STRENGTHENING ENGINEERING EDUCATION THROUGH INDUSTRIAL COLLABORATIONS WITHIN THE CDIO FRAMEWORK

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ABSTRACT

Industrial collaboration has become a cornerstone of modern engineering education, ensuring that students graduate with both technical competence and professional readiness. This study examines how structured industrial collaboration operationalizes the CDIO framework at the Australian University (AU) in Kuwait through a longitudinal institutional case study covering the period 2015–2025. It analyzes how industry engagement is integrated across multiple channels, including Industrial Advisory Boards (IABs), field trips, internships, industry-linked project-based learning (PBL), capstone projects, and research partnerships. These initiatives collectively support the Conceive–Design–Implement–Operate (CDIO) framework, providing students with authentic contexts in which to apply theoretical knowledge to real-world engineering challenges. Students conceive problems under the guidance of industry mentors and through structured field visits that expose them to operational and environmental constraints. In PBL and capstone courses, they design and implement feasible solutions to employer-defined briefs, often using real datasets and industry standards. At the same time, collaboration with practitioners enhances their design thinking, problem-solving, and communication skills. Through joint research and student–faculty co-authored publications, results are disseminated and evaluated to support continuous improvement. Evidence of impact includes data from 633 internship placements, 178 industrial judges evaluating graduation projects, and 205 students co-authoring 62 publications between 2015 and 2025. Early indicators reveal measurable improvements in employability, innovation, and teamwork, supported by structured feedback loops and accreditation-aligned evaluation. This study concludes that embedding industrial collaboration throughout the CDIO cycle strengthens learning, enhances professional competence, and offers a transferable model for universities seeking to modernize engineering curricula aligned with Industry 5.0 priorities.

KEYWORDS

Industrial Engagement, Industrial Collaboration, Project-Based Learning, Engineering Education, Standards: 1-3, 5, 7-11.

INTRODUCTION

Current engineering education pedagogies remain instructor-centered rather than student-centered, resulting in unmotivated and disengaged learners (Al-Khiami et al., 2024). As Gürdür Broo et al. (2022) note, "The World we live in has evolved tremendously while our education systems try to hold on to old patterns of teaching, learning, and consequently conferring qualifications." Many universities still measure educational success by classroom hours rather than competencies developed. Such approaches lead to weak knowledge retention, limited creativity, and poor problem-solving and critical thinking abilities, as well as higher dropout rates (Cantos et al., 2021; Christie & de Graaff, 2017). Consequently, many engineering graduates enter the workforce insufficiently prepared to meet the complex, interdisciplinary, and rapidly evolving demands of modern industry (Mathur et al., 2016).

This highlights the need for learner-centered approaches that actively engage students in problem-solving and decision-making within an authentic context. Engineering education is experiencing a paradigm shift driven by rapid technological change to accommodate a digital-native student body (Al-Khiami et al., 2024), sustainability imperatives, and evolving employer expectations. Industry leaders increasingly demand graduates who possess not only technical competence but also creativity, communication, teamwork, and adaptability (Gürdür Broo et al., 2022). To meet these demands, institutions are rethinking curricula to integrate industry-informed learning experiences that mirror professional practice. Collaboration between academia and industry has thus become essential for producing industry-ready engineers capable of navigating complex socio-technical challenges (Male et al., 2016).

The Conceive–Design–Implement–Operate (CDIO) framework offers a structured and widely adopted approach for bridging theory and practice, ensuring that graduates develop both disciplinary knowledge and professional skills within real engineering contexts (Edelbro et al., 2017; Mejtoft, 2015). CDIO provides a coherent model that embeds authenticity, interdisciplinarity, and reflection across the educational experience, thereby aligning learning outcomes with the complete engineering lifecycle. Across CDIO institutions, industrial engagement is embedded through multiple mechanisms, including Industrial Advisory Boards (IABs), internships and cooperative education, project-based learning (PBL), industry-outsourced capstone projects, and collaborative research. These elements collectively provide authentic opportunities for students to engage in the full engineering cycle, conceiving solutions to real problems, designing feasible systems, implementing prototypes, and operating within practical constraints.

Empirical studies demonstrate that such engagement enhances both learning outcomes and employability. For instance, project-based collaborations at Umeå University and Kristianstad University enabled students to deliver tangible prototypes to industry partners while strengthening problem-solving, teamwork, and communication skills (Mejtoft, 2015; Frisk et al., 2022). Similarly, the integration of outsourced CDIO projects has been shown to systematically embed employability competencies throughout the curriculum (Manna et al., 2023).

Internships and cooperative programs represent another critical avenue for authentic learning. Kamp and Verdegaal (2015) illustrated how the Delft University of Technology's structured internship model provided measurable learning outcomes and quality-assured assessment mechanisms that align with CDIO Standards 7, 8, and 11. Through intentional feedback loops between students, employers, and faculty, such programs enable continuous curriculum improvement and promote alignment with industry needs. Equally, industry-inspired experiential activities that use professional rubrics and self–peer assessments foster professional behaviors consistent with workplace standards (Tio, 2016), while direct interactions with industry representatives through Lean and Six Sigma projects enhance student engagement and reflective learning (Berglund et al., 2022).

At the institutional level, IABs play an essential role in sustaining curriculum relevance and responsiveness. These boards validate program outcomes, inform strategic curriculum redesign and competency frameworks (Edelbro et al., 2017). The emerging concept of Curriculum Agility, recently proposed within the CDIO community, further expands this notion by advocating adaptive and iterative curriculum models that respond swiftly to evolving industrial and societal demands (Lyng & Nortcliffe, 2024). Collectively, these studies reinforce that structured, long-term collaboration between academia and industry leads to stronger employability outcomes, continuous curriculum enhancement, and deeper professional identity formation among engineering students.

While most CDIO literature focuses on large or established universities, little research examines how emerging institutions apply the framework within fast-evolving industrial contexts. This paper addresses that gap through the Australian University (AU) model, which adapts CDIO-based industrial collaboration to the Gulf region.

This study examines how structured industrial collaboration operationalizes the CDIO framework at AU and presents an evidence-based institutional model for embedding industrial collaboration within developing higher-education systems while aligning engineering curricula with emerging Industry 5.0 and sustainability priorities (El Achkar, 2025). Specifically, the study examines how industry collaboration channels are integrated across the CDIO lifecycle at AU, what measurable institutional outcomes emerge from sustained collaboration between academia and industry, and how these practices may inform transferable models for engineering education in developing higher education systems.

Research Design and Data Sources

This study adopts a longitudinal institutional case study examining the implementation of industry collaboration at AU between 2015 and 2025. Data were collected from institutional sources including internship records, Industrial Advisory Board reports, capstone evaluation data, student reflections, and undergraduate research publication records.

Quantitative data, including internship numbers, sector distribution, student publications, and participation of industrial judges, were compiled from College of Engineering databases. Qualitative insights were derived from student reflections and employer feedback. Text preprocessing techniques (stop-word removal and term-frequency analysis) were used to generate thematic summaries and the word-cloud visualization presented in this study.

FRAMEWORK OF INDUSTRIAL COLLABORATION AT AU

Institutional Context

The Australian University (AU), established in 2004 in Kuwait, is a multidisciplinary institution comprising four academic units: the College of Engineering (CoE), the College of Business, the School of Aviation, and the School of Maritime Studies. Each contributes to AU's mission of delivering practice-oriented education aligned with national and industry priorities. This manuscript focuses on the CoE, which offers undergraduate programs in Civil, Mechanical, Electrical, and Petroleum Engineering through a 2+2 articulation model. In 2016, AU partnered with Aalborg University in Denmark to embed PBL across engineering curricula. This collaboration aligned the College with the CDIO framework after joining the initiative in 2018, fostering authentic, student-centered learning.

The College's programs are audited by Engineers Australia (EA), ensuring international standards and continuous improvement. Combined with IAB feedback, these audits reinforce CDIO Standards 9-11 on evaluation and improvement. Recent reforms have integrated digitalization, AI, and sustainability to prepare graduates for evolving challenges. Collectively, these initiatives provide the foundation for AU's evidence-based, industry-aligned implementation of the CDIO framework.

Channels and Mechanisms of Industry Collaboration

At AU, industry engagement operates through structured channels connecting engineering education with professional practice. These include IABs, internships, project-based and capstone courses, and joint research partnerships. Each mechanism targets specific phases of the student learning journey while reinforcing CDIO competencies across the curriculum.

The IABs serve as strategic platforms through which industry experts validate program learning outcomes, recommend curriculum updates, and advise on skill priorities emerging from the national and regional job market. Their guidance has directly influenced course revision cycles, particularly in sustainability and digitalization. This continuous dialogue ensures alignment with CDIO Standards 1 to 3 by linking program objectives to stakeholder needs.

Field trips represent another important channel for early industry exposure. Since Fall 2021, the College has coordinated 80 field trips, exposing students to engineering environments relevant to the "Conceive" stage of CDIO. These visits provide students with firsthand observation of industry practices and workplace requirements.

Internship placements serve as the primary vehicle for experiential learning. Students complete a minimum of 120 hours in industrial settings under joint supervision from academic mentors and field engineers, applying classroom knowledge to real-world engineering operations. Employers' feedback is formally incorporated into course reviews and accreditation reports, directly supporting CDIO Standards 7 and 8.

Within coursework, PBL and capstone projects act as structured interfaces between students and industry partners. Companies frequently outsource defined technical problems that students address through the CDIO process. These projects develop teamwork, communication, and system-thinking skills while reinforcing iterative CDIO design and implementation phases. Finally, research collaborations involving students and faculty provide opportunities for knowledge creation and dissemination through co-authored conference papers and journal publications. Such initiatives extend learning into the "Operate" stage of CDIO by emphasizing reflection, evaluation, and contribution to professional knowledge.

Alignment of Collaboration Channels with CDIO Stages

The CDIO framework provides the organizing structure that connects each collaboration channel to a defined phase of the engineering lifecycle. Figure 1 summarizes the alignment between AU's collaboration mechanisms and CDIO stages. This alignment ensures that industrial engagement is not fragmented but systematically integrated into every stage of student development, from problem conception to project operation.

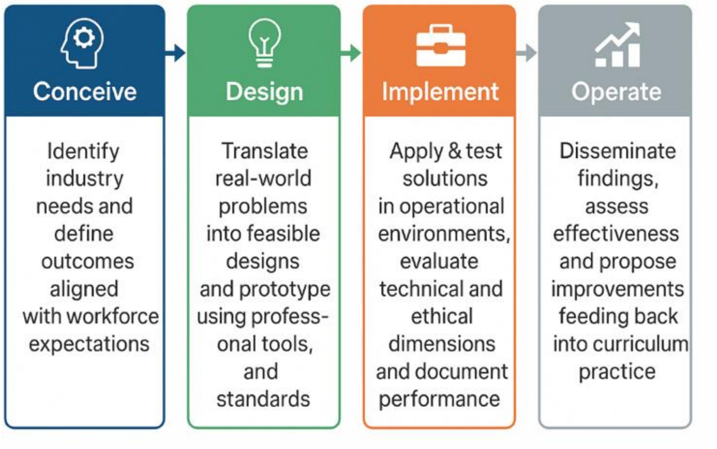

Figure 1. Alignment of Collaboration Channels with CDIO Stages at AU

Curriculum Integration

The CoE systematically embeds industrial collaboration within its curriculum architecture. Beginning in the diploma phase, students engage in introductory PBL modules emphasizing teamwork and technical communication. At the degree level, discipline-specific design courses incorporate authentic case studies provided by industry partners. Capstone projects constitute the culmination of this pathway, requiring students to synthesize technical, ethical, and sustainability considerations in employer-defined contexts. This progressive integration from diploma to bachelor level ensures continuous exposure to authentic engineering challenges and reinforces CDIO Standards 5 and 7 related to design-build experiences and integrated learning.

Industry feedback from IAB meetings and internship reports is analyzed annually to refine course learning outcomes. For example, the evaluation rubrics for capstone projects, often assessed by industry guest judges, now emphasize originality and innovation, technical quality, practical implementation, and societal impact, alongside explicit criteria for sustainability and safety awareness. These revisions ensure that student projects are judged not only on technical merit but also on their relevance to real-world challenges and communication effectiveness, as reflected in the structured evaluation framework used across the four engineering departments. This cyclical integration of external input demonstrates AU's sustained commitment to CDIO Standards 9–11, emphasizing evaluation, stakeholder feedback, and continuous improvement.

Representative Industry-Linked CDIO Projects

Several initiatives illustrate how AU operationalizes the CDIO framework through collaboration with external partners. The Life Energy Solar Laboratory and Solar Academy exemplify projects where students collaborated with industry engineers to design solar-PV container systems for remote oil-rig operations. These projects follow the CDIO cycle, where students conceive problems with industry partners, design solutions, implement simulations, and present operational outcomes to industry evaluators, demonstrating the practical feasibility of renewable energy solutions in remote industrial environments.

Interdisciplinary teams have also participated in national and international innovation competitions, where AU students achieved top rankings. Since Fall 2022, 178 industrial judges have evaluated senior projects during the Graduation Projects Exhibition, providing professional feedback and validating student outcomes. These initiatives demonstrate the effective application of CDIO principles through authentic, industry-driven learning experiences that enhance engagement and professional competence while reinforcing AU's reputation for innovation and practice-oriented education.

Feedback and Continuous Improvement

Feedback mechanisms form the backbone of AU's quality-assurance loop for industrial collaboration. Data sources include employer evaluations, student reflection reports, IAB consultations, and accreditation reviews. Quantitative internship feedback is aggregated annually to identify competency gaps, while qualitative testimonials inform curriculum enrichment.

Moreover, the CoE conducts biannual program review meetings in which faculty present evidence of CDIO implementation and discuss feedback received from industry mentors. Recommendations are documented and tracked in subsequent cycles to ensure that curriculum and facility updates are evidence-based, thereby institutionalizing continuous improvement and reinforcing CDIO Standards 10 and 11.

LESSONS LEARNED AND INSTITUTIONAL IMPACT

Observed Benefits

Over nearly a decade of practice, several key lessons have emerged. Formalizing partnerships through structured frameworks such as IAB charters and Memoranda of Understanding has proven critical for sustainability and accountability. Student engagement has also increased when industrial collaboration is introduced early in the curriculum rather than being reserved for the final year, while faculty capacity-building, including training in PBL facilitation and industry liaison, has further enhanced the effectiveness of CDIO integration. Collectively, these practices have strengthened graduate employability and professional readiness, as reflected in employer satisfaction and internship performance data. They have also improved curriculum agility, enabling the inclusion of emerging technologies and sustainability topics, and elevated the institution's visibility through student participation in research and innovation competitions.

Furthermore, these efforts have reinforced alignment with accreditation standards, including those of Engineers Australia and CDIO Standards 1–11. Embedding industrial collaboration across CDIO stages has produced a sustainable, evidence-driven model of engineering education that remains responsive to evolving regional and global needs. These institutional results are consistent with prior research demonstrating the dynamic integration of sustainability and climate change perspectives in engineering curricula via CDIO at AU (El Achkar & Alsaba, 2024).

Challenges

Despite the positive outcomes associated with AU’s industry collaboration model, several challenges remain in sustaining and scaling such partnerships. These challenges can be grouped into institutional, operational, and partnership-related factors, as summarized in Table 1. These challenges may affect several CDIO Standards, particularly Standards 5, 7, and 8 related to design-build and integrated learning experiences, as well as Standards 9–11 associated with faculty development, program evaluation, and continuous improvement.

Table 1. Key Challenges in Sustaining Industry Collaboration within the CDIO Framework at AU and Corresponding Mitigation Strategies

Challenge	Description	Mitigation Strategy
Institutional Coordination	Misalignment between academic and industry timelines limits mentor availability and project engagement.	Early coordination and flexible scheduling with industry partners.
Faculty Workload and Resource Constraints	Supervising internships and industry-linked projects requires significant faculty coordination.	Shared supervision and institutional support mechanisms.
Variability in Industry Project Scope	Differences in project scope, supervision, and data access affect consistency of learning outcomes.	Standardized project guidelines and evaluation rubrics.
Sustaining Industry Engagement	Smaller companies may lack resources for long-term collaboration.	Formal partnerships and regular advisory board consultations.

INSTITUTIONAL IMPACT

Internship Placement Outcomes (2015–2025)

The internship dataset spans academic years 2015–2016 to 2024–2025 and includes 633 interns from AU's CoE. The analysis first examines the distribution of interns across the four engineering programs, followed by an assessment of placements by host-sector category (Figure 2).

Placements were led by Mechanical Engineering (ME) (34.3%), followed by Petroleum Engineering (PE) (30.3%) and Civil Engineering (CE) (28.1%). Electrical and Electronics Engineering (EE) (7.3%) formed the smallest share, which may reflect cohort size and sectoral demand patterns. Overall, participation is broad across programs, with particularly strong engagement from ME and PE.

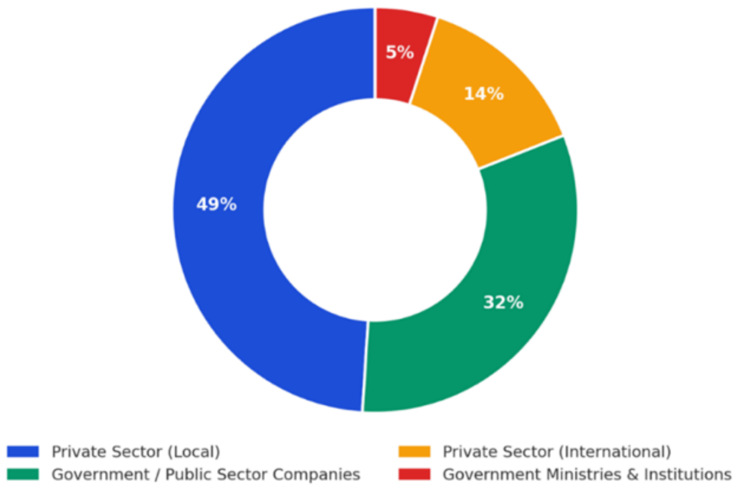

Figure 2. Distribution of Interns Across Organizational Categories

Nearly half of the interns (≈49%) were placed in the Private Sector (Local), indicating strong collaboration with national firms and consultancies. Government / Public Sector Companies accounted for ≈32%, reflecting the central role of state-owned enterprises, particularly in energy. Private Sector (International) represented ≈14%, providing exposure to global practices and standards, while Government Ministries & Institutions accounted for ≈5%. The distribution evidences a diversified placement ecosystem spanning both public and private stakeholders, ensuring broad exposure to industrial environments.

These results indicate that AU's internship model successfully connects students with both public and private engineering sectors. The strong representation of private-sector placements reflects effective collaboration with local industry partners, while international placements expose students to global engineering practices. This diversified placement ecosystem strengthens experiential learning and enhances graduate employability.

Beyond quantitative distributions, qualitative feedback from students was also examined to capture their perceptions of learning outcomes and internship experiences. Student evaluations collected over a five-year period were analyzed, and a word-cloud visualization was generated (Figure 3). The text body, containing 4,676 raw words, was processed using systematic text-cleaning methods that reduced it to 1,231 meaningful terms (a 73.7% reduction) by removing stop words and non-informative descriptors.

Figure 3. Word Cloud Derived from Qualitative Analysis of Student Internship Testimonials (Five-Year Dataset)

The most prominent themes emerging from student feedback centered on "field" (38.1% of comments), "skills" (36.5%), "real" (22.2%), and "project" (22.2%), highlighting students' emphasis on the practical relevance of their internship experiences. Thematic categorization revealed that students most frequently mentioned technical-skills development (76 mentions), professional development (51 mentions), academic learning connections (36 mentions), and real-world value (32 mentions). The word cloud effectively captures the dual-perspective nature of AU's internship program, where students recognized both the application of theoretical knowledge from university courses and the acquisition of workplace-relevant competencies such as teamwork, communication, and supervisory relationships.

Across 633 placements (2015–2025), the outcomes demonstrate that sustained multi-channel industry engagement within the CDIO framework yields broad opportunities across programs and sectors. These results reaffirm that AU's experiential learning model strengthens graduate readiness, aligns with regional workforce needs, and supports the university's commitment to industry-connected engineering education.

Student Involvement in Research Publications

An important institutional impact observed over the last ten years (2015–2025) is the significant engagement of undergraduate students in scholarly publications, both in journals and conference proceedings. Across the CoE, 62 publications have included undergraduate student participation, with 205 students listed as co-authors. This reflects how PBL and CDIO-oriented practices have successfully fostered student-led inquiry, collaboration with faculty, and early exposure to research dissemination.

The distribution of publications and student participation highlights notable trends. CE leads with 31 publications and 92 student co-authors, representing the largest share of undergraduate involvement. PE follows with 17 publications and 68 student co-authors, demonstrating strong integration of research within its curriculum. ME and EE also contributed with 9 publications (29 students) and 5 publications (16 students), respectively.

These patterns demonstrate that integrating research opportunities into undergraduate education strengthens not only student learning outcomes but also the institution's overall research culture. By embedding research participation in CDIO-based projects, students develop transferable skills in critical thinking, collaboration, and dissemination, thereby enhancing both institutional visibility and student preparedness for advanced studies or professional practice.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates how the Australian University (AU) has successfully integrated the CDIO framework across multiple channels of industrial collaboration to enhance engineering education. By aligning IABs, internships, project-based learning, and research partnerships with CDIO stages, the CoE has established a coherent system that connects academic learning with real-world engineering practice. The outcomes, evident through internship data, student feedback, and research engagement, confirm that CDIO-based industrial collaboration strengthens graduate readiness, fosters professional competencies, and sustains continuous curriculum improvement.

Institutional experience over the past decade highlights that success in such initiatives depends on structured partnerships, faculty capacity-building, and systematic feedback loops. The AU model may provide a transferable framework for universities seeking to modernize engineering programs through authentic, practice-oriented learning.

Future directions should focus on expanding cross-sector collaborations, particularly in renewable energy, automation, and data-driven engineering, to reflect emerging industry demands. Establishing more formalized mechanisms for long-term industry engagement, joint project supervision, and faculty internships within companies will further strengthen integration between academia and practice. Moreover, embedding data analytics into feedback systems can improve evidence-based curriculum updates, ensuring alignment with CDIO Standards 9–12. Through these continuous efforts, AU will continue to consolidate its role as a regional leader in innovative, industry-connected engineering education and contribute to shaping sustainable, forward-looking engineering practices.

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