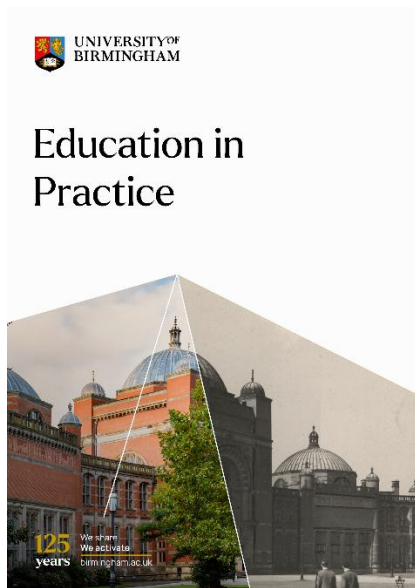




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Improving student outcomes from STEM projects by broadening goals, collaboration and dissemination: the Authentic, Industry-Driven Learning model (AIDL)

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Abstract

Traditional engineering and science Masters-level projects often follow a predictable path: students research a topic and plan experiments, collect laboratory data, analyse results, and write a report followed by a viva. While such projects develop a range of abilities, and authentically replicate *aspects* of post-graduation work, they can fall short of capturing the broader professional, global, and creative competencies beneficial in industry. The approach presented in this paper enhances this in three ways: Firstly, the potentially isolated project topics are linked with the United Nations Sustainable Development Goals (SDGs). Secondly, students engage directly with transnational research partners. Thirdly, the students explicitly work towards outputs that are disseminated in international conferences / publications, which feed into the traditional assessment framework of report, presentation and viva.

Comparative results show that groups adopting this approach achieved significantly better outcomes than their peers in the same cohort, demonstrating improved academic performance, enhanced collaboration, and stronger outcomes than those undertaking traditional projects. The model also demonstrates resilience to generative AI challenges by prioritising experiential creation over solely text-based assessments.

Broadening the relevance of assessment in this way should be considered for Masters-level engineering and STEM education, ensuring graduates emerge as adaptable, ethical, and industry-ready professionals.

Keywords: authentic assessment; industry collaboration; experiential learning; project-based education; transnational learning; employability skills; STEM education; sustainability; global citizenship; AI-resilient assessment

Introduction

In engineering and STEM education, particularly at the MEng/MSc level, project-based learning has long been considered the pinnacle of student achievement. Yet the traditional model of collecting laboratory data, producing a written report, and defending it in a viva, has changed little over decades. While effective in assessing technical competence, it often fails to cultivate the broader set of professional, creative, and ethical skills that modern engineers require (Cajander *et al.*, 2010; Chetehouna and Viola, 2024).

In today's rapidly evolving global landscape, graduates must demonstrate technical agility in addition to teamwork, communication, adaptability, and social responsibility (Wiek *et al.*, 2011). The rise of Artificial Intelligence (AI) has further exposed the limitations of conventional assessment, which relies heavily on written outputs that can be produced with minimal intellectual engagement (Kumar *et al.*, 2023; Chetehouna and Avital, 2025)

This study introduces an alternative Authentic, Industry-Driven Learning model (AIDL), which redefines the Masters project as a professional, collaborative, and globally relevant experience. Developed and implemented at Queen Mary University of London (QMUL), the framework embeds industrial mentorship, transnational collaboration, and real-world dissemination into the project. The model is grounded in principles of authentic learning (Herrington and Oliver, 2000), constructive alignment (Chetehouna and Viola, 2024), and experiential education (Kolb, 1984). By engaging students in socially meaningful projects aligned with the UN's Sustainable Development Goals, particularly SDG 4 (Quality Education) and SDG 7 (Affordable and Clean Energy), this approach shifts assessment from theoretical recall and text-based submissions to demonstrable competence and impact in a broader domain. (Students are still required to demonstrate their individual recall, understanding and analytic ability in parallel assessments, but the project part of the overall assessment becomes more authentic). Within this framework, SDG 4 is operationalised through the design of authentic, practice-oriented learning experiences that emphasise skill development, collaboration, and engagement with real-world challenges. SDG 7 is reflected in the specific application context of the project, which focuses on sustainable energy solutions through wind turbine design. The AIDL framework therefore serves as a transferable template that can be adapted across disciplines, enabling future implementations to align with different Sustainable Development Goals according to their specific educational and application contexts.

Methodology and Pedagogical Framework

Educational Context

The framework was implemented with a cohort of twelve students: two MSc and ten MEng students from QMUL. These students worked collaboratively within a transnational consortium involving academic partners from India, VIT Chennai and IIT Madras, and an industrial partner, Deutsche Wind Guard GmbH. The project theme, Wind Energy for Urban and Rural Applications, addressed sustainable energy challenges through small-scale turbine design. The framework followed a project-based and experiential learning approach consistent with established pedagogical research in engineering education (Lavado-Anguera *et al.*, 2024). While students retained the option to complete a traditional report-based project, participation in the authentic framework was voluntary but strongly encouraged. As recognition emerged, more students ultimately chose the authentic AIDL model route, drawn by its real-world relevance, exposure, and professional outcomes.

Structural Design

The AIDL model was scaffolded through three structured Training Work Packages (TWPs):

- TWP1 – Collaborative Training: Joint online seminars delivered by UK and Indian academics and industry partners. Topics covered rotor aerodynamics, structural dynamics, sustainability, and socio-economic aspects of energy access.
- TWP2 – Technical Skill Development: Hands-on training in computational and experimental methods, ensuring technical readiness for simulation, design, and testing.
- TWP3 – International Research Residency: Intensive workshops where students refined research briefs, produced design prototypes, and presented work to mixed panels of academics and professionals.

The UK based students primarily focused on horizontal-axis wind turbines (HAWTs), while Indian collaborators explored vertical-axis turbines (VAWTs) and decentralised energy storage.

Industry Integration

Industry experts (Deutsche Wind Guard) provided mentorship, milestone feedback, and technical validation. This ensured that academic learning directly mirrored professional engineering practice and exposed students to the standards of real-world design, analysis, and dissemination.

Assessment Approach

The authentic assessment framework retained the written report and viva examination as core components required for accreditation. However, these were repositioned within a broader, multi-layered evaluation framework designed to capture authentic professional competencies beyond traditional report-based assessment. Rather than

relying on a single summative output, student performance was evaluated and developed through a combination of academic judgement, formative development, and external professional validation.

Formal summative assessment remained anchored within institutional processes. Academic supervisors assessed the written reports and viva examinations, focusing on technical rigour, methodological justification, and depth of understanding. These judgements were subject to moderation and oversight by an external examiner, ensuring consistency with academic standards and comparability with traditional project pathways.

In parallel, a structured programme of formative assessment supported student development throughout the project. Regular supervisory meetings, combined with monthly interactions with industry partners (Deutsche WindGuard), provided iterative feedback on technical progress, design decisions, and practical feasibility. This continuous feedback loop enabled students to refine their work in response to real-world engineering constraints and professional expectations.

A distinctive feature of the framework was the inclusion of external professional validation through dissemination. Students developed conference papers and presented their work at international venues, where submissions were subject to peer review and, in some cases, competitive evaluation. Conference acceptance, presentation, and awards provided independent confirmation of the quality, originality, and relevance of the students' work within a professional engineering context.

Assessment criteria were aligned with multiple forms of evidence to ensure a comprehensive evaluation of student performance:

- **Technical performance and innovation** were assessed summatively through the written report and viva , evaluated by academic supervisors and moderated by the external examiner. These assessments focused on the quality of students' design work, as well as their analytical and computational approaches. Formative assessment was provided through regular supervisory meetings and monthly interactions with industry partners (Deutsche WindGuard), offering iterative feedback on technical progress and design decisions. Evidence of the standard and relevance of this work was provided through successful dissemination at international conferences.
- **Communication and dissemination quality** were evidenced through the clarity and structure of written reports, effectiveness of viva presentations, and the preparation and delivery of conference papers, including external peer-review outcomes.
- **Collaboration and teamwork** were evaluated through students' ability to work effectively within interdisciplinary and transnational teams, contribute to shared outputs such as co-authored publications, and engage in collective decision-making processes throughout the project.

- **Contextual, and sustainability awareness** were assessed through students' ability to justify engineering decisions within real-world constraints, including societal needs, environmental considerations, and application contexts aligned with sustainable energy challenges.

This multi-source assessment approach demonstrated in Table 1, ensured that the written report functioned as an integrative reflection of a broader body of work, rather than the sole determinant of performance. By combining academic evaluation with industry-informed feedback and external professional scrutiny, the framework provided a more authentic and robust measure of student capability, aligning assessment with the expectations of contemporary engineering practice.

Table 1: Multi-layered assessment framework illustrating the alignment of assessment types, assessors, evidence sources, and marking criteria across technical, communication, collaboration, and contextual dimensions.

Assessment Dimension	Type of Assessment	Assessor(s)	Evidence Mechanism	Assessment Focus
Technical performance and innovation	Summative	(1) Academic supervisors. (2) External examiner	(a) Written report. (b) Viva	(a) Application of engineering principles. (b) Problem-solving of complex challenges. (c) Modelling and simulation. (d) Justification and evaluation of methods and assumptions.
	Formative	(1) Academic supervisors. (3) Industry partner (Deutsche WindGuard)	(a) Regular supervisory meetings. (b) Monthly industry feedback. (c) Iterative design refinement.	(a) Development of technical solutions. (b) Responsiveness to feedback. (c) Iterative improvement. (d) Alignment with practical constraints.
	External professional validation	(4) Conference peer review and professional	(a) Peer-reviewed conference papers. (b) presentations.	(a) External recognition of technical quality. (b) Validation of innovation. (c) Professional relevance.

		evaluation panels	(c) Awards and feedback.	
Communication and dissemination quality	Summative	(1) Academic supervisors; (2) External examiner	(a) Written report. (b) viva presentation.	(a) Clarity and structure. (b) Logical argumentation. (c) Professional presentation.
	Formative	(1) Academic supervisors. (3) Industry partner (Deutsche WindGuard).	(a) Feedback on reports and presentations during meetings.	(a) Development of communication skills. (b) Refinement of technical writing. (c) Improvement of delivery.
	External professional validation	(4) Conference peer review and professional evaluation panels.	(a) Conference paper acceptance. (b) Presentation at international venues.	(a) Peer-reviewed dissemination. (b) Communication to professional audiences. (c) Alignment with international standards.
Collaboration and teamwork	Formative	(1) Academic supervisors. (3) Industry partner (Deutsche WindGuard).	(a) Team-based project work. (b) Co-authored outputs. (c) Coordination across transnational teams.	(a) Contribution to team objectives. (b) Shared accountability. (c) Interdisciplinary collaboration. (d) Cross-cultural coordination.
	Evidence of outcome	(1) Academic supervisors.	(a) Joint publications. (b) Coordinated project delivery.	(a) Demonstration of effective teamwork. (b) Integration of contributions. (c) Collective ownership.
Contextual, and sustainability awareness	Summative	(1) Academic supervisors.	(a) Evaluation within report and viva.	(a) Societal and environmental considerations. (b) Ethical

		(2) External examiner.		reasoning. (c) Alignment with sustainability goals.
	Formative	(1) Academic supervisors. (3) Industry partner (Deutsche WindGuard).	(b) Feedback on applicability and constraints.	(a) Integration of real-world constraints. (b) Contextual decision-making. (c) Responsiveness to societal needs.
	Evidence of outcome	(4) Conference peer review and professional evaluation panels.	(a) Application-driven project focus. (b) Alignment with real-world challenges	(a) Relevance to industry. (b) Alignment with sustainability challenges. (c) Practical applicability.

Dissemination and Exposure

The 12 students collectively produced and presented three international conference papers:

1. WES 2024, Southampton (September 2024): Two MSc students presented aerodynamic optimisation of small turbines (Gadda *et al.*, 2024)
2. AIAA Region VII and SciTech (Melbourne, November 2024; Orlando, January 2025): Six MEng students presented and won First Place at the student conference (Saini *et al.*, 2025)
3. IEEE ICMAE 2025, Rome (July 2025): Four MEng students presented work on rotor performance in confined and extraterrestrial conditions (Lesniakowski *et al.*, 2025)

These outputs represented the academic achievement and professional recognition, marking a significant departure from conventional assessments.

Findings and Outcomes

Motivation and Cultural Shift

The most immediate outcome was a profound cultural shift. Students who initially opted for the traditional path requested to join the authentic model after witnessing their peers' conference success (Gadda *et al.*, (2024); Saini *et al.*, 2025). This voluntary transition reflected a shift from grade-oriented compliance to increased engagement and ownership of the project work.

Peer collaboration and shared accountability flourished, as each publication or presentation carried all team members' names (Lesniakowski *et al.*, 2025). This collective visibility encouraged mutual support and professional conduct, effectively simulating the collaborative dynamics of real engineering teams.

Academic and Technical Performance

To evaluate the academic impact of the Authentic, Industry-Driven Learning (AIDL) framework, defined here as a collaborative, challenge-led, industry-integrated project model that prioritises authentic outputs, professional dissemination, and engagement with real engineering problems. A quantitative comparison of the ten MEng students' project performance across two consecutive years was conducted against twelve MEng students of the same discipline (aero-mechanical engineering), who did not go through the AIDL process. The analysis focussed exclusively on project grades, ensuring that the evaluation reflected the direct outcomes of the project-based experience rather than broader taught-module performance. Statistical analysis was performed using paired and independent two-sample t-tests, with p -values used to determine statistical significance and Cohen's d employed to quantify the magnitude of observed effects. A within-group comparison assessed whether students undertaking the AIDL model showed improvement from 2024 (BEng level) to 2025 (MEng level), and the same analysis was applied to a comparison cohort completing traditional projects. A between-group comparison examined whether the two cohorts differed in each year, while a difference-in-differences calculation determined whether the improvement in the AIDL cohort exceeded the natural year-on-year progression observed in the traditional cohort. Together, these complementary statistical approaches provide a strong basis for assessing the academic effect of the AIDL intervention, and the resulting performance trends are illustrated in Figures 1 and 2.

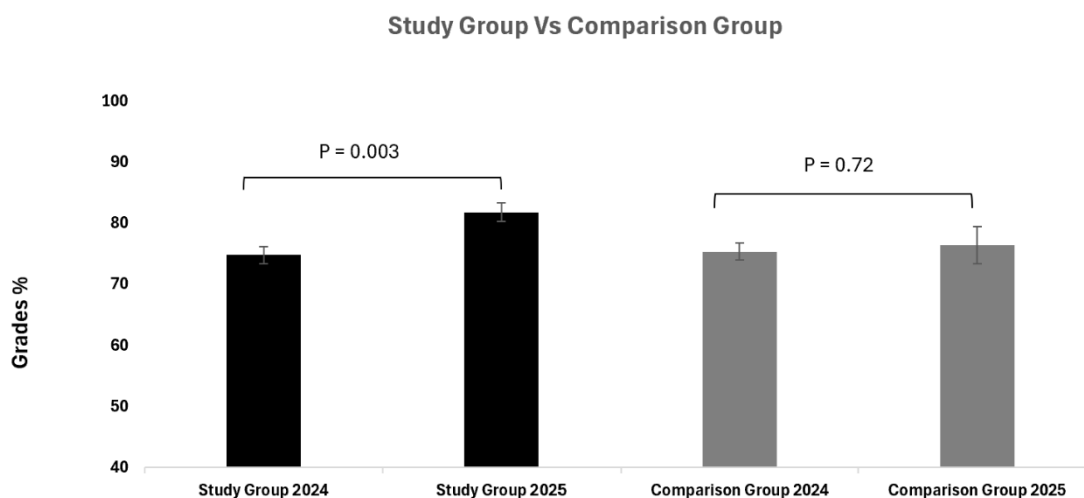


Figure 1: Mean project grades for the study group and a comparison group from the same cohorts in 2024 and 2025

Students in the AIDL (study) group showed a significant improvement from 2024 to 2025 ($p = 0.003$, $d = 1.31$), whereas the comparison group showed no meaningful improvement ($p = 0.72$). Both groups had equivalent baseline performance in 2024 ($p = 0.80$). Error bars represent standard error of the mean.

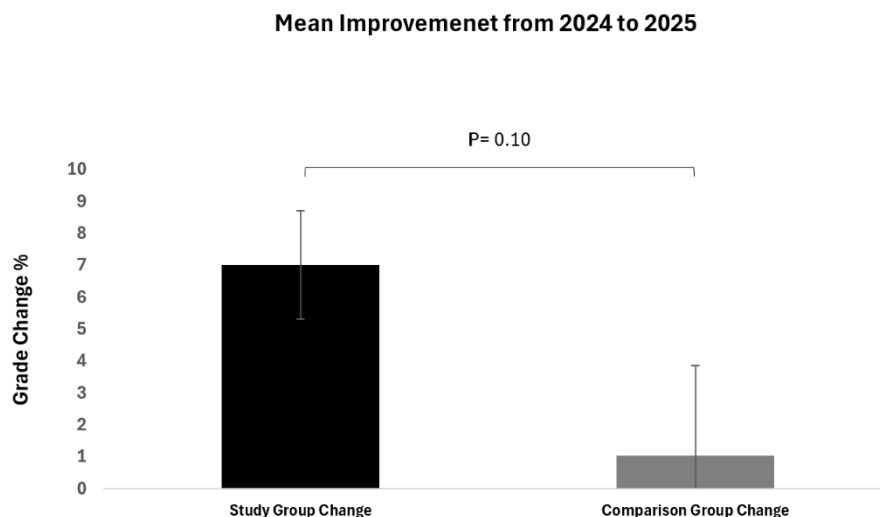


Figure 2: The AIDL-study group improved by an average of 7.02 percentage points, compared with 1.05 points in the comparison cohort

The AIDL-study group improved by an average of 7.02 percentage points, compared with 1.05 points in the comparison cohort. This difference in improvement approached significance ($p = 0.099$), indicating a substantially greater gain for students engaged in authentic, industry-driven learning.

To evaluate the academic impact of the Authentic, Industry-Driven Learning (AIDL) framework, project grades were analysed across two consecutive years using paired and independent t-tests. Statistical significance was assessed using p-values. The effect size (Cohen's d) was calculated to indicate the standardised magnitude of the difference, providing an estimate of its practical and educational relevance independent of sample size.

As shown in Figure 1, both cohorts began from an equivalent baseline in 2024 (Study Group mean = 74.78; Comparison Group mean = 75.31; $p = 0.80$). The high p-value and negligible effect size ($d = -0.11$) indicate that no statistically or educationally meaningful difference existed at the outset, providing a robust baseline for subsequent comparisons.

By 2025, a clear separation had emerged between the two pathways. Students undertaking the AIDL model achieved higher project grades (mean = 81.80) than peers completing traditional laboratory-based projects (mean = 76.36). These grades are derived from parallel assessments undertaken by all student groups under the same marking criteria and moderated by the same academic staff (the module organiser and deputy), ensuring consistency and comparability across cohorts. The medium-to-large effect size ($d = 0.67$) reflects a substantive and educationally meaningful difference in performance, beyond what would be expected by sampling variation alone.

The within-group comparison provides the strongest evidence of the AIDL impact. The Study Group cohort showed a statistically significant improvement from 2024 to 2025 ($p = 0.003$, $d = 1.31$). The p -value indicates a significant difference in performance, while the large effect size reflects a substantial progression in learning outcomes. By contrast, the Comparison Group cohort demonstrated no statistically significant progression ($p = 0.72$, $d = 0.11$), with the negligible effect size confirming that performance remained essentially unchanged across the two years. This divergence indicates that the improvement observed in the AIDL cohort cannot be attributed to routine year-on-year academic development.

The difference-in-differences analysis, presented in Figure 2, reinforces this interpretation. The Study Group improved by 5.97 percentage points more than the traditional cohort ($p = 0.099$). Although marginal in statistical terms, this result indicates a directionally meaningful differential gain, particularly given the stability of the comparison cohort and the small sample sizes involved.

Taken together, these findings demonstrate that the AIDL framework generated measurable and educationally significant improvements in academic and technical performance. Engagement with authentic engineering challenges, industry mentorship, iterative design work, and professional dissemination appears to have supported deeper conceptual learning and enhanced technical and reflective capabilities. The absence of comparable gains in the traditional cohort highlights the limitations of isolated report-based assessments. These outcomes are further reinforced through additional dimensions of student development introduced by the AIDL framework, including professional competencies, collaborative practice, and externally validated outputs such as peer-reviewed conference dissemination and competitive achievements, as summarised in Table 2. In this context, the framework extends the scope of evaluation beyond conventional academic metrics, capturing aspects of performance that are not typically represented within traditional project models and therefore not directly comparable within a purely grade-based framework. Overall, the observed performance patterns align with established theories of authentic and experiential learning, indicating that industry-integrated, performance-based project work leads to more substantial and transferable learning outcomes than conventional project models.

Table 2: The multi-dimensional impact associated with the AIDL framework across academic and technical performance, professional competencies, and collaborative practice.

Outcome Dimension	Evidence Source	Demonstration
Academic performance	Project grades and statistical analysis	Significant improvement compared to control cohort.
Technical capability	Design, analytical, and computational work	Successful completion of complex engineering tasks and validated solutions.
Communication and dissemination	Conference papers and presentations	Peer-reviewed publications and presentations at international conferences.
External validation	Conference evaluation and awards	Acceptance through peer review, and recognition through awards and professional feedback.
Industry engagement	Interaction with Deutsche WindGuard	Ongoing formative feedback and alignment with real-world engineering constraints.
Collaboration and teamwork	Transnational group work and co-authored outputs	Joint publications and coordinated project delivery across institutions.
Professional readiness	Early career outcomes	Students securing engineering roles and postgraduate positions prior to graduation.

Employability

The AIDL framework demonstrated a clear impact on students' early career progression. Even before graduation, almost half of the students had secured competitive engineering roles, highlighting the immediate professional relevance of their experience. In addition, one student obtained a fully funded PhD position, further reflecting the academic strength and confidence developed through the project. Students also demonstrated a high level of readiness for both industry and postgraduate opportunities, as evidenced by their engagement in international conference dissemination, cross-institutional collaboration, and the authentic, industry-integrated nature of their work.

Institutional and Societal Impact

The model enhanced the institutional profile of QMUL and its partners. Students acted as ambassadors, representing their university in global academic arenas such as the AIAA SciTech (a world leading aerospace engineering conference) and the IEEE-ICMAE conference. The approach also attracted interest from external partners and sponsors, demonstrating potential for scalability and continuation.

Supervisor Workload and Collaborative Efficiency

While the initial setup of the AIDL framework required additional time to establish industrial partnerships, coordinate with collaborators, and design authentic assessment mechanisms, this investment rapidly translated into a more distributed and efficient supervisory model. Once implemented, supervision became a shared responsibility among all stakeholders, academic leads, industry partners, technicians, and student teams, each contributing to progress tracking, milestone feedback, and professional guidance.

The students' growing independence and professionalism further reduced the supervisory burden. Regular meetings evolved into focused, high-level discussions rather than administrative check-ins, as students actively sought advice, presented progress to partners and peers, and supported one another across tasks and time zones. This peer-led collaboration, underpinned by external mentorship, minimised routine queries and logistical demands, allowing supervisors to focus on the strategic and developmental aspects of learning. The result was a more balanced and sustainable supervisory ecosystem that maintained quality while enhancing efficiency.

Discussion

The AIDL model operationalises constructive alignment (Biggs and Tang, 2011; Gulikers *et al.*, 2004) by linking outcomes, activities, and assessments within real professional contexts. Students learned through doing, reflection, and dissemination, which are the key tenets of authentic learning (Herrington and Oliver, 2000) and experiential learning (Kolb, 1984).

The authentic nature of the work being industry-supervised, disseminated publicly, and aligned with societal needs ensured learning outcomes extended beyond knowledge acquisition to include judgement, ethics, and communication. The collaboration across borders cultivated global citizenship, aligning with UNESCO (2017) vision of education for sustainable development. Students developed intercultural awareness and adaptability, experiencing first-hand how engineering solutions vary according to regional and socio-economic constraints. The industry involvement further transformed the learning experience into a simulation of professional practice. By engaging directly with engineers and mentors, the students received authentic feedback, navigated real project constraints, and developed advanced communication skills. This approach bridged the academia–industry gap, a long-standing challenge in engineering education (Kolmos and Holgaard, 2010).

The framework also rendered the AI-related threats to assessment largely obsolete, as generative systems cannot replicate the physical elements of prototyping, the iterative problem-solving inherent in design sessions, or the public defence of ideas at professional conferences. Recent studies emphasise that assessment integrity in the age of generative AI depends not on avoidance but on design. Authenticity, process transparency, and performance-based evaluation are key to ensuring meaningful engagement and academic integrity (Kofinas *et al.*, 2025).

The model also created a “community of practice” (Lave and Wenger, 1991) among students, academics, and industry partners. Shared goals, peer accountability, and public dissemination cultivated a culture of excellence, motivation, and collaboration rarely achievable through isolated report-based work.

Conclusion and Recommendations

The Authentic, Industry-Driven Learning framework demonstrates that replacing traditional, report-based project models with collaborative, transnational, challenged, and industry-integrated approaches not only maintains academic rigour but actively enhances it. Through engagement with real-world engineering problems, international teamwork, and dissemination at global conferences, students demonstrated enhanced technical understanding, as evidenced by improved academic performance, successful conference dissemination, and engagement in collaborative, transnational project work. These outcomes reflect a broader, multi-dimensional model of student performance, encompassing not only academic achievement but also professional competencies, collaborative practice, and externally validated outputs.

Although the initial establishment of such a model requires thoughtful coordination with partners and careful project design, once in place it enables a more distributed and efficient supervisory structure. Stakeholders share responsibility for feedback and progression monitoring, while students’ increased independence and professionalism reduce routine supervisory demands, making ongoing oversight more sustainable without compromising quality.

These outcomes, combined with the measurable improvement in academic performance observed in the AIDL cohort, provide a compelling case for broader adoption of this framework within engineering education and, more widely, across STEM disciplines where authentic, practice-based learning can be effectively embedded. As implementation expands to larger and more diverse student groups, further insights and evidence will strengthen its applicability across diverse educational and disciplinary contexts. The following recommendations outline key considerations for embedding authentic, industry-driven, project-based learning within engineering and related STEM programmes.

While the AIDL framework provides a structured approach, its implementation may require additional time and coordination, particularly during initial adoption. In practice, elements of the framework can be introduced incrementally, allowing educators to adapt selected components, such as industry engagement or dissemination activities, according to their institutional context and resources.

Key Recommendations:

1. Embed authentic assessment through structured dissemination opportunities. Traditional report-based outputs should be supplemented with deliverables such as conference papers and presentations. As demonstrated in this study, dissemination provides an additional layer of evaluation and enables students to present their work within a professional context.
2. Integrate industry partners as contributors to the learning and feedback process. Industry engagement should be incorporated throughout the project lifecycle, providing input on technical direction, practical constraints, and application relevance through regular interactions and feedback.
3. Facilitate collaborative and, where possible, transnational project structures. Designing projects that involve teamwork across disciplines or institutions supports the development of collaborative working practices and exposes students to different engineering contexts and approaches.
4. Design assessment to include multiple forms of performance evidence. Evaluation should not rely solely on written reports, but should also reflect technical outputs, presentations, and externally reviewed work, allowing a broader representation of student capability.
5. Align project themes with real-world and socially relevant challenges. Framing projects within applied contexts, such as sustainability or industry-defined problems, enhances engagement and supports the application of engineering knowledge to practical situations.
6. Incorporate experiential and process-based learning elements. Emphasising iterative design, problem-solving, and active project development ensures that learning is grounded in practice and cannot be easily replicated through purely text-based or generative AI approaches, as it relies on engagement with real-world constraints, collaboration, and performance-based outputs.
7. Leverage student dissemination to enhance institutional representation. Student participation in international conferences and collaborative outputs provides opportunities for institutions to be represented within global academic and professional contexts. As observed in this study, students acted as ambassadors for their institution through their participation in international dissemination activities.

The framework is scalable across disciplines and institutions. By aligning learning with professional authenticity and ethical purpose, it ensures graduates are not only

technically capable but also globally aware, socially responsible, and prepared to lead in the evolving landscape of engineering and technology.

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