embedding these industry-based projects into appropriate modules presents an additional challenge. Projects must align with module learning outcomes and depend on the expertise of academic staff, which can vary. Furthermore, projects are typically time-bound, requiring solutions to be developed within strict academic timelines, which may not always align with industry expectations.

In spite those limitations, findings from the 25 CDIO projects at Canterbury Christ Church University show how learners become better prepared through improved self-confidence and better professional portfolios. These educational and professional advancement opportunities prepare engineering students for industry, eliminating employability challenges. The study also links CDIO projects to numerous social, industry and HEI benefits. Among HEIs, for example, the evaluation reveals the evidence of robust pedagogical frameworks, evidence-informed practice, better knowledge exchange programs, and innovative pathways for impact generation. At the industry level, stakeholders acquire innovative ideas, low-cost research and development, talent sourcing, and sponsorship opportunities. The study also links CDIO projects to further social benefits, such as the development of high-quality professionals and long-term sustainability. To strengthen support systems, it would be beneficial to introduce dedicated support for HEIs to collect CDIO-based projects and industry engagement activities. Financial support would enable institutions to better resource these projects and reduce reliance on internal budgets. In addition, establishing a more structured industry–academia collaboration model within the curriculum could significantly improve outcomes. This could include designated personnel or liaison roles responsible for identifying, sourcing, and maintaining relationships with industry partners, as well as coordinating project opportunities. Such an approach would reduce the burden currently placed on academic staff and streamline communication with industry and ensure a pipeline of suitable industry-linked activities.

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BIOGRAPHICAL INFORMATION

Dr Soumya Kanti Manna is currently a Principal Lecturer at the School of Science, Psychology, Art and Humanities, Computing, Engineering & Sport, Canterbury Christ Church University, UK. Soumya is also currently a Senior Fellow of the Higher Education Academy. Soumya completed his master's in Mechatronics and PhD in Robotics. Soumya's research interest primarily lies in the areas of designing assistive devices and healthcare. He has expertise in engineering education-based research using CDIO-based project curricula to explore new pedagogy approaches. He has a track record of publications in engineering education at previous CDIO conferences, Advance HE etc.

Dr Nabila Naz is currently a Senior Lecturer in Engineering at Canterbury Christ Church University, UK. She is a Fellow of the Higher Education Academy (FHEA) and did her PhD in computational modelling in fluid mechanics. She has nearly 8 years of experience in designing and delivering innovative, research-informed engineering curricula across the UK and internationally. Nabila leads and co-develops modules in design, manufacturing and engineering science, embedding CDIO pedagogy, inclusive assessment design, flipped learning, and industry-sourced projects to enhance engagement and professional readiness.

Dr Salman Saeidlou is Head of Sustainable Engineering and the Built Environment at Canterbury Christ Church University (CCCU). He is a Fellow of the Institution of Engineering Designers (FIED), a Chartered Mechanical Engineer (CEng, MIMechE), a Chartered Environmentalist (CEnv), a Member of the Institution of Civil Engineers' Wind Energy Society (ICE) and a Senior Fellow of the Higher Education Academy (SFHEA). Salman holds both an MEng (Hons) and a PhD in mechanical engineering from the University of Birmingham. He has extensive experience in teaching and supervising undergraduate and postgraduate engineering programmes in UK higher education. His research interests focus on intelligent manufacturing systems, distributed and agent-based systems, big data analytics in manufacturing, data mining, and machine learning, and he has actively implemented the CDIO methodology across a range of engineering modules at CCCU.

Prof. Anne Nortcliffe is Dean of the Faculty of Arts, Computing and Engineering at Wrexham UK. Anne has a degree in Chemistry, MSc in Control Engineering, PhD in Process Control Engineering, industrial experience in artificial intelligence and software engineering for the Chemical Engineering Industry. Anne has been an academic in several institutions teaching, leading in areas of automation, manufacturing, software entrepreneurship, mechanical and materials engineering. Anne is an active engineering education researcher with an international reputation in engineering employability development, learning technology to support computing and engineering education and pedagogical approaches.

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