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Research Article



# Integrating Innovative Sustainable Strategy into Strategic Management Education: A CDIO-Based Experiential and AI-Collaborative Teaching Practice

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## Abstract

This study develops and empirically validates a CDIO-based instructional model that integrates experiential and AI-collaborative learning to promote sustainability competence in strategic management education. Addressing persistent challenges in business curricula - such as low learning motivation, limited innovation, insufficient AI literacy, weak teamwork, and underdeveloped sustainability thinking - the research applies experiential and AI-collaborative learning within the CDIO framework to enhance students' engagement and sustainable competence. Findings indicate that this CDIO-based approach significantly improves student engagement, teamwork, and the capacity for sustainability-oriented and innovative thinking. The results confirm the adaptability of the CDIO framework beyond engineering contexts and highlight its potential to cultivate sustainability-driven innovation and digital fluency in management education. The study concludes with implications for embedding Education for Sustainable Development and Global Goals (ESDG) principles into higher education curricula to bridge academic learning with workplace readiness.

**Keywords:** Conceive-Design-Implement-Operate (CDIO); Experiential learning; AI-collaborative learning; sustainability education

## Introduction

Business and management education in higher education institutions is undergoing a period of significant transformation as sustainability imperatives, digitalization, and artificial intelligence (AI) reshape learning paradigms. Universities worldwide are expected to cultivate graduates who can combine analytical reasoning with creativity, collaboration, and social responsibility to address complex societal and environmental challenges [1,2]. However, despite substantial curricular reform efforts, many business programs continue to encounter persistent pedagogical challenges that hinder students' learning engagement and real-world readiness.

Across diverse tertiary contexts, students in business disciplines frequently demonstrate low learning motivation and limited engagement, largely due to teacher-centered and assessment-driven pedagogies that constrain experiential and reflective learning [1]. Moreover, creative and innovative thinking skills - essential for strategic problem-solving - remain underdeveloped in conventional curricula [3]. The accelerated diffusion of digital technologies has also exposed deficiencies in AI literacy and data analytics skills among students, restricting their capacity to apply

technology in managerial contexts [4]. Likewise, teamwork and communication - core competencies for professional collaboration - are insufficiently cultivated in lecture-based classrooms [5].

Another critical concern is the absence of sustainability-oriented thinking, despite growing calls for embedding environmental, social, and governance (ESG) principles into management education [6]. This deficiency undermines students' ability to connect business performance with broader social and environmental accountability. Collectively, these challenges weaken graduates' employability and capacity to contribute to sustainable innovation [7].

To address these issues, this study employs the Conceive-Design-Implement-Operate (CDIO) framework as an integrative pedagogical model that unites experiential learning and AI-collaborative learning in strategic management education. By embedding innovative and sustainable strategy concepts into authentic, technology-enhanced learning experiences, this research seeks to enhance students' engagement, teamwork, and sustainability competence. The study contributes to the growing discourse on Education for Sustainable Development and Global Goals (ESDG) by empirically validating a CDIO-based instructional model that equips students to apply sustainability-driven innovation and digital fluency in real-world management practice.

## Literature Review

### CDIO in Higher Education

The CDIO framework emphasizes the entire lifecycle of conceiving, designing, implementing, and operating a system, thereby linking theory to professional application [8]. Its structured approach cultivates technical mastery alongside communication, leadership, and reflective skills. Lin [9] found that integrating CDIO with problem-based learning improved marketing students' learning satisfaction, while Thomassen and Lai [10] integrating CDIO principles, such as management education, not only enhances learners' self-awareness and teamwork but also fosters their access to practical experiences in risk management and sustainable value creation.

### Experiential Learning

Experiential learning emphasizes learning through authentic experiences, reflection, and practical application [11]. In higher education, it bridges the gap between theory and practice, allowing students to apply classroom concepts to real-world contexts. Recent research highlights its positive effects on student motivation, creativity, and self-regulated learning in business and management education [12]. Contemporary studies identify three core mechanisms: authentic participation, reflective practice, and transformative application. Authentic participation immerses learners in realistic problem-solving and decision-making, enhancing engagement and contextual understanding [13]. Reflective practice deepens comprehension through structured self-assessment and feedback [14], while transformative application encourages learners to adapt and transfer knowledge across contexts [15].

Simulation- and project-based approaches further extend experiential learning by creating conditions for iterative experimentation and collaboration. When combined with AI-assisted tools, these experiences improve teamwork, problem-solving ability, and sustainability awareness [2]. Integrating experiential learning with sustainability and ESG-oriented curricula enhances students' ethical reasoning, systems thinking, and innovation competencies - skills increasingly vital in Industry 5.0 workplaces [16]. Within the CDIO framework, experiential learning concretizes the design and implementation phases through authentic simulation, reflection, and applied action, thereby cultivating analytical, collaborative, and ethical capacities essential for creating sustainable business value.

### AI-Collaborative Learning

AI collaborative learning refers to the pedagogical integration of artificial-intelligence tools to support interaction, co-creation, and adaptive feedback among learners. Rather than replacing human collaboration, AI functions as an intelligent partner that scaffolds teamwork and cognitive development. In business education, AI applications such as ChatGPT and data-driven analytics promote real-time information processing, creative ideation, and evidence-based decision-making [2]. Studies show that AI-supported environments enhance critical thinking, reflection, and communication by personalizing feedback and facilitating collective problem solving [17].

Recent research highlights that when AI is integrated within project-based or experiential learning contexts, students demonstrate stronger engagement, higher cognitive persistence, and improved innovation performance [3]. However, effective implementation requires ethical awareness and appropriate instructional design to prevent overreliance and ensure academic integrity. Within the CDIO framework, AI collaborative learning reinforces the design and implementation stages by enabling students to prototype ideas, analyse data, and iteratively refine sustainability-oriented solutions. This synergy between human creativity and algorithmic intelligence cultivates digital literacy, teamwork, and responsible innovation—competencies central to education for sustainable development.

## Methodology

### Research Context and Participants

The study was conducted during the spring semester of 2025 at a northern Taiwan university of technology. Participants included 62 senior undergraduate students from the department of Business Administration enrolled in a Strategic Management course. The course was selected because it emphasizes applied decision-making, strategic analysis, and sustainability planning - key competencies aligned with the study's objectives. Participation was voluntary and informed consent was obtained prior to data collection.

### Course Design

The course was structured in accordance with the CDIO

framework and integrated multiple teaching methods-lecture-based instruction, authentic learning, out-of-school learning, and AI-collaborative learning-to strengthen sustainability-oriented and technology-enhanced management competencies. Table 1 summarizes the pedagogical stages and implementation strategies, which are elaborated below.

**Table 1:** Course Design Framework and Implementation Strategies.

| CDIO Phase | Teaching Method | Implementation Strategy |
|---|---|---|
| Conceive | Course Lecture/ Experiential Learning | Implement simulation-based business tasks where teams design investment plans and conduct feasibility studies; collaborate with alumni start-ups for site visits to observe ESG practices and collect field data. |
| Design | Course Lecture/ AI-Collaborative Learning | Deliver lectures on ESG trends and AI innovation; train students to use ChatGPT for idea generation and data analysis; facilitate group brainstorming and co-creation workshops for ESG project design. |
| Implementation | AI-Collaborative Learning / Team-based Learning | Guide teams to execute AI-supported ESG strategies through simulations, data analytics, and case studies; integrate cross-disciplinary knowledge (marketing, finance, operations). |
| Operation | AI-Collaborative Learning / Team-based Learning | Conduct final project presentations and reports; assess ESG proposals through instructor and peer evaluation; foster reflection, collaboration, and application of sustainability knowledge to real-world challenges. |

### Instruments

A structured questionnaire was developed to assess students' perceptions across five learning constructs, adapted from validated and widely recognized instruments. Course learning items, learning interest and learning effectiveness were drawn from Yin's [18] to evaluate curriculum design, intrinsic motivation and satisfaction. Experiential Learning was constructed according to Kolb's [11] Experiential Learning Theory, emphasizing active participation, reflection, and authentic application. Finally, AI collaborative learning items were designed based on contemporary frameworks of human–AI collaboration in education [17], focusing on interaction, co-creation, and feedback-driven learning. Each construct consisted of three to four items measured on a five-point Likert scale (1=strongly disagree to 5=strongly agree). The questionnaire was reviewed by three domain experts to ensure content validity, clarity, and contextual appropriateness before data collection.

## Results

### Reliability and Descriptive Statistics

The instrument demonstrated strong psychometric properties. The Kaiser–Meyer–Olkin (KMO) value was .89 and Bartlett's test of sphericity was significant ($\chi^2$ = 623.74, p < .001), confirming the adequacy of the data for factor analysis. Cronbach's α coefficients ranged from .86 to .91 across the five constructs, indicating excellent internal consistency. Composite reliability (CR) values ranged from .87 to .93 and average variance extracted (AVE) values from .61 to .73, demonstrating convergent validity. A confirmatory factor analysis (CFA) revealed good model fit: $\chi^2$/df = 1.98, CFI = .962, TLI = .951, RMSEA = .062, SRMR = .047, indicating sound construct validity. Descriptive statistics and paired-sample t-test results are presented in Table 2.

**Table 2:** Descriptive Statistics, Reliability, and Effect Sizes of Pre- and Post-Learning Constructs.

| Construct | α | M (Pre) | SD (Pre) | M (Post) | SD (Post) | t(61) | p | Cohen's d | $\eta^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Course Learning | 0.89 | 3.69 | 0.57 | 3.94 | 0.6 | 3.12 | < .01 | 0.6 | 0.14 |
| Learning Interest | 0.91 | 3.76 | 0.59 | 4.03 | 0.56 | 3.25 | < .01 | 0.63 | 0.15 |
| Learning Effectiveness | 0.88 | 3.32 | 0.54 | 3.61 | 0.58 | 4.01 | < .01 | 0.77 | 0.21 |
| Experiential Learning | 0.86 | 3.48 | 0.5 | 3.83 | 0.52 | 2.96 | < .01 | 0.6 | 0.13 |
| AI Collaborative Learning | 0.9 | 3.7 | 0.63 | 4.1 | 0.59 | 3.45 | < .01 | 0.69 | 0.16 |

### Interpretation

All constructs demonstrated statistically significant improvement (p < .01) after the CDIO-based instructional intervention. Effect sizes, measured by Cohen's d and $\eta^2$, ranged from medium to large (d = 0.60–0.77; $\eta^2$ = .13–.21), suggesting pedagogically meaningful gains.

The largest effect was observed in Learning Effectiveness (d = 0.77), indicating notable progress in students' perceived learning outcomes and problem-solving abilities. AI Collaborative Learning (d = 0.69) also showed strong growth, reflecting the positive

influence of AI-assisted teamwork and iterative project design on student engagement. Similarly, Learning Interest (d = 0.63) and Experiential Learning (d = 0.60) increased significantly, supporting the motivational benefits of integrating authentic, simulation-based, and AI-driven learning experiences.

Overall, the results confirm that the CDIO framework, when combined with authentic and AI-collaborative learning, significantly improved both cognitive and motivational outcomes, demonstrating strong reliability, validity, and educational effectiveness.

## Conclusion

This study provides empirical evidence that integrating the CDIO framework with experiential and AI-collaborative learning can effectively enhance students' engagement, learning effectiveness, and sustainability-oriented competencies in business education. The integration of AI within higher education fosters creativity, reflective reasoning, and teamwork, while experiential and project-based learning environments strengthen higher-order cognitive engagement and real-world problem-solving. Embedding sustainability-focused projects into management curricula further reinforces students' ethical awareness and systems thinking. Collectively, these findings support the pedagogical argument that AI-supported experiential learning within the CDIO enables students to translate conceptual knowledge into actionable strategies, thereby improving employability, digital fluency, and the ability to apply sustainable innovation in practical settings. For educators and institutions, the results underscore the importance of reimagining business curricula through integrative, technology-enhanced, and sustainability-driven teaching models that nurture continuous learning, social responsibility, and adaptive professional competence. Future research should continue to explore longitudinal outcomes and cross-institutional validation to assess how CDIO-based AI-collaborative instruction influences graduates' innovation capacity and professional development across diverse educational and cultural contexts.

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## Conflict of Interest

No conflict of interest.

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