REVIEW OF CDIO SYLLABUS VERSION 3.0 TO INCLUDE DEVELOPMENT OF AI-HUMAN COMPETENCIES

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ABSTRACT

This paper shares an approach in using generative artificial intelligence (GenAI) to assist in reviewing and updating of the CDIO Syllabus, reflecting the continual improvement nature of the CDIO Framework to keep abreast with changing educational landscape. The advent of GenAI and its rapid adoption across all spectrums of industries and educational institutions necessitates that faculty prepare graduates for the workplace of the future. Two main drivers for change are identified: first, to reaffirm the role of humans in an AI-dominated world; and second, to equip them with new competencies required for effective human–machine collaboration. The first concern arises from the rapid advancement of GenAI technologies which has fuelled fears that machines already surpassed humans in terms of intelligence and encroached upon traits that were once perceived as uniquely human, such as creativity, empathy, complex reasoning. This had important implications for the second concern, when humans and machines have to work together to derive maximum benefits leveraging on technological advancement supported by human oversight of work done by machines. The human-machine collaboration in particular holds great promises in addressing sustainability issues and sustainable development challenges. The CDIO Framework with its 12 Core Standards and an updated CDIO Syllabus lend itself readily to aid curricular redesign to address these challenges. The proposed revised CDIO Syllabus will incorporate skills and attitudes: (1) from AI Literacy Framework for Students from the United Nations Educational, Scientific and Cultural Organization; (2) from core human capacities that are distinct from GenAI no matter how sophisticated the algorithm driving GenAI behaviour develops, (3) needed for harnessing the “missing middle” – a collaborative space where human judgment, creativity, and empathy merge with the speed, pattern recognition, and scale of AI systems to achieve unprecedented productivity and performance gains, (4) required to support the development of a sustainability mindset. The rest of the paper discusses the relative merits of having a separate heading for human-AI collaboration compared to distributing them into relevant parts of existing heading, limitation of the approach used and plans for moving forward.

KEYWORDS

AI Literacy, Human-AI Collaboration, Missing Middle, Hybrid Competency, CDIO Syllabus

INTRODUCTION

In the advent of generative artificial intelligence (GenAI), many authors have called for our education system to be revamped to integrate practical, hands-on learning that emphasizes critical thinking, problem-solving, and creativity, while also building AI literacy and ethical AI use. Key strategies include embedding AI and digital tools into the curriculum, fostering strong soft skills like communication and teamwork, encouraging multi-disciplinary real-world projects through industry partnerships, etc; to prepare graduates for the workplace of the future.

Against this backdrop, the CDIO Framework can be investigated if it remains relevant to guide faculty in executing the required curriculum changes using GenAI. In his other work, the author has argued that the 12 Core CDIO Standards can be effectively used in conjunction with appropriate AI literacy framework to guide the process of curriculum redesign in general, and more specifically how each individual standard can also provide faculty with human-in-the-loop oversight during the redesign process (Cheah, 2026a; Cheah, 2026b). The author is motivated by the discussions at the 2025 CDIO International Working Meeting in Linkoping, Sweden where the need to review the CDIO Syllabus was mooted, to address the challenge of artificial intelligence (AI). This paper is the author's contribution to this on-going discourse.

Scope of This Paper

This paper reviews the existing CDIO Syllabus (currently at version 3.0) to ascertain its adequacy in covering the skill and attitudes students need in the AI-dominated workplace of the future. It shares the approach adopted by the author which consists of two major threads:

(1) Identify new skills and attitudes that need to develop, or existing ones that need to be enhanced, to enable individuals to function effectively in today's AI world. In the context of this paper, they will be referred to as "human competencies". "Human competencies" also include skills and attitudes required to reduce the erosion of innate human capacities due to over-reliance on AI technologies.

(2) Identification of emerging skills and attitudes individuals will need for workplace of the future, focusing on those needed for human-machine collaboration, using a framework suggested by Daugherty & Wilson (2024). In the context of this paper, they will be referred to as "hybrid competencies".

The existing CDIO Syllabus was then compared on how well it can cover the above 2 sets of competencies and improvements are suggested as appropriate. Subsequently the coverage was expanded to include competencies needed for sustainable development, as part of continual improvement of this author and coworkers' effort in using CDIO to design education for sustainable development (Cheah *et al*, 2025).

LITERATURE REVIEW: THE SHIFT IN THE FUTURE OF WORK

The CDIO Syllabus is the cornerstone of the CDIO Framework. It offers rational, complete, universal, and generalizable goals for undergraduate engineering education (CDIO, n.a.). It allows adoption for any field of program by allocating a placeholder for the disciplinary fundamentals (Part 1), focuses on personal and professional skills and attributes (Part 2), interpersonal skills (Part 3) and skills in conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context (Part 4).

The current syllabus (version 3.0), published in 2022 (Malmqvist *et al*, 2022) was a significant "upgrade" from the version 2.0 published in 2011. It addressed challenges in sustainable development, digitalization and demands of a rapidly changing world; as well as insights from the CDIO community. This version retained the previous version's format which is based on the UNESCO 4 Pillars of Learning aligned at a high level, national accreditation and evaluation standards of several nations (Crawley *et al*, 2011).

The quickening pace of technological advancements notably in AI in general and GenAI in particular necessitates another review. The advent of these technologies has resulted in significant changes in all aspects of work, emergence of new job roles that demand different competencies or enhancement of existing ones.

The World Economic Forum's *Future of Jobs Report 2025* makes clear that we are entering an era defined by human-AI collaboration: by 2030, technological and demographic shifts are expected to create 170 million new jobs while displacing 92 million, with the fastest growth in roles that combine AI literacy with human skills such as creativity, collaboration, and critical thinking (WEF, 2025a). The future of work is not about humans being replaced, but about humans and AI co-evolving. There will be significant increase in roles that combine domain-specific expertise with AI literacy – including AI system architects, ethics and governance specialists, human-AI collaboration designers, and physical AI specialists working in robotics and autonomous mobility (WEF, 2025b).

Some categories of work have shifted entirely from humans to machines because they involve high-volume, repetitive, rules-based tasks where machines excel at speed, accuracy, and scale. Examples include transaction processing, routine scheduling, or large-scale data iteration – activities that demand consistency but little judgment. Machines outperform humans here because they can process vast amounts of information without fatigue or error. By contrast, other types of work are best done through human-machine collaboration. These tasks combine the strengths of both sides: machines contribute pattern recognition, predictive analytics, and generative options, while humans provide creativity, ethical judgment, empathy, and contextual decision-making. The shift reflects a pragmatic division of labour: machines taking over what is routine and computationally intensive, while humans and machines together tackle complex, creative, and ethical challenges

Therefore, new industries built around AI-driven physical systems and AI-augmented decision-making are likely to emerge, creating new types of jobs and economic growth in untapped areas. A transdisciplinary systems mindset in education is essential to create a pipeline of graduates with these key skills to enable students to integrate across disciplines and work with AI systems.

A survey carried out by Portocarrero Ramos *et al* (2025) showed a widespread feeling among students of insufficient preparation for the challenges of the current labour market. AI skills are becoming a key differentiating factor in employability and formal incorporation into university curricula is urgently needed. Likewise, Bone *et al* (2025) reported from their study that a clear paradigm shift is occurring among employers, in that AI skills are increasingly more valuable than degrees in determining employability and wages. Employers are broadening their talent pools by dropping degree requirements and rewarding practical competencies.

The increasing use of AI technologies in the workplace also created a new kind of skills and attitudes required of human employees: the coexistence between human intelligence and AI; collaborating to leverage on the relative advantages of both for mutual enhancement that can benefit various sectors of society (Botha, n.a.). Not only that, AI-related jobs also have a higher skill intensity, which refers to the number and diversity of skills required in a job posting. It's essentially a measure of how "complex" or "multi-skilled" a job is compared to the average role in the labour market. A study by Bone *et al* (2025) noted that the skill intensity for AI-related job roles in the U.K. stands at an average of 15 to 16 skills per position, compared to the average job posting in the broader labour market demands of around 5 skills.

METHODOLOGY

This paper investigates the skills and attitudes required in the age of GenAI from 3 different perspectives: (1) from the perspective UNESCO literacy which is to assist educators in preparing students to be responsible users and co-creators of AI; (2) from a wider philosophical humanistic perspective of what differentiates humans from machines focusing on traits that can be enhanced and notion of what it means to be human; and (3) from the workplace perspective so that humans can collaborate with machines powered by GenAI to accomplish tasks that humans alone cannot do and not being subordinated to GenAI. We use the term “human competencies” for skills and attitudes from (1) and (2); and the term “hybrid competencies” for (3).

Human competencies need to be strengthened against over-reliance on GenAI can be identified from the extant literature. Human competencies needed to co-exist in the world of GenAI can be from the AI Competency Framework for Students (AI CFS), published by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2024). Hybrid competencies for human-AI collaboration will largely be drawn from the work of Daugherty & Wilson (2024) who did extensive empirical research on 1,500 organizations examining how businesses are implementing AI to drive innovation and transformation, rather than just automation. The following sections explain how if the existing CDIO Syllabus adequate covers the skills and attitudes needed for human competencies and hybrid competencies.

AGE OF GEN AI: EXISTING HUMAN COMPETENCIES TO BE ENHANCED

This section addresses the skills and attitudes required for human competencies. With the advent of AI, there had been much discourse on what it means to be human; and calls for inclusion of AI Literacy in the curriculum. An AI Literacy curriculum can be based on the UNESCO AI CFS is shown in Table 1.

Table 1. UNESCO AI competency framework for students

Competency Aspects	PROGRESSION LEVELS		
	UNDERSTAND	APPLY	CREATE
Human-centered Mindset	Human Agency	Human Accountability	Citizenship in era of AI
Ethics of AI	Embodied Ethics	Safe & Responsible Use	Ethics by Design
AI Techniques & Applications	AI Foundations	Application Skills	Creating AI Tools
AI System Design	Problem Scoping	Architecture Design	Iteration & Feedback Loops

The UNESCO AI competency framework for students aims to help educators in this integration, outlining 12 competencies across four dimensions: Human-centred mindset, Ethics of AI, AI techniques and applications, and AI system design. These competencies span three progression levels: Understand, Apply, and Create. Detailed discussions on the competencies that students need to develop are beyond the scope of this paper. Suffice to note that one of emerging key skills to possess in interacting with AI is prompt engineering. Although not explicitly mentioned in the UNESCO framework, this is captured under the competency of "AI Techniques & Applications". Appendix 1 presents the mapping of UNESCO's AI Competency Framework for Students to the CDIO Syllabus, highlighting where existing outcomes already align (e.g. AI foundations, ethics, system design) and where new competencies such as prompt engineering, explainability, and sustainability of AI models need to be added. Gaps identified will be covered in later section of this paper.

This paper suggests that in addition to the above, we need to strengthen skills and attitudes needed to support the key aspects of human capacities to guard against deterioration resulting from GenAI overuse. Botha (n.a.) provides a summary of 6 key human capacities as shown in Table 2.

Table 2. Key aspects of distinctive human capacities

Aspect	Description
Emotions and Empathy	Humans possess emotional intelligence, allowing us to understand, experience, and respond to emotions. This capability fosters empathy, compassion, and nuanced social interactions. Computers can simulate emotional responses but lack genuine emotional experiences.
Creativity and Innovation	Human creativity involves intuition, imagination, and novel problem-solving. Computers can generate new outputs based on data and patterns but lack the spontaneous creativity and intuitive leaps that define human innovation.
Consciousness and Self-awareness	Humans possess consciousness and self-awareness, enabling introspection and reflection on thoughts, emotions, and experiences. This self-awareness plays a role in personal growth and ethical decision-making. Computers, in contrast, lack consciousness and self-awareness.
Holistic Understanding	Humans can integrate diverse information sources, consider context, and draw on personal experiences for a holistic understanding. Computers process information more compartmentalised and data driven.
Adaptability and Flexibility	Humans can learn and adapt to new situations without predefined rules. Computers rely on algorithms and data, making them less flexible in novel situations.
Ethics and Morality	Humans can weigh multiple perspectives, values, and consequences in ethical decision-making. Computers can follow ethical guidelines but lack a nuanced understanding of conflicting values

The underpinning skills and attitudes were again investigated and mapped over to the CDIO Syllabus using GenAI, and results are shown in Appendix 2. This analysis shows that while many human capacities are partially addressed, explicit outcomes for emotional intelligence, creative metacognition, mindfulness, and pluralistic ethics are missing. Together, the two appendices provide a structured gap analysis that informs the proposed revisions to the syllabus, ensuring both AI literacy and the preservation of core human capacities are embedded in future curriculum design.

EMERGING COMPETENCIES DESIRED BY EMPLOYERS: HYBRID COMPETENCIES

Daugherty & Wilson (2024) suggested that work activities in the world of AI can be organized into three broad zones, as shown in Figure 1:

- Human-only activity: tasks that rely on uniquely human capabilities such as leadership, empathy, creativity, and ethical judgment. Machines cannot replicate them meaningfully.
- Machine-only activity: tasks best handled by machines, such as repetitive transactions, rapid iteration, large-scale prediction, and adaptive optimization.

- Human-machine hybrid activity: This is the fusion zone where humans and AI collaborate – they are hybrid activities that represent new roles and skills that emerge when humans complement machines and machines augment humans.

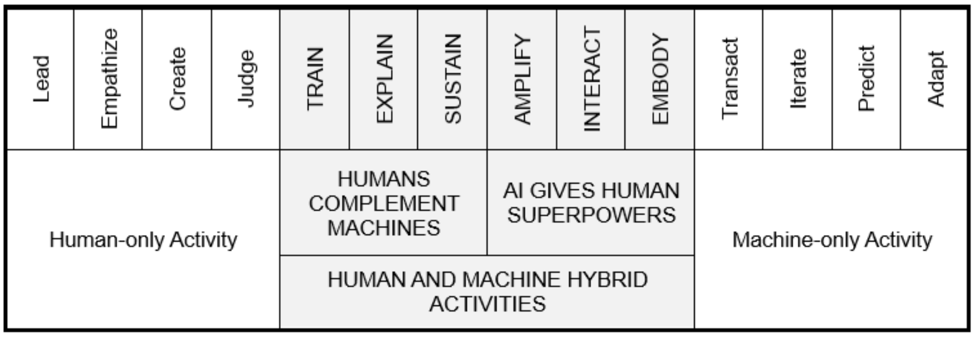

Figure 1. “Hybrid competencies” of the “missing middle” (Daugherty & Wilson, 2024)

Figure 1 shows the different strategies that can be used in each zone, the discussion of which is beyond the scope of this paper. The focus of this paper is the hybrid competencies needed for the hybrid zone, the area that redefine the future of work where humans and AI work together in a symbiotic, collaborative relationship. Daugherty & Wilson (2024) called it the “missing middle” because few companies are actively focused on this space, with most focusing on either full human labour or complete automation. But the real transformation lies in the hybrid zone. As noted in the WEF report from the previous section, this is now an emerging area, and the focus of this paper is on finding the skills and attitudes that humans will need to work collaboratively with machines in the hybrid zone. This is where curriculum design and assessment need to focus: developing hybrid skills such as trust calibration, ethical oversight, openness to machine creativity, and collaborative problem-solving with AI. The workflow of our approach is shown in Figure 2.

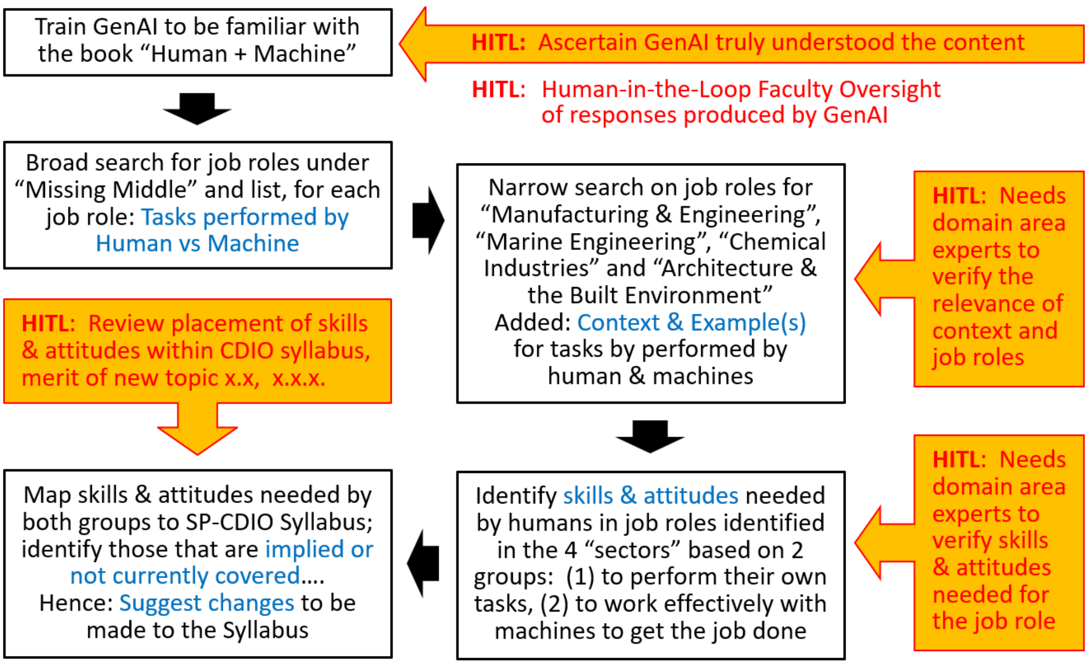

Figure 2. Approach used to determine hybrid competencies for the future of work

Skills and Attitudes Needed for the Future of Work

Figure 2 shows that skills and attitudes identified for the hybrid competencies were separated into 2 groups: (1) For humans to perform their own tasks, i.e. areas where humans complement machines, and (2) For human to work effectively with machines in completing the hybrid tasks. The rationale for doing so will be explained later, when we discuss the review and suggested revision of the CDIO Syllabus.

As the findings in this work is meant to be discipline agnostic and to be applicable to a wide range of programs, we relied heavily on the use of GenAI to help us. Therefore, it must be noted that outputs from GenAI need to be validated by experienced professionals with the domain knowledge for example on the job roles reported by GenAI which may be known differently in the workplace as GenAI is known to fabricate its own catchy terms. Likewise, the underpinning skills and attitudes also need to be validated. “HITL Markers” are shown in Figure 2 at various junctures in the process as requiring human-in-the-loop oversight.

The outcome from the process depicted in Figure 2 is a set of skills and attitudes needed for the hybrid competencies. For validating the GenAI’s outputs, we narrowed the work to focus on 1 generic area called “Manufacturing & Engineering” and 3 areas that are more targeted: “Marine Engineering”, “Chemical Industries” and “Architecture & the Built Environment”. The reason for this is simple: As we are exploring what GenAI can do, as a “proof-of-concept” so to speak, we strive to keep the task manageable, therefore limiting the number of subject matter experts to review the GenAI responses for this run. Appendix 3 provide the job roles identified for the “missing middle” for the 4 areas, and Appendix 4 shows the required skills and attitudes. These were then checked with the respective faculty within Singapore Polytechnic.

As in earlier work, we also investigated which skills and attitudes are already covered in the existing CDIO Syllabus and what are the gaps – for both groups of 2 groups: where humans are to perform their own tasks and where humans to work effectively with machines in completing the hybrid tasks. Perhaps not surprisingly, since the CDIO syllabus had been formulated to prepare graduates for the workplace, the skills and attitudes required by humans to perform their own tasks are very well covered, and hence not reported in this paper. This exercise reveals several gaps in skills and attitudes that humans need to work collaboratively with machines. These gaps together with those from earlier studies will be addressed next.

GAPS IN EXISTING CDIO SYLLABUS BASED ON STUDY IN THIS PAPER

For each of the 3 perspectives on skills and attitudes required in the age of GenAI, we supplied the GenAI tool with a copy of the SP-CDIO Syllabus and asked that it identify the gaps in the respective area. The results are shown in Tables 3, 4 and 5 respectively.

Next, we tasked the GenAI tool to combine the inputs from all 3 areas to produce a draft version of the revised SP-CDIO Syllabus. The process can be visualized as shown Figure 3(a). The figure also highlights areas where faculty oversights are needed against the outputs produced by GenAI, as marked by “HITL” for human-in-the-loop intervention. Indeed, it is the author’s experience that using GenAI to carry out the gap analysis and mapping exercises do not always yield satisfactory results after one pass. This brings to fore the lack of transparency in how GenAI went around executing its algorithm. In the case of Figure 3(a), satisfactory drafts of the mapping were obtained independently of one another for each of the 3 aspects of UNESCO, human capacities and “missing middle”, using 3 different sessions of GenAI engagement. “HITL” is administered to each one of the sessions. There were relatively minor discrepancies between what it flagged as missing or inadequate in the existing syllabus and it proposed for the revised syllabus in each case. However, when it was asked to synthesis a draft syllabus by combining all 3 aspects (UNESCO, human capacities, and “missing middle”) while removing overlapping skills and attitudes and rationalizing the entries; it made more omissions in the combined proposed revision to the syllabus.

Table 3. Suggested skills and attitudes to be added to CDIO based on UNESCO AI CFS

Competency Area	Missing Specific Requirement	Explanation of Gap & Rationale for Addition	Suggested Location: CDIO (x.x.x)
B3: Create: Ethics of AI	Explicit requirement for designing for Transparency & Explainability (XAI).	The Syllabus addresses "supervision" (4.4.6) but lacks the specific modern ethical mandate to engineer for *explainable* outcomes in opaque AI models. <u>Suggested outcome</u>: Assess the trade-off between AI model complexity and the necessity for its decisions to be transparent, auditable, and explainable (XAI) based on the application's risk profile.	4.4.6 Design for Sustainability, Safety, Aesthetics, Operability and Other Objectives : Add subtopic: *Demonstrate design for explainability, transparency and auditability*
C2: Apply: AI Techniques & Applications	Explicit literacy in Generative AI (e.g. Prompt Engineering).	The Syllabus covers "data mining and analytics" (2.1.2), but this is insufficient for the unique skills required to effectively and critically use Large Language Models (LLMs) and other generative tools. <u>Suggested outcome</u>: Formulate precise, goal-oriented prompts for Generative AI tools and critically evaluate the fidelity, bias, and authenticity of AI-generated outputs.	2.1.2 Analytic Reasoning and Problem Solving Add subtopic:
D3: AI System Design (Create)	Explicit focus on environmental & computational cost of AI models.	The Syllabus mentions "sustainability" broadly (4.1.2) but lacks a direct requirement to quantify and mitigate the significant energy footprint of developing and deploying modern, large-scale AI systems. <u>Suggested outcome</u>: Analyse the resource consumption (data, energy, computational hardware) of a proposed AI solution and design for computational efficiency and environmental sustainability.	4.1.2 Address the Impact of Engineering on Society and the Environment

Expansion of Work Done

After several iterations where amendments were made and omissions included, we arrived at a working draft of the proposed revised SP-CDIO Syllabus. Next, we use GenAI to add 2 more aspects to the document to widen the coverage of the revised syllabus. The process is shown in Figure 3(b). First, we added an expanded skills and attitudes required for job roles performed by the “missing middle” beyond the initial 4 areas of “Manufacturing & Engineering”, “Marine Engineering”, “Chemical Industries” and “Architecture & the Built Environment”. The purpose is to ensure that other skills and attitudes that may be more relevant to non-engineering/technology fields are adequately captured.

Table 4. Suggested skills and attitudes to be added to CDIO based on human capacities

Aspect	Missing Elements in CDIO and Rationale for Addition	Suggested Location: CDIO (x.x.x)
Emotions & Empathy	• CDIO emphasizes communication and equity but lacks explicit training in *emotion regulation* and *restorative practices*. • Needed because students must navigate emotionally charged, diverse environments and build trust in human-AI collaboration	2.5.5 Demonstrate Respect for Equity, Justice, Diversity and Inclusiveness
Creativity & Innovation	• CDIO covers creative thinking but does not emphasize *creative metacognition* (awareness of one's creative process) or *incubation strategies*. • Needed because innovation requires not just generating ideas but managing the creative process and tolerating uncertainty.	2.4.4 Creative Thinking
Consciousness & Self-awareness	• CDIO includes reflection but misses *mindfulness* and *identity development*. • Needed because self-awareness is foundational for ethical decision-making and resilience in complex contexts.	2.4.6 Demonstrate Self-Awareness, Self-Reflection, Metacognition and Knowledge Integration
Holistic Understanding	• CDIO covers systems thinking but lacks explicit *integration of personal experience* and *well-being considerations*. • Needed because holistic understanding requires connecting disciplinary knowledge with lived experience and sustainability.	2.3.2 Understand Interactions in Systems and External to Systems
Adaptability & Flexibility	• CDIO mentions resourcefulness but does not explicitly cover *stress coping* and *cognitive reappraisal*. • Needed because adaptability is not just technical improvisation but emotional regulation under uncertainty.	2.4.3 Demonstrate Resourcefulness and Flexibility in Adapting to Change
Ethics & Morality	• CDIO emphasizes ethics but does not explicitly cover *civic reasoning* and *pluralistic ethics navigation*. • Needed because professionals must weigh conflicting values in diverse societies and act responsibly beyond compliance.	2.5.1 Apply Knowledge of Sound Values and Ethics, and Demonstrate Social Responsibilities

Second, we also added in skills and attitudes needed to support development of students' sustainability mindset, as a follow-up to our work in this area (Cheah *et al*, 2025), which we had noted that gaps existed in the existing SP-CDIO Syllabus. Recent developments had pointed to a convergence between GenAI and sustainability, with research showing its dual role as a driver of sustainable innovation and a subject of ecological concern. GenAI has been applied to forecast sustainability trends for policymaking, optimize smart energy systems and buildings, and advance circular economy practices, while scholars also highlight its significant carbon footprint and resource demands. This convergence underscores the need for a sustainability mindset so that professionals can harness GenAI responsibly while aligning practice with planetary well-being (see for examples Kim *et al* 2025; Hernandez *et al*, 2025; Sharma *et al*, 2025; Vamvakas *et al* 2025).

We asked GenAI to study the 12 sustainability mindset principles (Rimanoczy, 2021) and identify the underpinning skills and attitudes needed, how much of these are already covered in existing SP-CDIO Syllabus (i.e. gaps analysis) and suggestions to required skills and attitudes to close the gap.

Table 5. Suggested skills and attitudes to be added to CDIO based on workplace job requirement for human-machine collaboration

Gaps: Skill / Attitude	Comments on Rationale for Addition	Suggested Location: CDIO (x.x.x)
Tolerance for ambiguity	CDIO mentions uncertainty but not explicitly "comfort with ambiguity" as a mindset.	2.4.1 Demonstrate Positive Attitude and Willingness to Make Decisions in Face of Uncertainty
Trust calibration with machines	No explicit guidance on how to calibrate trust in AI outputs.	2.5.2 Demonstrate Professional Behaviour at Work and in Society
Openness to machine creativity	Creativity is covered, but openness to *AI-generated creativity* is not.	2.4.4 Creative Thinking
Collaborative mindset with AI systems	CDIO covers teamwork with humans, but not collaboration with AI agents.	3.1.3 Participate in Multi-perspective Collaboration
Skepticism balanced with trust	Critical thinking is covered, but balancing skepticism with trust in AI is absent.	2.4.5 Critical Thinking
Comfort with automation	CDIO covers technology use broadly but not attitudes toward automation.	2.4.3 Demonstrate Resourcefulness and Flexibility in Adapting to Change
Humility to cross-check machine outputs	Self-awareness is covered, but humility in relation to AI is not explicit.	2.4.6 Demonstrate Self-Awareness, Self-Reflection, Metacognition and Knowledge Integration
Vigilance for false positives/AI errors	CDIO covers error analysis in human problem-solving, but not vigilance for AI-specific errors.	2.1.3 Analyze Results
Stewardship mindset (environmental + AI governance)	Sustainability is covered, but stewardship in AI-human collaboration is not.	2.5.1 Apply Knowledge of Sound Values and Ethics
Collaborative design attitude with AI	CDIO covers multidisciplinary teamwork, but not human-AI design collaboration.	4.4.1 Formulate the Design Process
Attentiveness to AI alerts	CDIO covers monitoring systems, but not specifically AI-driven alerts.	2.4.2 Demonstrate Perseverance, Sense of Urgency and Will to Deliver
Ethical labour practices in AI optimization	CDIO covers ethics broadly, but not AI-driven labour allocation.	2.5.5 Demonstrate Respect for Equity, Justice, Diversity and Inclusiveness

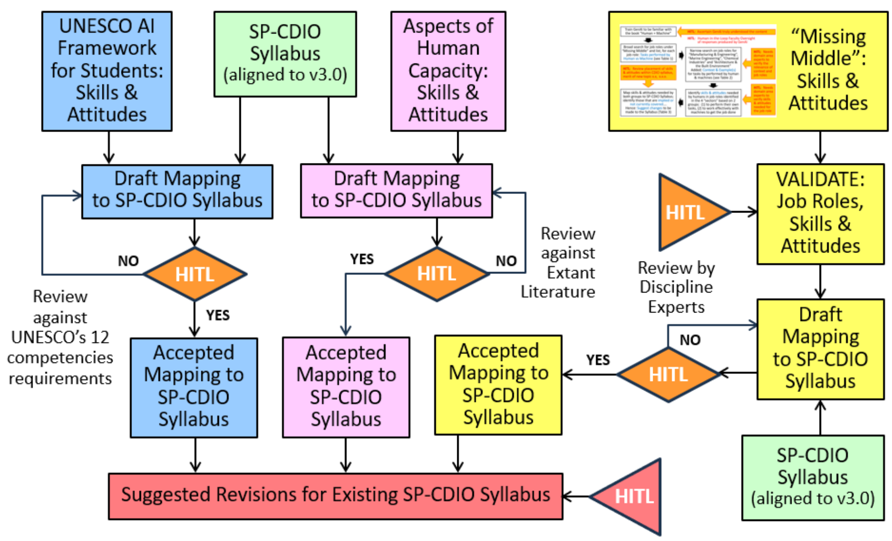

Figure 3(a). Original scope for revised SP-CDIO syllabus

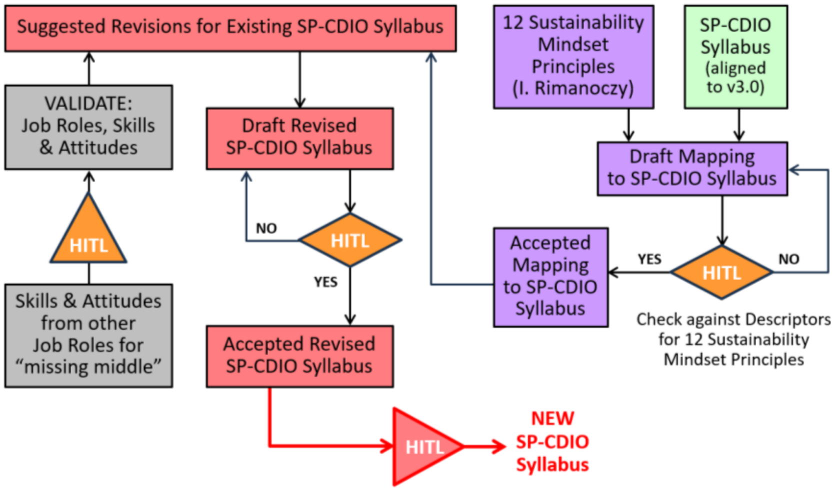

Figure 3(b). Widened scope of revised SP-CDIO syllabus

OVERALL CHANGES NEEDED FOR CDIO SYLLABUS VERSION 3.0

The integration of the drivers culminates in the proposed revisions for the CDIO Syllabus, as consolidated in Appendix 6. Note that the Syllabus still follows version 3.0's format. The additional skills and attitudes identified above are added to existing sections in the syllabus and shown in bold text.

It can be seen that much of the changes impacted Part 2 Personal and Professional Skills and Attributes of the CDIO Syllabus the most, notably Section 2.4 Attitudes, Thought and Learning, and Section 2.5 Ethics, Equity and Other Responsibilities. Next are selected topics in Part 4 Conceiving, Designing, Implementing and Operating Systems in the Enterprise, Societal and Environmental Context. This is hardly surprising, as it is expected that the shifts to human-AI collaboration would demand more adjustments on the side of humans to take advantage of the partnership with machines. Of particular importance is the need to retain core human abilities to guard against over-reliance of GenAI use.

Viewing the changes through the lens of the Conceive-Design-Implement-Operate lifecycle, Table 6 highlights a critical shift in engineering practice, summarised as "pros" and "cons" of impact of GenAI. While GenAI offers significant "pros" such as accelerated prototyping in the *Design* phase and proactive maintenance in the *Operate* phase, it also introduces "cons" like the potential loss of deep operational knowledge or the risk of "black box" outputs during *Implementation*. This table serves as a functional map for navigating these trade-offs, ensuring that human oversight remains the anchor for ethical and sustainable engineering. The implications of using GenAI in the context of CDIO Framework is discussed in detail elsewhere by the author (Cheah, 2026b).

DISCUSSIONS: USING THE SP-CDIO SYLLABUS

An important consideration when formulating the new SP-CDIO Syllabus is its utility. Past iteration of the syllabus have resulted in an increase in the number of pages. So, it is not entirely surprising that this is also the case with the current revision. Members within the CDIO community have already feedback that the syllabus in its current topical form is cumbersome to use. This is the dilemma confronting how best to present or structure the syllabus, as there are relative merits to having the new additions placed under new headings or add to existing headings. The next section explores this challenge in greater detail, using human-AI collaboration as the topic of discourse.

Table 6. Impact of GenAI on engineering practice

Stage	Positive Impacts	Negative Impacts
Conceive	Faster, broader ideation with richer context: AI can rapidly analyze market data, user feedback, and technical constraints, helping teams identify opportunities and risks more comprehensively. Humans bring judgment, empathy, and ethical foresight to ensure conceived ideas align with societal needs.	Conceived solutions may reflect machine bias rather than human values: Over-reliance on AI-generated insights may narrow human creativity or embed hidden biases in problem framing.
Design	Expanded creative space, accelerated prototyping, better-informed design decisions: GenAI tools can propose thousands of design alternatives, simulate performance, and highlight trade-offs. Human designers evaluate feasibility, aesthetics, and compliance.	Loss of transparency and accountability in design choices: AI-generated designs may be technically optimal but socially or ethically inappropriate. Humans must guard against “black box” outputs.
Implement	Increased efficiency, reduced error rates, and more time for humans to focus on higher-level problem-solving: Machines automate repetitive coding, manufacturing, and testing tasks, while humans oversee integration, quality assurance, and safety.	Reduced resilience if systems fail and humans lack deep operational knowledge: Automation can deskill human workers if they are excluded from meaningful tasks. Humans may lose hands-on expertise.
Operate	Proactive maintenance, improved reliability, and enhanced sustainability.: AI systems monitor performance, predict failures, and optimize resource use. Humans interpret anomalies, make ethical decisions, and ensure sustainability.	Ethical lapses, safety hazards, or inequitable resource allocation: AI-driven optimization may prioritize efficiency over fairness or safety. Humans must remain vigilant to override harmful machine decisions.

New Separate Headings vs. Adding to Existing Headings

There are clear advantages to having a separate section for Human-AI Collaborations, summarized briefly as follows:

- Visibility & Emphasis: A dedicated section signals that human-AI collaboration is a core competency, not just a technical addition. It elevates these skills to the same level as analytic reasoning, system thinking, and ethics.
- Clarity for Faculty: Instructors can easily locate all AI-related outcomes in one place, rather than hunting across multiple headings.
- Curriculum Coherence: Students see the hybrid skillset as a distinct domain, reinforcing the idea that working with AI requires unique dispositions (trust calibration, humility, vigilance) beyond traditional problem-solving.
- Future-proofing: As AI evolves, new competencies can be slotted into the new heading without disrupting the rest of the syllabus.
- Assessment Alignment: Easier to design rubrics and evaluation protocols specifically for human-AI collaboration.

Potential drawbacks of having new, separate headings include the following:

- Some of the competency associated with human-AI collaboration are higher-order competencies. Their development needs to be scaffolded progressively from underpinning foundational skills and attitudes; which also form the building blocks of other high-order competencies. As such, these foundational skills and attitudes will necessarily remain in the current locations in the syllabus.

- Faculty need to be cognizant to be thorough in identifying the required foundational skills and attitudes to build up the higher-order competencies; and knowing where to link back to the existing sections for the required foundational skills and attitudes.
- Faculty may suffer from cognitive overload, running through lines and lines of outcome statements. It may be challenging for faculty to distinguish between what are new against what are existing ones.
- Focusing solely on the topics in the separate heading and missing out on some foundational skills and attitudes in existing sections may result in suboptimal development of the required higher-order competencies. It may also result in misguided treatment of AI as "separate" rather than embedded.

This is not a new dilemma though. When version 3.0 of the CDIO Syllabus was formulated, a similar conundrum arisen with regards to either retaining the subsection *Sustainability and the Need for Sustainable Development* from version 2.0 and expanded it to include additional skills and attitudes needed for sustainable development; or to do away with the subsection and redistribute the topics therein along with additional skills and attitudes into relevant sections in the new version 3.0. The decision taken then was to remove the subsection (Malmqvist *et al*, 2022). This was in line with the integration of other skills and attitudes introduced into version 2.0 to update the syllabus incorporating emergence of external change drivers (sustainability, digitalization, acceleration) and internal experiences within the CDIO community.

Limitation of This Work

The search for hybrid skills and attitudes required by humans to work alongside machines was carried out solely with the use of GenAI, due to the lack of extant literature at the time. We do not know how the GenAI tool that we used – Copilot and Gemini – went around conducting the search, and therefore the comprehensiveness of the search. The author did note that on more than one occasion, he found the GenAI outputs to be not satisfactory and he had to make more than one attempt with revised prompts. While this may be reflective of the author's poor grasp of the principles of prompt engineering, he did notice improvements in the GenAI outputs.

The job roles identified are likely not comprehensive. The current revision likely did not account for ongoing developments that identify skills and attitudes beyond the scope of this work. These unaccounted-for capabilities may stem from emerging tasks such as working with generative videos, proactive chatbots, privacy-focused GenAI, and utilizing synthetic data for analytics and simulation. Even GenAI will not be able to predict future job roles that are yet to be defined and not captured in the databases that it used.

In any case, the naming of "industry sectors" used by GenAI also did not conform to standard classifications such as the U.S. Standard Industrial Classification, Bloomberg Industry Classification Standard, just to name a few. Furthermore, due to limitation of time, not all the job roles, skills and attitudes needed for the "missing middle" were validated by experts.

Moving Ahead: Stakeholder Engagement and Validation

The skills and attitudes needed for the future of work, as espoused in this paper, needs to be validated by key stakeholders. As noted earlier, this work was prepared as contribution to the discourse of the future of CDIO Syllabus. There may be other inputs not covered in the paper from other stakeholders, hence the suggested additions as shown in Appendix 6 are likely not exhaustive. This will largely depend on how CDIO Council decides on the future version of the CDIO Syllabus – a new release as version 4.0, or as update for example version 3.1 to align current syllabus reflecting inclusion of GenAI. Any stakeholder engagement (faculty, students, industries) will follow after the final draft of the revised CDIO Syllabus is worked out, to validate the suggested competencies. This author opines that a new version 4.0 is warranted given the number of changes identified in this paper alone.

Moving Ahead: Future Work

The advent of GenAI allows the automation of the tasks of scanning the CDIO syllabus to look for all the necessary skills and attitudes needed for any higher-order competencies, including those needed by humans to work collaboratively with machines. The unpacking of a given job role into the underpinning skills and attitudes required can be handled by GenAI. It can then prepare a cross-referencing index that provides clear guidance to faculty who needs to know which underpinning skills and attitudes are required and where in the CDIO syllabus they can be found.

The 5-step structured workflow is shown in Figure 4, which show how GenAI automates the creation of cross-reference indexes for job roles against the revised SP-CDIO syllabus, and supporting the entire process of designing a learning task for student learning.

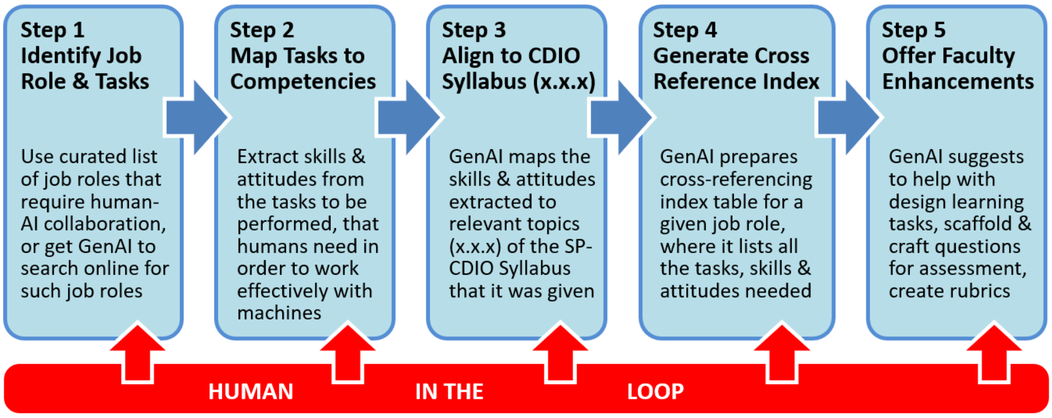

Figure 4. Workflow for using GenAI to prepare cross-reference index

We also emphasize in Figure 4 the needs for faculty oversight – Human-in-the-Loop – to review GenAI outputs for content accuracy and validity, diversity and biases, legal and ethical considerations, etc. In addition, where researching for emerging job roles for “missing middle” it is recommended that faculty adopted a more structured approach (e.g. PRISMA) within one’s own professional field. Lastly, the CDIO Syllabus needs to be validated with key stakeholders.

CONCLUSIONS

This hefty paper proposes that the existing SP-CDIO Syllabus be updated to reflect new requirements of skills and attitudes brought about by the use of GenAI. Specifically, the updates included new skills and attitudes needed for humans to work effectively with machines powered by AI, for humans to retain key capacities over what GenAI can do, and for humans to contribute positively to sustainable development via development of sustainability mindset.

The proposed revised syllabus may not be comprehensive. The approach shared in this paper, however, serve less as an endpoint and more as a critical signpost highlighting the accelerating, uncontained evolution of the digital workspace. The gaps identified in this work did more than just point out missing competencies; it foreshadows the emergence of entirely novel job roles and human capacities. As the exploration and application of GenAI continue to intensify, it is inevitable that this technological frontier will not just reshape existing positions, but will necessitate the continuous creation of new, currently unimagined professional categories and responsibilities.

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Full Declaration: Extensive use of GenAI tools – namely Copilot and Gemini – were used in the preparation of this paper. Their use is mainly to capitalize of their capability to search for vast quantities of data demanded by the scope of this paper. GenAI is used to scan the use of human-AI collaboration across a wide range of industries, to highlight the skills and attitudes required termed "hybrid competencies". GenAI is also used to arrive at common denominator of what constituted core human traits termed "human competencies". Prompts used will include listing of resources from which GenAI drew its output from, to enable the author to search for the articles to validate the work done by GenAI. GenAI is used to accelerate the comparisons of skills and attitudes required in this new age of GenAI, against current covered in existing SP-CDIO Syllabus. The flowcharts in Figure 3(a) and Figure 3(b) illustrate where GenAI is used and the HITL triangle pinpoint the area where faculty oversight is introduced to review the GenAI output. The prompts used and responses obtained can be found in the link below in the PDF file "107". An important point to note the prompts and responses shown in the document did not necessarily follow the sequence of topics in this paper, because the way this author uses GenAI: as a consulting/reference tool as and when he revises the manuscript. GenAI is also used to create the first draft of the abstract from which the author revise it to his preference.
https://drive.google.com/drive/folders/1h5gPaRxba899Yjk2GbR5JqJ4jeeqMqLo?usp=sharing

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BIOGRAPHICAL INFORMATION

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APPENDIX 1. UNESCO'S AI COMPETENCIES FOR STUDENTS MAPPED TO EXISTING CDIO SYLLABUS

Dimension (Level)	Specific Competency	Corresponding SP CDIO Syllabus Entries (x.x.x) *Italic implies a level inside x.x.x*
A1: Human-Centred Mindset (Understand)	AI Literacy and Awareness *Understanding AI's potential, limits, and the need for human control.*	2.3.2 *Explain human-system integration and interaction*.
A2: Human-Centred Mindset (Apply)	Critical Evaluation of AI & Human Accountability *Assessing validity, proportionality, and ensuring human oversight.*	2.4.5 *Use a range of critical thinking skills (e.g. analysis, compare and contrast, inference and interpretation, evaluation).* 2.5.2 *Explain ethical issues in use of artificial intelligence (AI), e.g. discern validity, applicability and implications of recommendations from AI.* 4.4.6 *Demonstrate design for human factors, interaction and supervision*.
A3: Human-Centred Mindset (Create)	Citizenship in the Era of AI *Promoting human rights, inclusion, equity, and participation in AI governance.*	2.5.1 *Practice ethical reasoning on issues relating to personal and professional conduct.* 2.5.5 *Explain the need to treat others with equity and justice, including gender, race, ethnicity, religion, etc*
B1: Ethics of AI (Understand)	Embodied Ethics *Internalizing ethical principles and reflecting on personal values toward AI use.*	2.5.1 *Explain concepts of fairness, justice and responsibilities* 2.5.2 *Explain ethical issues in use of artificial intelligence (AI).* 4.1.4 *Explain the precautionary principle in the face of uncertainty over potential impact of one's work on society or environment*
B2: Ethics of AI (Apply)	Safe and Responsible AI Use *Identifying, assessing, and mitigating bias, privacy, and security risks in data/models.*	2.1.1 *Identify assumptions and sources of bias.* 2.1.2 *Identify uncertainty and ambiguity in information*. 2.2.3 *Manage experimental data* (this point may need to be enhanced, to be more explicit for managing for security/privacy). 2.5.5 *Explain the need to treat others with equity and justice, including gender, race, ethnicity, religion, etc*
B3: Ethics of AI (Create)	Designing for AI Ethics *Embedding ethical principles, accountability, and governance into system design.*	4.4.6 *Demonstrate design for human factors, interaction and supervision.* (Significant gaps exist)
C1: AI Techniques & Applications (Understand)	Foundational AI Concepts *Understanding data, algorithms, and different types of AI models.*	2.1.2 *Identify and select suitable conceptual, quantitative and/or qualitative models, where appropriate.* (Need context for AI)
C2: AI Techniques & Applications (Apply)	Effective Use of AI Tools *Utilizing AI tools and managing data for real-world problem-solving.*	2.1.2 *Identify limitations in digital tools.* 2.1.2 *Perform data mining and analytics.* 2.2.3 *Manage experimental data, e.g. organize, classify, categorize, especially big data.*
C3: AI Techniques & Applications (Create)	Developing AI Models *Building, training, and testing basic AI components and solutions.*	4.4.1 Formulate the Design Process (Significant gaps exist)
D1: AI System Design (Understand)	AI Problem Scoping *Defining the challenge, identifying constraints, and understanding the context for an AI system.*	2.1.1 *Select key issues to be resolved* *Write a problem statement.* 4.3.2 Understand Needs and Goal Setting
D2: AI System Design (Apply)	AI Architecture Design *Developing the conceptual and detailed structure of the AI system, including components and data flow.*	2.3.2 *Explain human-system integration and interaction*. 4.3.3 Evaluate Function, Concept and Architecture.(in context of AI) 4.4.6 Design for Sustainability, Safety, Aesthetics, Operability and Other Objectives (Need context for AI)
D3: AI System Design (Create)	Iteration & Feedback Loops *Developing systems using iterative processes and incorporating user/system feedback.*	4.6.4 Manage System Improvement and Evolution (Significant gaps exist)

APPENDIX 2. SKILLS & ATTITUDES NEEDED FOR HUMAN CAPACITIES MAPPED TO EXISTING CDIO SYLLABUS

Human Capacity	Skills Needed	Attitudes Needed	CDIO Section(s) Covered
Emotions & Empathy	• Identify and label own emotions • Listen actively to others' feelings • Express empathy verbally and non-verbally • Regulate emotional responses in group settings	• Willingness to consider others' perspectives • Patience in emotionally charged situations • Respect for differences	2.5.5 Demonstrate Respect for Equity, Justice, Diversity and Inclusiveness 3.2.7 Demonstrate Effective Interpersonal Communication, Inquiry, Listening, Dialog and Argumentation 4.3.2 *Demonstrate empathy for end users*
Creativity & Innovation	• Generate multiple solutions to a problem • Reframe problems from different angles • Combine ideas into new configurations • Use creative tools (e.g., brainstorming, mind-mapping)	• Curiosity to explore beyond the obvious • Openness to novelty • Playfulness in experimentation	2.4.4 Creative Thinking 4.4.1 Formulate the Design Process
Consciousness & Self-awareness	• Reflect on personal strengths and weaknesses • Monitor own thinking (metacognition) • Articulate personal values and beliefs • Adjust behaviour based on self-reflection	• Honesty with self • Willingness to accept feedback • Confidence balanced with humility	2.4.6 Demonstrate Self-Awareness, Self-Reflection, Metacognition and Knowledge Integration 2.4.7 *Explain how emotions and beliefs affect learning*
Holistic Understanding	• Gather information from diverse sources (technical, social, personal) • Compare and synthesize across contexts • Apply knowledge to real-world scenarios with multiple factors • Identify links between personal experience and disciplinary knowledge	• Openness to integrate different perspectives • Responsibility to consider wider impacts • Comfort with ambiguity and complexity	2.3.1 Understand the Basis and Methods of System Thinking 2.3.2 Understand Interactions in Systems and External to Systems 4.1 External, Societal and Environmental Context
Adaptability & Flexibility	• Adjust strategies when conditions change • Improvise solutions with available resources • Manage stress in uncertain situations • Learn new methods quickly	• Resilience in setbacks • Willingness to change course • Persistence in pursuing goals	2.4.2 Demonstrate Perseverance, Sense of Urgency and Will to Deliver 2.4.3 Demonstrate Resourcefulness and Flexibility in Adapting to Change
Ethics & Morality	• Identify ethical dilemmas • Weigh consequences of actions • Apply ethical reasoning frameworks • Resolve conflicts fairly	• Integrity in decision-making • Fairness toward others • Commitment to social responsibility	2.5.1 Apply Knowledge of Sound Values and Ethics, and Demonstrate Social Responsibilities 2.5.2 Demonstrate Professional Behaviour at Work and in Society

APPENDIX 3. SELECTED JOB ROLES WITH DIVISION OF TASKS WHERE HUMAN & MACHINE WORKING COLLABORATIVELY

MANUFACTURING & ENGINEERING		
Generative Design Engineer	**Human**	**Machine**
Context: Automotive and aerospace *Example:* Airbus engineers use AI-generated wing structures, then select viable designs	Define design constraints, evaluate manufacturability, approve final prototypes	Generate thousands of lightweight design options, simulate stress/fatigue
Digital Twin Orchestrator	**Human**	**Machine**
Context: Smart factories *Example:* Siemens turbines monitored by AI twins, engineers decide maintenance actions	Decide intervention strategies, set fidelity requirements	Run real-time simulations, detect anomalies, optimize throughput
CHEMICAL INDUSTRIES		
Process Optimization Specialist	**Human**	**Machine**
Context: Petrochemical plants *Example:* BASF uses AI to optimize catalyst performance; chemical engineers validate outputs	Define safety margins, interpret anomalies, approve process changes	Monitor sensors, run predictive models for yield/energy efficiency
Sustainability & Emissions Analyst	**Human**	**Machine**
Refining and chemical manufacturing *Example:* Dow Chemical integrates AI dashboards for emissions; humans decide corrective actions	Set compliance targets, interpret environmental trade-offs	Track emissions in real time, simulate reduction strategies
Lab Automation Supervisor	**Human**	**Machine**
Pharmaceutical R&D *Example*: Novartis labs use robotic AI systems for drug screening, scientists interpret findings	Design experiments, interpret results, decide next research steps	Automate repetitive assays, generate preliminary data
ARCHITECTURE & THE BUILT ENVIRONMENT		
Building Information Modelling (BIM) Coordinator	**Human**	**Machine**
Context: Construction firms *Example:* Arup architects use AI-driven BIM to optimize building layouts, humans finalize designs	Define design intent, resolve conflicts, ensure compliance	Generate 3D models, detect clashes, simulate energy efficiency
Smart Construction Planner	**Human**	**Machine**
Context: Prefabrication and modular construction *Example:* Singapore's Housing Development Board uses AI to plan modular housing assembly	Approve sequencing, manage safety and labour constraints	Optimize logistics, simulate assembly schedules
Green Building Strategist	**Human**	**Machine**
Context: Sustainable architecture *Example:* Architects in Singapore use AI to meet Green Mark standards	Set sustainability goals, balance aesthetics and regulations	Model energy flows, simulate daylight and HVAC efficiency
MARINE ENGINEERING		
Hull Design Engineer	**Human**	**Machine**
Context: Shipbuilding *Example:* Hyundai engineers use AI to propose fuel-efficient hulls, humans validate	Define hydrodynamic constraints, approve safety standards	Generate hull shapes, run CFD (computational fluid dynamics) simulations
Predictive Maintenance Specialist	**Human**	**Machine**
Context: Offshore oil rigs, shipping fleets *Example:* Maersk uses AI predictive systems for engine maintenance, engineers decide interventions	Interpret sensor anomalies, schedule repairs, ensure safety compliance	Monitor vibration, corrosion, and fatigue data; predict failures
Port Operations Optimizer	**Human**	**Machine**
Context: Maritime logistics hubs *Example:* Singapore's PSA International uses AI to optimize port operations, humans oversee exceptions	Manage labour, safety, and regulatory compliance	Optimize container routing, crane scheduling, berth allocation

APPENDIX 4. SELECTED JOB ROLES WHERE SKILLS & ATTITUDES NEEDED BY HUMANS TO PERFORM HUMAN PART OF TASKS AND TO WORK COLLABORATIVELY WITH MACHINES ON MACHINE PART OF TASKS

Job Role (Industry Context)	Skills & Attitudes (Human Job)	Skills & Attitudes (Human Working with Machines)
Generative Design Engineer (Automotive, Aerospace)	Systems thinking, engineering judgment, creativity, tolerance for ambiguity, safety-first mindset	Openness to machine creativity, critical evaluation of AI outputs, collaborative mindset, ethical responsibility
Digital Twin Orchestrator (Smart Factories, Energy)	Analytical rigor, decision-making under uncertainty, risk awareness, operational leadership	Trust calibration, ability to interpret simulation data, vigilance for false positives, adaptive problem-solving
Process Optimization Specialist (Chemical & Petrochemical)	Chemical engineering expertise, safety culture, resilience, detail orientation	Data literacy, openness to continuous improvement, skepticism balanced with trust, ethical oversight
Sustainability & Emissions Analyst (Chemical Manufacturing)	Environmental ethics, regulatory knowledge, systems thinking, long-term orientation	Attitude of stewardship, ability to interpret dashboards, collaborative sustainability mindset
Lab Automation Supervisor (Pharmaceutical R&D)	Scientific curiosity, hypothesis-driven thinking, precision, patience	Comfort with automation, ability to validate machine outputs, humility to cross-check
BIM Coordinator (Architecture & the Built Environment)	Spatial reasoning, design creativity, negotiation skills, regulatory awareness	Visualization literacy, openness to machine suggestions, collaborative design attitude
Smart Construction Planner (Modular Construction)	Project management, safety leadership, adaptability, communication	Trust in machine optimization, ability to interpret scheduling outputs, pragmatic flexibility
Green Building Strategist (Sustainable Architecture)	Ethical responsibility, creativity, systems thinking, stakeholder empathy	Environmental literacy, openness to machine insights, collaborative sustainability mindset
Hull Design Engineer (Marine Engineering)	Engineering rigor, safety-first mindset, creativity, resilience	Ability to interpret simulations, openness to machine creativity, vigilance for safety-critical outputs
Predictive Maintenance Specialist (Offshore Rigs, Shipyards)	Diagnostic reasoning, safety culture, resilience under pressure	Attentiveness to alerts, skepticism toward false positives, collaborative problem-solving
Port Operations Optimizer (Maritime Logistics Hubs)	Operational leadership, negotiation, fairness, adaptability	Systems thinking, openness to machine optimization, vigilance for ethical labour practices

APPENDIX 5. GAP ANALYSIS FOR SKILLS & ATTITUDES NEEDED FOR SUSTAINABILITY MINDSET PRINCIPLES

Sustainability Mindset Principles	Ecoliteracy
Sections in CDIO Syllabus (1.4), (2.3), (4.1)	Ecoliteracy requires understanding of ecological systems and planetary boundaries. CDIO's system thinking and societal/environmental context explicitly embed ecological awareness.
	Gaps: Adequately covered
Sustainability Mindset Principles	My Contribution
Sections in CDIO Syllabus (2.5), (3.1), (4.1.1)	This principle emphasizes agency and responsibility. CDIO's ethics and professional responsibility sections operationalize this through social responsibility and professional conduct.
	Gaps: Adequately covered
Sustainability Mindset Principles	Long-Term Thinking
Sections in CDIO Syllabus (2.1), (4.1.6), (4.3.1)	Long-term thinking aligns with foresight, scenario planning, and sustainability visioning in CDIO. It also links to risk analysis and resilience.
	Gaps: Adequately covered
Sustainability Mindset Principles	Flow in Cycles
Sections in CDIO Syllabus (2.3), (4.4), 4.3.4)	CDIO explicitly references cradle-to-cradle and lifecycle design. Flow in cycles reinforces circular economic thinking in engineering design.
	Gaps: CDIO references cradle-to-cradle and lifecycle design but doesn't explicitly embed *circular economic thinking* or natural cycles beyond engineering context.
Sustainability Mindset Principles	Both-And Thinking
Sections in CDIO Syllabus (2.3.4), (3.2.8), (4.3.3)	Both-And thinking avoids false dichotomies. CDIO's trade-off analysis and conflict resolution sections operationalize this principle.
	Gaps: CDIO covers trade-offs and synergies but tends to emphasize resolution. Missing explicit cultivation of paradox tolerance (holding tensions without premature closure).
Sustainability Mindset Principles	Interconnectedness
Sections in CDIO Syllabus (2.3), (3.1.3), (4.1.2)	Interconnectedness is core to systems thinking and stakeholder collaboration. CDIO embeds this in multi-perspective teamwork and societal impact analysis.
	Gaps: Adequately covered
Sustainability Mindset Principles	Creative Innovation
Sections in CDIO Syllabus (2.4.4.), (4.2.3), (4.4)	Innovation is central to CDIO's design and entrepreneurship sections. Creative innovation principle strengthens the sustainability lens in these processes.
	Gaps: Adequately covered
Sustainability Mindset Principles	Reflection
Sections in CDIO Syllabus (2.4.6), (2.4.7), (3.2.7)	Reflection is embedded in metacognition, self-awareness, and dialog. CDIO already emphasizes reflective practice, which aligns with sustainability mindset.
	Gaps: CDIO emphasizes metacognition and critical thinking, but reflection is mostly cognitive. Missing paradigm-level reflection (questioning worldviews, assumptions about growth, progress, consumption).
Sustainability Mindset Principles	Self-Awareness
Sections in CDIO Syllabus (2.4.6), (2.5.3), (3.2.7)	Self-awareness in CDIO is explicit. Sustainability mindset deepens this by linking personal values to planetary responsibility.
	Gaps: CDIO includes self-awareness, but mostly in terms of skills and weaknesses. Missing explicit recognition of *biases, privilege, and positionality* in sustainability contexts.
Sustainability Mindset Principles	Purpose
Sections in CDIO Syllabus (2.5.3), (4.1.6), (4.2.2)	Purpose aligns with CDIO's emphasis on vision, career planning, and enterprise mission. Sustainability mindset ensures purpose is socially and environmentally aligned.
	Gaps: CDIO includes personal vision and career planning, but purpose is framed narrowly (professional development). Missing explicit alignment with *meaning, contribution, and sustainability*.
Sustainability Mindset Principles	Oneness with Nature
Sections in CDIO Syllabus (2.3.2), (4.1.2), (4.1.6)	CDIO references human-system integration and environmental impact. Oneness with nature extends this to experiential and ethical belonging.
	Gaps: CDIO mentions environmental impact and human-system integration, but it frames nature as an external system to be managed, not as a relational identity. Missing experiential and affective connections to nature.
Sustainability Mindset Principles	Mindfulness
Sections in CDIO Syllabus (2.3.2), (4.1.2), (4.1.6)	Mindfulness maps to CDIO's emphasis on self-regulation, reflection, and empathetic communication. It strengthens resilience and ethical decision-making.
	Gaps: CDIO covers reflection, metacognition, and emotional regulation, but mindfulness as *present-moment awareness* and *non-judgmental attention* is absent.

APPENDIX 6. PROPOSED SP-CDIO SYLLABUS VERSION 4.0

1 FUNDAMENTAL KNOWLEDGE AND REASONNING (UNESCO: Learning to Know)
1.5 KNOWLEDGE OF COGNITIVE SCIENCE

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES (UNESCO: Learning to Be)
2.1 ANALYTIC REASONING AND PROBLEM SOLVING
2.1.2 Formulate a Strategy to Solve Problems
- **Formulate precise, goal-oriented prompts for Generative AI tools and critically evaluate AI outputs (Prompt Engineering).**
- **Show curiosity and tolerance when dealing with ambiguous information.**

2.1.3 Analyze Results
- **Detect AI-specific errors (false positives/negatives) and calibrate vigilance when interpreting machine outputs.**
- **Interpret calibration, confidence intervals, and uncertainty quantification in AI outputs.**

2.3 SYSTEM THINKING
2.3.2 Understand Interactions in Systems, and External to Systems
- **Integrate personal experience, well-being, and sustainability considerations into system perspectives (Holistic Understanding).**

2.3.4 Understand Trade-offs, Synergies, Judgment and Balance in Resolution
- **Exhibit courage and responsibility in taking calculated risks.**

2.4 ATTITUDES, THOUGHT AND LEARNING
2.4.1 Demonstrate Positive Attitude and Willingness to Make Decisions in Face of Uncertainty
- **Demonstrate comfort with ambiguity as a mindset.**

2.4.2 Demonstrate Perseverance, Sense of Urgency and Will to Deliver
- **Demonstrate optimism and ability to learn from setbacks.**

2.4.3 Demonstrate Resourcefulness and Flexibility in Adapting to Change
- **Apply stress coping and cognitive reappraisal strategies.**
- **Demonstrate comfort with automation as part of adaptation.**

2.4.4 Demonstrate Creative Thinking
- **Demonstrate openness to AI-generated creativity.**

2.4.5 Demonstrate Critical Thinking
- **Balance skepticism with trust when evaluating AI outputs.**

2.4.6 Demonstrate Self-Awareness, Self-Reflection, Metacognition and Knowledge Integration
- **Demonstrate humility by validating AI outputs against independent evidence and acknowledging model limits.**

2.4.7 Demonstrate Learning Agility, Engage in Lifelong Learning and Educating
- **Cultivate emergent learning and serendipity with AI; reflect and integrate insights into personal learning plans.**

2.4.8 Manage Time, Technology and Resources
- **Prioritize and respond appropriately to AI-driven alerts based on risk and urgency.**

2.4.9 Practice mindfulness and presence
- **Explain the role of mindfulness in attention regulation and decision-making under uncertainty.**
- **Demonstrate mindfulness techniques (e.g. breathing, grounding, mindful listening) in personal and team contexts.**
- **Apply mindfulness to enhance resilience, clarity, and ethical judgment in complex situations.**

2.4.10 Hold paradoxes and embrace both-and thinking
- **Explain the concept of paradox and its relevance to sustainability challenges.**
- **Demonstrate tolerance for ambiguity and explore integrative Both-And solutions.**
- **Resist premature closure by holding tensions and proposing balanced outcomes in problem-solving.**

2.4.11 Experiential connection with nature
- **Explain cultural and historical perspectives on human–nature relationships.**
- **Engage in practices that foster sensory awareness and immersion in natural systems.**
- **Articulate how personal well-being is linked to planetary well-being and integrate this awareness into decision-making.**

2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES

2.5.1 Apply Knowledge of Sound Values and Ethics, and Demonstrate Social Responsibilities

- **Practice civic reasoning and pluralistic ethics navigation.**
- **Adopt stewardship mindset in AI-human collaboration (environmental + governance).**

2.5.2 Demonstrate Professional Behaviour at Work and in Society

- **Calibrate trust in AI outputs and override when necessary.**
- **Ensure privacy-by-design in AI-assisted decisions.**

2.5.5 Demonstrate Respect for Equity, Justice, Diversity and Inclusiveness

- **Demonstrate emotion regulation and restorative practices in diverse environments.**
- **Address ethical labour practices in AI optimization.**

2.5.7 Articulate Purpose and meaning in professional life

- **Explain the importance of purpose and meaning in professional and personal development.**
- **Define a personal sense of purpose that integrates values with contribution to sustainability.**
- **Demonstrate purpose-driven leadership in professional, enterprise, and community contexts.**

2.5.8 Reflect on Paradigms and Worldviews

- **Explain dominant paradigms (e.g. growth, consumption, progress) and their sustainability implications.**
- **Critically examine assumptions underlying professional and societal practices.**
- **Propose alternative paradigms that support regenerative and sustainable futures.**

2.5.9 Identify Biases, Privileges, Positionality

- **Explain the role of personal biases, privileges, and positionality in sustainability contexts.**
- **Recognize how positionality influences engagement with diverse stakeholders.**
- **Demonstrate awareness of biases and privileges to ensure equity and inclusiveness in sustainability practice.**

3 INTERPERSONAL SKILLS: COLLABORATION, TEAMWORK, AND COMMUNICATION (UNESCO: Learning to Live Together)

3.1 TEAMWORK AND COLLABORATION

3.1.3 Participate in Multi-perspective Collaboration

- **Collaborate with AI systems as partners in problem-solving and design.**
- **Orchestrate human and AI contributions to improve team decisions; document trade-offs.**

3.2 COMMUNICATIONS

3.2.1 Design Appropriate Communications Strategy

- **Communicate AI reasoning, uncertainty, and limitations to stakeholders.**

3.2.7 Demonstrate Effective Interpersonal Communication, Inquiry, Listening, Dialog and Argumentation

- **Apply restorative dialogue foundations (active listening, emotion labelling, neutral language, summarizing shared points).**

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS (UNESCO: Learning to Do)

4.1 EXTERNAL, SOCIETAL AND ENVIRONMENTAL CONTEXT

4.1.2 Address the Impact of Engineering on Society and the Environment

- **Analyse environmental and computational cost of AI models; design for efficiency and sustainability.**

4.1.3 Recognise How One's Profession is Regulated in Society

- **Apply privacy-by-design (data minimization, consent, retention) to AI workflows.**

4.1.6 Describe a Vision for the Future

- **Construct AI-assisted scenarios; compare plausible outcomes and policy implications.**

4.2 ENTERPRISE AND BUSINESS CONTEXT

4.2.6 Understand New Technology Development and Assessment

- **Appraise AI governance controls (documentation, lineage, audits) and recommend safeguards.**

- **Evaluate synthetic data appropriateness and validate representativeness; document risks.**

4.3 CONCEIVING, SYSTEM ENGINEERING AND MANAGEMENT
4.3.3 Evaluate Function, Concept and Architecture
- **Specify appropriate levels of automation and human control points.**

4.3.6 Develop a Product Information and Knowledge Management System
- **Maintain artifact lineage, reproducibility, and auditability for AI-enabled assets.**

4.4 DESIGNING
4.4.1 Formulate the Design Process
- **Demonstrate collaborative design attitude with AI systems.**

4.4.6 Design for Sustainability, Safety, Aesthetics, Operability and Other Objectives
- **Demonstrate design for explainability, transparency and auditability (XAI).**

4.4.7 Integrate circular economy and regenerative design principles.
- **Explain the principles of circular economy and regenerative design.**
- **Apply lifecycle and circular economy analysis in product, process, and system design.**
- **Create designs that embed regenerative outcomes, ensuring sustainability beyond cradle-to-cradle.**

4.5 IMPLEMENTING
4.5.5 Conduct Test, Verification, Validation and Certification
- **Design red-team scenarios and AI safety tests; analyze outcomes and implement corrective actions for AI-in-the-loop systems.**

4.6 OPERATING
4.6.4 Manage System Improvement and Evolution
- **Establish telemetry and feedback loops for AI-in-operations; implement iterative refinements based on monitored performance and error modes.**

5 THE OPTIONAL CDIO SYLLABUS: LEADERSHIP, ENTREPRENEURSHIP AND RESEARCH
5.1 LEADING ENGINEERING ENDEAVORS
5.1.2 Thinking Creatively and Communicating Possibilities
- **Incorporate AI-augmented creativity while maintaining reflective evaluation of originality, feasibility, ethics, and societal impact.**

5.1.3 Defining the Solution
- **Define oversight checkpoints, levels of automation, and escalation pathways for AI-in-the-loop solutions.**

5.1.6 Planning and Managing a Project to Completion
- **Integrate AI safety tests, documentation, and governance checkpoints into project plans for AI-enabled solutions.**

5.1.7 Exercising Project/Solution Judgment and Critical Reasoning
- **Balance skepticism with trust in AI-generated evidence; justify overrides and escalation decisions transparently.**

5.2 ENGINEERING ENTREPRENEURSHIP
5.2.5 Conceiving Products and Services around New Technologies
- **Evaluate AI governance, privacy, and fairness implications in productization; define oversight and audit mechanisms.**

5.3 RESEARCH
5.3.1 Identification of needs, structuring and planning of research projects
- **Include plans for AI data governance, privacy protection, fairness assessments, and reproducibility audits where applicable.**

5.3.2 Execution of research
- **Detect and document AI-specific failure modes (e.g., hallucinations, miscalibration); justify overrides and escalation.**

5.3.3 Presentation and evaluation of research
- **Communicate AI reasoning, confidence, and limitations transparently; share governance and audit outcomes.**

5.3.4 Research ethics
- **Apply precautionary principle for AI-related risks; ensure equitable and privacy-preserving data practices.**