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Research article

Project-work Artificial Intelligence Integration Framework (PAIIF): Developing a CDIO-based framework for educational integration

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Abstract: Artificial intelligence (AI) and generative AI (GenAI) have sparked confusion and concern regarding their impact on education. Beyond the assessment integrity risks that currently draw the most attention, technologies such as ChatGPT, Copilot, and Gemini have also been identified as tools that can support learning. Project work, especially when there is no single correct solution, provides a great opportunity for integration, fostering technology knowledge and higher learning standards. However, no AI-integration framework for project-based work is available, resulting in a limited understanding of how AI integration can occur or be maximized. To address this, a collaborative effort of 16 educators from 9 Australian universities has led to the development of a generic AI implementation framework, built upon the CDIO approach. With a focus on engineering education, this framework can be adapted to other project-based learning contexts, where educators can pick and choose the relevant implementation items as needed. This framework is called the Project-work Artificial Intelligence Integration Framework (PAIIF), and its development and structure are outlined here. Initial implementations have shown the effectiveness of promoting reflection and guidance on where and how AI integration can occur.

Keywords: Artificial intelligence (AI), CDIO, ChatGPT, educational integration, generative AI (GenAI), project-based learning (PBL)

1. Introduction

In late 2022, generative artificial intelligence (GenAI), through the release of ChatGPT-3.5, sent shockwaves across the academic community when it was discovered that it was highly capable of passing assessment tasks across all levels of education [1]. This development highlighted the transformative potential of AI, including GenAI, not only in education but also in the broader context of work and society [2]. To avoid confusion, the term AI is used in this study to represent all forms of AI, including GenAI. By early 2024, the expanding availability of AI models and tools, including ChatGPT, Copilot, and Gemini, heightened academic integrity concerns across higher education, but project-based work was identified as a prime opportunity to integrate these technologies [3]. A key reason is that project-based work, especially if open-ended, requires problem-solving, critical thinking skills, and commonly multidisciplinary knowledge. These skills are centered on *evaluative judgment*, a future-facing skill defined by the need of students to learn in order to assess the quality and appropriateness of the information they have been provided [4].

While some educators advocate for integration and adaptation of assessments to leverage AI's capabilities to enhance professional skills such as critical thinking, there are concerns regarding the impact on competency development [5] and ethical use [6,7]. This transformative landscape should be navigated thoughtfully, ensuring that AI enhances, rather than substitutes, students' agency, critical thinking, problem-solving, and creative abilities. To achieve this, we consider AI as a co-intelligence [2] or a virtual teammate [8] rather than a direct replacement of human capability. This works in lockstep in helping students develop evaluative judgment. Based on the work of Nikolic et al. [3], this paper considers how AI can be used as a tool to enhance project work, providing an important and much-needed guide for subject coordinators on when and how to integrate AI. Such guidance may help improve performance expectancy, removing barriers to wider uptake [9].

Project work is considered an authentic assessment, providing an experience that improves student motivation, promotes inclusion, fosters employability capabilities, prepares students for employment, and engages critical thinking and problem-solving capabilities through real-world challenges [10,11]. In an engineering-focused higher education context, project work typically involves students collaborating on open-ended, real-world (or simulated) problems, integrating theoretical knowledge with hands-on application, and producing tangible outcomes (e.g., prototypes, designs, or research findings) [12]. This approach emphasizes problem-solving, teamwork, communication, and the iterative refinement of solutions reflecting the professional practices of the engineering field.

Integrating AI in project work can enhance the educational experience by providing personalized feedback, generating ideas, streamlining research processes, and enabling more complex problem-solving capabilities that align with real-world professional contexts [13]. As an example, a pilot work by Nikolic and Beckman [14] found that integration could lead to students acquiring new digital literacy skills and producing project solutions that exceeded expectations. This suggests that AI could help support creativity rather than limit it [15]. However, the ad hoc nature of the implementation was a challenge. A structured and comprehensive implementation overview was necessary, but such solutions were unavailable in the existing literature. This gap created the purpose of developing a project-based AI-integration framework. Grounded in the well-established CDIO (Conceive, Design, Implement, Operate) approach widely used in engineering education [16], the framework harnesses a real-world focus that aligns AI tools and practices with engineering project processes.

The current implementation of AI in educational project work has been largely experimental, with many institutions adopting a trial-and-error approach. AI integration is difficult due to a lack of exemplars, training, and resources [17]; often, it is in a fragmented state, a paradoxical perspective observed by Lim et al. [18]. This ad hoc approach has resulted in inconsistent outcomes and left educators unsure about the best practices to adopt. A systematic literature review by Nikolic et al. [19] found such challenges universal, leading to a lack of acceptance of AI integration, which is a major impediment.

To address these challenges, there is a critical need to develop a comprehensive framework that guides the integration of AI into project work systematically and equitably. Such a framework would provide educators with the tools and strategies to incorporate AI effectively. It is an important starting point. Developing a structured framework would facilitate the alignment of AI integration with pedagogical goals, ensuring that AI is used not just as a tool for efficiency but as a means to deepen learning and enhance educational experience. By fostering a guided approach, educators can better support students in navigating the complexities of AI-enhanced project work, promoting responsible use and maximizing the technology’s potential to enrich learning outcomes.

To address this limitation, this work results from a collaboration between 16 educators from 9 Australian universities who act as either subject coordinators or educational designers for courses that implement engineering project work, bringing together insights from diverse engineering disciplines and experiences. The goal was to develop a framework that catered for engineering project work with broad adaptability, which aided student learning and provided academic guidance. This work will outline the design of this framework, creating a key advantage for educators by providing them with much-needed practical guidance on how AI integration can occur.

2. Related literature

The literature review commences by considering the importance of AI integration. It is followed by an investigation of two of the most implemented project structures, problem/project-based learning (PBL) and conceiving, designing, implementing, and operating (CDIO).

2.1. The case of AI integration

AI tools like ChatGPT have undergone much experimentation, testing implementations like supporting learning in programming [20], improving writing [21], and tutoring [22]. Most literature surveys, such as those by Liu et al. [23] and Baig and Yadegaridehkordi [13], highlight that many concerns arise regarding its integration; at the same time, its potential to enhance learning is appreciated. The interrelationship between concerns, expectations, perceptions, and attitudes among different stakeholders suggests that the integration of AI in higher education requires a holistic approach [24]. Implementing robust training, guidelines, and/or policies to ensure alignment with necessary skills reflects the complexity of designing AI-adaptable curricula [19]. In such rapidly developing technology, policies are becoming outdated before they are implemented [25]. There is a constant state of change within implementation guidelines amongst higher education providers that causes difficulties in undertaking a full implementation cycle. To overcome such challenges, researchers are trying to propose new frameworks, such as those targeting holistic integration. This includes the AI literacy model [26], which is a curriculum-level framework consisting of enabling AI, knowing and understanding AI, using and applying AI, evaluating and creating with AI, and AI ethics. Another is the Adoption of GenAI in Education Framework [27], which has the elements of embracing, enabling, experimenting, and exploiting AI. Alternatively, there are targeted frameworks such as PAIGE (Promoting Assignment Integrity using Generative AI in Education) by Shanto et al. [28], targeted at assessment integrity. In this context, PAIIF is designed as a targeted framework for project work.

In terms of project work, ChatGPT was tested by Ambikairajah et al. [29] in an engineering design proficiency course in which students were encouraged to consult it for design solutions, explanations, and suggestions. 70% of the students used it to enhance their understanding. Similarly, Nikolic and Beckman [14] found that if used correctly, especially when there is no single correct solution, AI could improve learning opportunities and project outcomes, but better implementation guidance was needed. Furthermore, Salinas-Navarro et al. [30] found ChatGPT well-suited to be used alongside experiential learning experiences and authentic assessment. Beyond the classroom, Prieto et al. [31] explored using ChatGPT to aid the scheduling of construction projects, finding it valuable but needing improvement. Fosso Wamba et al. [32] surveyed operations and supply chain management practitioners and found that increased efficiency was a key benefit. Notably, those with firsthand experience using AI perceived fewer challenges and threats than non-adopters, suggesting that targeted professional development can enhance readiness for, and the effectiveness of, AI integration. Similarly, Manresa et al. [33] found that familiarity in use was essential to unlocking efficiency gains. An early 2024 study in Denmark found that ChatGPT was finding its way into professional use, with journalists, software developers, IT, and marketing professionals leading the way with usage rates above 50% [34]. This highlights how ignoring AI is impossible and helping both students and educators develop their digital literacy skills in this area is important.

2.2. Projects

Project work plays a pivotal role in linking classroom-based learning to real-world applications [11]. Synthesizing theoretical and practical skills like problem-solving and teamwork can lead to a positive impact on student's academic achievement [35]. Table 1 summarizes the different types of projects and how the authenticity, strengths, and weaknesses depend on the focus, implementation, and targeted learning objectives. Regardless of the format, be it lab projects, case studies, design tasks, or simulations, the core benefit of project work lies in its authenticity and the way it fosters active, hands-on learning [36]. Authentic tasks can inspire students to learn [37]. They also enable a variety of assessment types allowing for learning triangulation [38]. However, project work can be difficult to implement, requiring appropriate scaffolding, guidance, and feedback [39]. Two of the most common project work implementations are PBL and CDIO.

Table 1. Types of projects and associated outcomes.

Project-work category	**Project outcome**
Research projects (theses, dissertations)	Research skills, critical thinking, and in-depth knowledge of a subject
Capstone projects	Provide practical experience and integrate knowledge from multiple courses
Group projects	Teamwork, leadership, and interpersonal skills
Industry-based projects	Bridge the gap between academic knowledge and professional practice
Design and development projects	Creating new products, systems, or solutions
Simulation and role-playing projects	Simulated environments to replicate real-life scenarios for problem-solving

2.3. Problem/project-based learning (PBL)

Project- and problem-based learning (generally both abbreviated to PBL) approaches have been used for decades and are closely related and widely used across most disciplines and education levels. This includes engineering [36], social sciences [40], and K-12 education [41], showcasing its versatility. PBL is an approach where students work on a project brief that culminates in a tangible product, such as a design or simulation, and usually includes a written report outlining the problem, constraints, and evidence-based solutions [35]. Underpinned by constructivist theory, PBL emphasizes active knowledge construction, the influence of prior knowledge, incremental understanding, and purposeful, effortful engagement [42]. Due to their wide-reaching uses, they are interpreted and implemented in various ways, with numerous definitions and perspectives due to the lack of a governing organization to control any standards [43]. The main difference is that project-based learning emphasizes applying knowledge, whereas problem-based learning focuses on acquiring knowledge [12]. In PBL, projects are the platform for students to attain competencies, integrate interdisciplinary knowledge, and enhance skills like self-directed learning, project management, and collaboration, with the learning process owned by the student but guided by a facilitator [43].

2.4. Conceiving, designing, implementing, and operating (CDIO)

CDIO was developed in engineering in the late 1990s to strengthen the values related to engineering practice [44], differentiating itself from PBL, which emerged across disciplines. Developed by MIT in the USA and the Royal Institute of Technology (KTH) in Sweden, the CDIO approach extends project-based learning by emphasizing the entire engineering project lifecycle [45]. It is used across many engineering disciplines, such as software, mechanical, chemical, and biomedical [46]. CDIO describes the stages of product or system development: conceiving (from market identification to conceptual design), designing (covering disciplinary and multidisciplinary design), implementing (including processes, testing, and verification), and operating (managing operations, lifecycle, and end-of-life planning) across hardware, software, and process industries [16]. CDIO focuses on learning outcomes in engineering education, with the approach to learning being shaped by what students need to learn [43].

The CDIO initiative introduced its first syllabus in 2001 and a revised syllabus in 2011; it has been supported by annual conferences since 2005 [47]. This regular engagement and oversight has kept CDIO relevant, and in 2022, a third revision was introduced with an updated statement of goals [48]. CDIO aligns learning outcomes with professional practice (whereas PBL aligns the learning process itself) and has a governing organization [43].

The CDIO framework is represented in Figure 1, demonstrating that CDIO is built upon the building blocks of technical knowledge and reasoning, personal professional skills, and interpersonal skills [16]. This structure outlines that in order for students to conceive-design-implement-operate (Level 4, CDIO), they must also have the capability to collaborate in a modern team-based environment (Level 3, Interpersonal), grow into mature and thoughtful individuals (Level 2, Personal), and manage complex value-added engineering systems (Level 1, technical). This holistic perspective and engineering focus made CDIO favorable for this study over PBL.

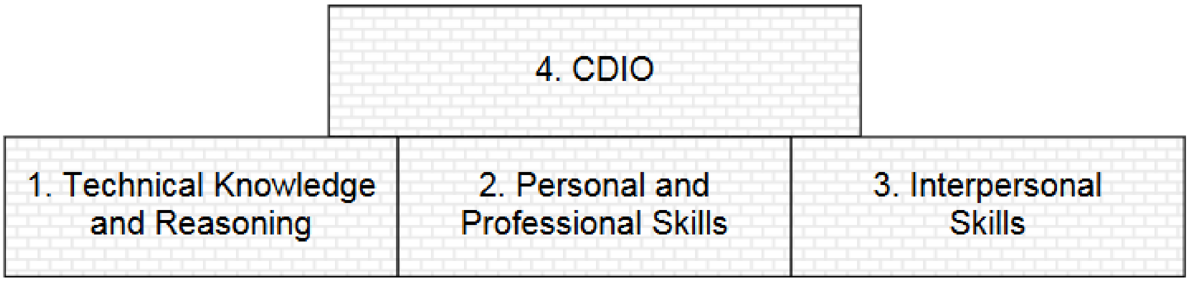

Figure 1. Building blocks of knowledge, skills, and attitudes necessary for CDIO [16].

3. Framework development

The Project-work Artificial Intelligence Integration Framework (PAIIF) was developed throughout 2024, based on a reflective and iterative process gathering input from a group of experts, which included academics with teaching experience in project-work integration at a higher education level and education designers. The process followed the general principles of the Delphi methodology [49,50], which ensured that a consensus-driven, reflection-based solution was determined. Each step of the process is defined in the following sub-sections.

3.1. Defining the problem

In a first-round attempt at integrating GenAI into a project work subject, Nikolic and Beckman [14] found the ad hoc nature of the implementation to be a challenge. Missing was a lack of clarity on how integration should occur and where and how it should be taught. A literature search for a guiding framework was unsuccessful. Therefore, a Project-work Artificial Intelligence Integration Framework was needed.

3.2. Team expertise

A call was made to the Australasian engineering education community in February 2024, seeking experts with an interest in participating in the development of the PAIIF framework. From this call, a team of 16 educators from 9 Australian universities was formed. These team members form the author list of this paper. With diverse demographic backgrounds such as gender, age, and professional level, the collaboration provided a wide range of perspectives and experience in project work in an engineering setting. Some of the educators involved were subject coordinators who facilitate project-based experiences for students ranging from first-year undergraduates to master students, covering a diverse range of engineering disciplines and many multidisciplinary project aspects. Additionally, some of the educators involved were learning designers with expertise in best pedagogical practices.

3.3. Framework guiding principles

Due to the novelty of this work, with no exemplars, the team of experts undertook an iterative process of consultation to determine the guiding principles. The following guiding principles were developed by consensus:

1. **Universal in design**, which covers all stages of engineering project work. Coordinators could select elements that correlate with specific learning objectives. This accounted for the rapid policy changes surrounding GenAI tools that could be used. This would also allow the framework to be used outside of engineering.
2. At a minimum, it would be **holistic** and cover all learning objectives across subjects taught or supported by the project team.
3. Provided **explicit guidance** and reflection opportunities on how AI or GenAI could be integrated into project work.

Beyond this, the following supporting conditions were considered:

1. The framework needed to provide **scalability and flexibility** so that it is adaptable to various class sizes, from small groups to large cohorts and multidisciplinary.
2. The framework needed to **clearly align with assessment** strategies that accurately measure the intended learning outcomes of project work.
3. The framework needed to incorporate current **industry practices** and trends, aligning with the skills and competencies needed in the workplace.
4. The framework needed to consider **ethics, human factors, resource efficiency and safety, standards, and sustainability implications**.
5. Given the advantages AI can provide to students with diverse needs, considerations of how it can be used to improve **inclusivity and accessibility** should be considered.

3.4. Guiding framework

By census, it was decided that the PAIIF should build upon a readily used project-work framework rather than building upon something new. This started with a discussion on project frameworks already used by the team and was followed by a literature analysis of the frameworks as outlined in the literature review. Multiple rounds of engagement with literature, brainstorming, and analysis were undertaken to develop this foundation. Key pillars of practice were filtered down to Level 4 of CDIO [16], project-based learning [51], Design for Six Sigma (DFSS) [52], and applying the engineering method [53]. As outlined in the literature review, CDIO was selected as the best foundational framework for project work due to its completeness and engineering focus. Therefore, the CDIO framework was selected as setting the foundation of PAIIF, presenting four core stages:

Stage 1: Conceiving; **Stage 2:** Designing; **Stage 3:** Implementing & **Stage 4:** Operating

However, as demonstrated in Figure 1, CDIO requires foundational blocks of knowledge, skills, and attitudes to enable successful implementation. Much of this is scaffolded across the entire degree and underpinned by a variety of pedagogical factors. Being a team of Australian engineering educators, the PAIIF framework needed to emphasize the *engineering method*, a pedagogical problem-solving approach taught in many Australian undergraduate engineering schools, which describes the way engineers approach problems and projects, especially in an educational setting [53]. The engineering method consists of five distinct steps: 1, exploring the problem; 2, exploring alternative solutions; 3, evaluating alternative solutions; 4, engineering decision-making; and 5, communicating your recommendation. Therefore, while project work is the process, the framework is designed to ensure that core competencies of educational importance are emphasized. To address this, four additional sub-stages were added beyond the core four stages. These sub-stages augment the project process by providing additional depth where necessary, enabling educators to better reflect on and identify integration opportunities relevant to their learning objectives.

The first step, *Exploring the problem*, was already well comprehensively covered in Stage 1, so a supporting process was not developed. However, the other four steps of the engineering method (exploring alternative solutions, evaluating alternative solutions, engineering decision-making, and communicating your recommendation) were not sufficiently covered in Level 4 of CDIO, primarily covered in the foundational levels 1–3. This synthesis prompted the creation of four sub-stages to provide greater flexibility and reflection. During the review of the text by Dowling [53], three chapters were dedicated to communication, underscoring its importance. As a result, communication was recognized as an essential process that warranted special attention, leading to the development of **Sub-stage 1:** Presentation and Documentation. This sub-stage can be connected to any of the four stages and is strongly correlated to the educational assessment of project work.

The **Sub-stage 2:** Testing and Evaluation can be utilized at any stage but is most valuable during Stages 2 and 3. Testing and evaluating provide significant opportunities for assessing options, leading to informed decision-making. This additional depth is especially beneficial for hands-on project work where students are required to build prototypes or similar outputs. **Sub-stages 3 and 4** focus on reflective review processes for informed decision-making; one sub-stage centers on review and revision at any stage, while the other emphasizes post-project analysis.

3.5. Framework composition

With the stages and sub-stages decided, the next process involved determining the framework items. This was accomplished through a structured, multi-stage process developed collaboratively by consensus among the team members.

Stage 1: Identifying learning objectives

The first stage involved using ChatGPT-4 to help determine the possible learning objectives associated with each stage and sub-stage, with particular reference to the subjects run by the authors and the selected literature. This created a draft list of learning objectives that correlated to each stage and sub-stage. The team members were then asked, "Does the list cover all *learning objectives*?" To answer this, all team members needed to check the learning objectives list against all the subjects they were involved with and other experiences for holisticness. Edits were then made to the list as required. This involved evaluative judgment based on their experience in previous and current project-based subjects they had been involved in. This stage concluded once the team reached a consensus on a comprehensive and holistic list of learning objectives.

Stage 2: Identifying student activities

Next, the same stage-1 process was repeated with a new focus: identifying *student activities* that could effectively demonstrate the learning objectives defined in the first stage. These activities were refined collaboratively, ensuring alignment with the learning goals and practical applicability across diverse contexts.

Stage 3: Integrating AI

In the third stage, the process was repeated to identify *opportunities for AI integration*. The team worked to determine how AI tools could support the previously established learning objectives and student activities. Each proposed AI integration was critically assessed and refined to ensure its alignment and feasibility.

Stage 4: Final confirmation

In the fourth stage, all team members reviewed the complete list of learning objectives, activities, and AI integration opportunities to confirm their relevance to the subjects they taught or had been involved with. The goal was to ensure that the framework included all necessary elements and that no critical components were omitted. This ensured that it was implementable across all engineering project-work subjects at the nine Australian universities regardless of year level or discipline. The framework was intentionally designed to accommodate additional elements where appropriate but to avoid any omissions.

Stage 5: Framework testing

The final stage was to test the framework. A select number of team members put the framework into practice. This provided an opportunity to test and reflect on the framework in real learning environments. A part of this process included refining the terminology further (to ensure students and staff could understand the descriptors) and confirm no item was missing. The final reflection occurred during the creation of this journal paper, presenting a final opportunity for all team members to confirm the acceptance of the decisions made and the framework structure. This process has resulted in the Project-work Artificial Intelligence Integration Framework (PAIIF), and its connection to CDIO is shown in Figure 2.

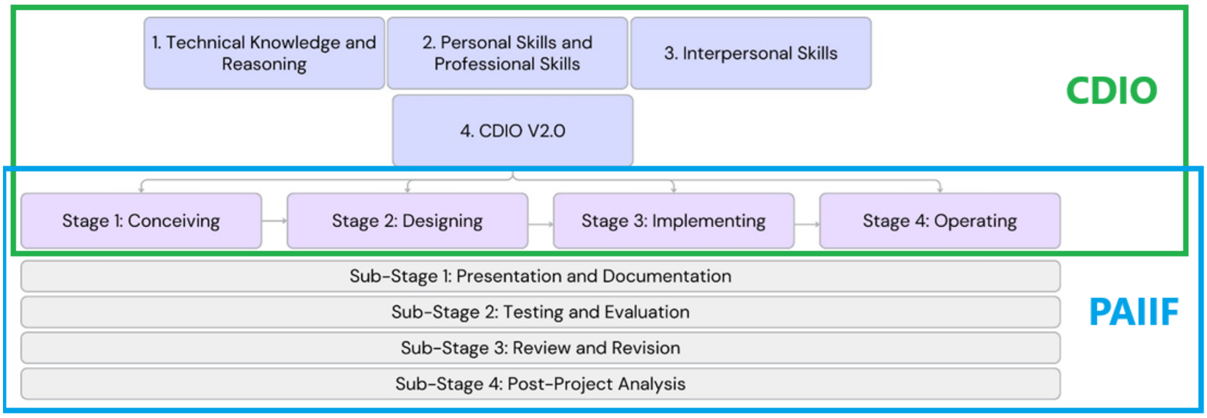

Figure 2. The PAIIF framework and its connection to CDIO. The purple boxes represent the four CDIO-based stages, and the grey boxes represent the sub-stages.

4. The Project-work Artificial Intelligence Integration Framework (PAIIF)

This framework is not associated with any single technology. Its purpose is to provide guidance on integration opportunities. The decision on which technology, platform, or tool to use is based on the evaluative judgment of the decision maker. It is probable that the most effective implementations would require variety. Nikolic et al. [3] discussed the benefits of using multiple GenAI tools for project work, allowing for variations in ideas, resources, and functionality.

Effective use of the framework requires AI integration to be taught as a co-intelligence [2] or as a virtual teammate [8]. It must be made explicit that AI should not be used as a direct replacement for human capability. Students must be guided to apply evaluative judgment with every use. This should be considered within AI ethics. Therefore, the authors recommend that an introduction to AI ethics be a pre-requisite before integration from either educator or student. This concurs with the AI literacy framework [26]. This recommendation goes beyond the use of the PAIIF and is relevant for any implementation of AI. This can be in the project subject itself or a pre-requisite subject. As outlined by Quince et al. [6], AI ethics require greater attention. A systematic literature review by Bukar et al. [54] identified 26 different ethical implications associated with AI. All of these are important, but some key areas of focus associated with project work include data confidentiality and consent, ensuring that students are considerate (e.g., don't violate copyright or confidentiality agreements) of any information they upload to the AI, especially if working on an industry-based project.

As part of the CDIO V2.0 framework and aligned educational materials, students are required to engage with key areas, including relevant standards, safety protocols, human factors, sustainability, risk assessment and management, equity, and ethical practices. These elements are collectively categorized within PAIIF as **governance, compliance, and ethical standards**. Engaging with these components of the framework is important because learning will take place when these factors are prompted into the AI by the students. Teaching staff are encouraged to adapt and integrate these components to suit their learning objectives, ensuring educational outcomes align with professional and industry standards. The four stages and four sub-stages of the PAIIF are outlined in Table 2.

Table 2. PAIIF: Stages, activities, and AI integration opportunities.

PAIIF stage	**Project-work activity (activities students perform)**	**AI integration opportunity (how AI can be used to support project work)**
Stage 1 Conceiving	Problem analysis	Utilize AI tools to help students analyze and understand the problem, including root cause analysis and problem definition.
	Brainstorming	Use AI to generate creative project ideas and scenarios aligned with customer/project needs. Refine and synthesize with other steps to create initial project concepts and high-level designs.
	Enhanced research	Deploy AI for literature reviews, gap analysis, and identifying relevant governance, compliance, and ethical standards.
	Customer feedback analysis	Use AI to analyze customer feedback and identify key requirements and preferences.
	Requirement documentation	Use AI to help document and prioritize customer requirements based on collected data
	Planning	Use AI to estimate project timelines and resourcing requirements and understand the team.
	Competitor & trend analysis	Use AI to perform competitor analysis, identifying the strengths and weaknesses of similar projects or products. Analyze market trends and predict future needs based on historical data.
Stage 2 Designing	Project outlining	Use AI tools to structure the project plan, suggest timelines, and incorporate customer requirements. Use to aid in resource allocation and aligning team roles.
	Resource allocation	Use AI to analyze data to recommend the optimal allocation of physical resources required for the project, such as materials, components, fixtures, and equipment, including sustainable and ethically sourced resources.
	Safety and risk analysis	Use AI tools to incorporate safety measures and standards, consider human factors, perform risk assessments, and evaluate ethical implications.
	Design alignment	Use AI to align design with enterprise and business implications. Consider alignment with the disciplinary, multidisciplinary, and multi-objective design decisions.
	Evaluate design options	Use AI to analyze the economic and non-economic options associated with the proposed design.
	Design optimization	Use AI to optimize designs for efficiency, cost-effectiveness, and performance.
	Design validation	Use AI tools to simulate and validate designs against customer requirements. Use to identify potential design challenges and constraints.

	Project outlining	Use AI tools to structure the project plan, suggest timelines, and incorporate customer requirements. Use to aid in resource allocation and aligning team roles.
Stage 3: Implementing	Content creation	Use AI to assist in drafting written content, code, and designs within relevant governance, compliance, and ethical standards.
	Simulation and modeling	Use AI to simulate outcomes, model scenarios, consider user and human factors, and ensure compliance with relevant governance, compliance, and ethical standards.
	Automation and efficiency	Integrate AI tools to automate tasks, enhance accuracy, and monitor compliance with relevant governance, compliance, and ethical standards.
	Implementation guidance	Use AI to provide step-by-step guidance for implementing complex systems or components, ensuring adherence to best practices.
Stage 4: Operating	Lifecycle planning	Use AI tools to optimize the lifecycle process and prepare for responsible end-of-life disposal.
	Real-time adjustments	Use AI tools for real-time risk monitoring relevant governance, compliance, and ethical standards, making ethical adjustments as required.
	User feedback analysis	Use AI tools to collect and analyze user feedback within ethical standards.
	Predictive maintenance	Use AI tools to predict when maintenance is required, reducing downtime and improving reliability.
	Performance monitoring	Use AI tools to continuously monitor system performance, providing insights and alerts for deviations from expected operation.
Sub-stage 1: Presentation and documentation	Automated reporting	Ethically use AI tools to generate automatic reports on performance and relevant governance, compliance, and ethical standards.
	Report generation	Use AI tools ethically to prepare reports and presentations regarding scope, progress, compliance, performance, user feedback, and the project's broader impacts.
	Visualizations	Use AI tools to create dynamic visualizations of progress, performance, and relevant governance, compliance, and ethical standards.
	Documentation	Use AI tools to implement methodological documentation processes. This includes creating, editing, and critiquing reports and presentations.
	Data summarization	Use AI tools to summarize large datasets into key insights and actionable points for easier understanding and presentation.
Sub-stage 2: Testing and evaluation	Testing and compliance	Implement AI to automate testing processes and ensure compliance with relevant governance, compliance, and ethical standards.
	Test feedback	Use AI tools to collect and analyze test feedback from stakeholders within ethical standards.
	Environmental impact assessment	Deploy AI tools to assess environmental impacts and suggest ethical improvements.

	Evaluation analytics	Use AI tools to analyze test results to identify trends, anomalies, and areas for improvement, evaluating against initial goals.
Sub-stage 3: Review and revision	Performance review	Use AI tools to review project, performance, and business outcomes, as well as relevant governance, compliance, and ethical standards and external outcomes against goals.
	Iterative improvement	Utilize AI to suggest revisions and further iterations based on detailed analyses of performance, compliance, and feedback.
	Scenario analysis	Use AI tools to analyze feedback to model different revision scenarios to predict potential outcomes and guide decision-making.
	Historical data analysis	Use AI tools to analyze all outcomes, performance, and compliance with past projects to identify patterns and best practices that can inform current project revisions.
Sub-stage 4: Post-project analysis	Data synthesis	Use AI tools to synthesize findings on all aspects of the project.
	Lessons learned	Use AI tools to analyze the project lifecycle to identify key lessons and best practices.
	Post-project reports	Use AI tools to analyze and report on the broader impacts of the project, summarizing outcomes, performance, user satisfaction, lessons learned, and recommendations.
	Future project recommendations	Use AI tools to provide data-driven recommendations for future projects based on post-project analysis.

5. The application of PAIIF

While PAIIF is an engineering-focused framework, it can apply to other disciplines. The goal is to provide options for the academic community so that they can pick and choose components that are relevant. The following is a general guide on how to apply PAIIF.

Stage 1: PAIIF application

1. What experience do you have with AI?

For an educator new to AI, the suggestion is to start small, possibly focusing on one or two items within the conceiving stage. There is much to learn regarding assessment, delivery, and logistics. The best learning comes from experience and making mistakes. The work of Nikolic and Beckman [14] provides a good overview of the initial challenges to implementing AI in project work.

2. What are the learning objectives?

PAIIF was designed by connecting activities to learning objectives. Start by exploring the PAIIF stages and sub-stages and identifying which *Project-work Activity* aligns with the subject learning objectives.

3. Consider the AI integration opportunity

When a match is found, consider the associated *AI Integration Opportunity*. For example, the selected activity may be *brainstorming*, and the associated opportunity being *Use AI to generate* *creative project ideas and scenarios aligned with customer/project needs. Refine and synthesize with other steps to create initial project concepts and high-level designs*. This provides the descriptor of how you would integrate AI into the activity.

Stage 2: Practical implementation

4. AI integration is about co-intelligence

Co-intelligence [2] is about using AI to help humans perform better and not replace them. As the framework is CDIO-based, do not ignore the traditional approach. Using the earlier brainstorming example, guide students in the theoretical frameworks associated with brainstorming. This could include frameworks such as 5 Ws and H, Six thinking hats, and Synectics [53]. Have the students integrate the best theoretical framework within their prompt design. This process requires evaluative judgment, further discussed in step 6.

5. Consider ethical considerations and prompting techniques

Before students engage with AI, be sure that they understand the ethical considerations such as those listed by Bukar et al. [54], particularly data confidentiality and consent, especially if working on a project that involves a third-party client. Then, engage them with a prompt engineering structure that is most relevant. For example, one structure is Clear objective, Context provision, Specific instructions, Examples (if applicable), Constraints and boundaries. Take note that prompting techniques are evolving, and different AI tools react differently to prompts. Further ethical awareness can be gained by including PAIIF items with an ethics component, in which through prompting and exploring the output, students can engage with the ethics-based recommendations provided by GenAI. This is an example of learning by doing.

6. Apply evaluative judgment

The final step is the most important. Students must learn the application of evaluative judgment [4] to develop their critical-thinking skills by considering the quality of the suggestions given. Factors to consider include whether the output provided by the AI is correct, relevant, fit for purpose, holistic, ethical, feasible, culturally sensitive, and sustainable, aligns with objectives and standards, is biased, and, most importantly, has source validity (connected to traditional credible and current sources). Depending on the output, multiple pathways of further investigation can be taken, as would traditional project-based activities. One pathway could be reflecting on the output and prompt and adjusting the prompt.

6. Evaluation

The development of PAIIF had three main objectives, which included being universal in design to cover all stages of engineering project work and all learning objectives associated with the diverse implementations of all team members. It also had to provide appropriate guidance and reflection on integrating AI. The primary evaluation method was a final cross-checking by all team members that the framework applied to all subjects. By using a CDIO-base and covering over 16 project-based implementations from 9 different universities covering a diverse range of engineering backgrounds, this check provides a high level of assurance of greater applicability. Further checks were conducted by implementing the framework into appropriate subjects. Extensive data was collected to evaluate the different teaching and learning approaches associated with different implementations of the framework, and these will be made available in future research papers. Some initial implementation observations and reflections are provided as guidance.

While the development of PAIIF was conducted by a diverse range of engineering educators, they are all Australian-based. Learning objectives and project scope may differ internationally, but the authors believe that by using a CDIO-base, any variances should be limited. Furthermore, given the engineering focus, the items listed may not be holistic for other disciplines. What we know from the literature is that most academics are not making a start on AI integration because they do not know where to start [19]. This work provides the starting point for practical implementation and discussion, and the authors expect that further refinements will be made with further implementation experience. Also missing from this study are empirical insights into usage. These insights are currently being collected across the research team and will be made available in future contributions. These studies will demonstrate and evaluate the success of different approaches to applying PAIIF.

6.1. Initial implementation observations

The authors successfully applied the framework to their subjects in an initial implementation. The means of implementation within the individual subjects is dependent on the subject delivery style. Some subjects deliver material related to the use of AI and aspects of the framework in lectures or tutorials, either with or without associated activities. Other subjects, such as studios or workshops, used a dynamic approach, using the framework as a tool for direct conversation with the students.

Prior to the commencement of these subjects, a key practice involved identifying which elements of the framework to implement in the subject. Once the subject was running, the authors reviewed and documented those that were actually being used. This process highlighted that additional framework elements had been integrated in hindsight or were observed to be used by students completing work for the subject. These aspects might not have been considered without this reflective approach and suggest that the framework has enough flexibility to be adopted in action by academics and students.

6.2. Reflection on initial student engagement

The integration of AI into project-based learning presents some distinct benefits but also several challenges. AI can shorten the time students need to progress from one task to the next. For instance, in Stage 1: Conceiving, AI bibliometrics tools such as Scite and Elicit allow students to screen, summarize, and review a large volume of literature. AI conversation tools help students refine survey and interview questions and simulate the interview process so that students can practice, as well as envisage the user research output and outcomes. Students who were going through the engineering design process with the purpose of building and validating a physical prototype freely used AI tools through all stages to improve their work.

When students possess good evaluative judgment skills, this can be powerful. It allows them to develop solutions and ideas beyond standard expectations. However, if they lack these skills, it can encourage laziness or ignorance, with students overly trusting or becoming complacent with the information AI provides without critical thinking. This reliance can be detrimental to learning unless leveraged as part of the learning experience. Similarly, the use of AI tools can inadvertently increase the cognitive load and biases of learners by increasing the amount and immediacy of information they have access to. This cognitive load may also bias students toward accepting AI-generated answers and solutions.

Further risks to learning can come from students questioning well-understood learning scaffolds. For instance, Scite has the capability to generate a seemingly comprehensive review of the literature. This has led students, and even some instructors, to question whether literature review is a skill that still needs to be taught and learned, or whether efforts should be directed to skills that are deemed more “high value”.

Taken together, these early integrations of AI into project-based learning point to the fact that some AI tools, designed for higher-level tasks, are not suitable for use in learning and teaching without first considering the alignment of its use with learning outcomes, as well as the instruction/learning design.

7. Conclusions

This study has made a contribution to the field by outlining the Project-work Artificial Intelligence Integration Framework (PAIIF), including its development. Due to a lack of literature and educator experience in AI integration, this framework has been developed to guide educators on how AI can be integrated across the engineering project work lifecycle. Educators can select the elements most relevant to their particular subject's learning objectives and be guided on when and how to undertake the integration. This work has only undergone limited practical testing to date, and further refinements are expected after substantial wider use. To date, the authors found that greater clarity and opportunity were gained by subject coordinators by reflecting on the AI integration possibilities highlighted by PAIIF. Project-based work is an important aspect of the engineering curricula because it prepares work-ready engineering graduates. It has also been emphasized that project-based work provides great potential for using GenAI as a co-intelligence. With no guiding framework available to date, this proposed framework is important for engineering education and its application within other disciplines. This is because most project elements are consistent across engineering disciplines, and any irrelevant activity can be excluded from use. This work provides a benchmark for the authors and other educators to build upon. Future work is already in progress that explores the educational implications and student perspectives of PAIIF.

Author contributions

Sasha Nikolic served as the project leader and principal author of this manuscript, while Zach Quince undertook the primary proofreading role, ensuring clarity and consistency throughout the text. All authors thoroughly reviewed and helped improve the paper and contributed significantly to the development of the framework described in Section 3.

Use of Generative-AI tools declaration

As outlined in the methodology, ChatGPT-4 was utilized for brainstorming and aligning framework elements. All outputs were reviewed and verified by the authors, who take full responsibility for the final content. Additionally, Grammarly was employed for proofreading to ensure accuracy and clarity.

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Conflict of interest

The authors have no conflicts of interest in this paper.

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Ethics declaration

Human research ethics was not required for this work.

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