



Journal of Hunan University (Natural Sciences)

Vol. 52 No. 11
November 2025

Available online at
<https://ionuns.com>



ELSEVIER
Scopus



Clarivate
WEB OF SCIENCE

Open Access Article

 <https://doi.org/10.55463/issn.1674-2974.52.11.11>

CDIO Projects in Electronic Engineering Education: An Educational Innovation at the University of Quindío

Jorge Alejandro Aldana Gutiérrez^{1*}, Henry Reyes Pineda^{2*}, Alexander vera Tasamá^{1*}

¹ Faculty of Engineering, Quindío's University, Armenia, Colombia,

² Faculty of Agro-industrial Sciences, Quindío's University, Armenia, Colombia,

* Corresponding author: jaldana@uniquindio.edu.co

Article history:

Received: October 19, 2025

Revised: November 27, 2025

Accepted: December 9, 2025

Published: December 30, 2025

Abstract: Engineering education is undergoing a profound transformation driven by technological advances, digitalization, automation, and the evolving demands of global industry. These challenges require a shift from traditional teaching models toward approaches that foster practical competencies, problem-solving skills, interdisciplinary collaboration, and active engagement with real-world contexts. Within this framework, the CDIO (Conceive, Design, Implement, Operate) initiative emerges as a comprehensive pedagogical model that bridges theory and practice while positioning students at the center of the learning process.

This article presents the implementation of the CDIO framework in the Electronic Engineering program at the University of Quindío (Colombia) as an innovative curricular strategy aimed at strengthening professional training through active, contextualized, and project-based learning. The paper describes the methodological foundations, stages of design and implementation, and the progressive integration of the CDIO model into the curriculum, as well as strategies for engagement with industrial sectors, local communities, and external stakeholders.

Based on a sequential mixed-methods approach, the study analyzes data collected between 2021 and 2024, combining quantitative performance indicators with qualitative evidence from surveys, interviews, and project documentation. The results reveal significant improvements in the development of technical, transversal, and socio-emotional competencies, as well as increased student motivation, retention, and the ability to design and implement relevant technological solutions. Furthermore, the implementation of CDIO has enhanced the university-industry-society relationship, thereby increasing the social relevance of engineering education. These findings demonstrate



Copyright: © 2025 by the authors. Licensee JHU

This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>)

that the CDIO framework is an effective tool for addressing contemporary challenges in higher education and for preparing future engineers capable of leading innovation and technological transformation in complex and dynamic environments.

Keywords: CDIO, educational innovation, engineering education, active learning, transversal competencies, university-industry collaboration.

电子工程教育中的CDIO项目：金迪奥大学的教育创新

摘要：工程教育正经历由技术进步、数字化、自动化以及全球产业需求变化所推动的深刻变革。这些挑战要求教育模式从传统教学转向注重实践能力、问题解决能力、跨学科协作以及与现实环境互动的新型模式。在这一背景下，CDIO（构思、设计、实施与运营）框架作为一种综合性的教育理念，连接了理论与实践，并将学生置于学习过程的中心。

本文介绍了哥伦比亚金迪奥大学电子工程专业在课程体系中实施CDIO框架的创新实践。研究描述了该模式的理论基础、设计与实施阶段，以及CDIO在教学计划中的逐步整合，同时分析了与产业部门、地方社区及外部利益相关者的互动机制。

研究采用顺序混合方法，结合2021年至2024年间收集的定量与定性数据，综合分析学生表现、问卷调查、访谈及项目文档的结果。研究发现，CDIO实施显著提升了学生的技术能力、跨学科技能及社会情感能力，同时提高了学习动机、学业留存率以及设计与实施技术解决方案的能力。此外，大学-产业-社会之间的联系得以加强，从而提升了工程教育的社会相关性。结果表明，CDIO框架是一种有效的工具，能够应对高等教育的当代挑战，培养能够在复杂与动态环境中引领创新与技术变革的未来工程师。

关键词：CDIO；教育创新；工程教育；主动学习；跨学科能力；校企合作

1. Introduction

Rapid advances in technology, digital transformation, and global challenges such as sustainability and automation demand that engineering education evolve beyond traditional theoretical instruction. These shifts require a new pedagogical approach that fosters practical competencies, interdisciplinary collaboration, and innovation as essential pillars of professional formation [1-3].

In this context, the CDIO (Conceive-Design-Implement-Operate) framework, initially developed at the Massachusetts Institute of Technology (MIT) and later expanded across Europe, has become a benchmark model for engineering education reform [4]. Its purpose is to bridge the gap between theory and practice by integrating design-based, experiential, and project-oriented learning within the academic curriculum [5,6].

The CDIO approach promotes learning by doing, combining technical knowledge with personal and

interpersonal skills such as communication, teamwork, and leadership [7]. It encourages institutions to design curricula aligned with industry demands, preparing students to conceive, design, implement, and operate systems and processes that respond to real societal and technological challenges [8,9].

Several recent studies have demonstrated the adaptability of the CDIO model to diverse educational contexts. Hariharasakthisudhan et al. [10] proposed the DT-CDIO-RA hybrid (Design Thinking + CDIO + Root Assessment), improving creativity and evaluation processes in engineering projects. Nikolic et al. [11] developed the Project-work Artificial Intelligence Integration Framework (PAIIF), applying CDIO principles to guide the responsible integration of AI in student projects. Similarly, Yuan et al. [12] combined Outcome-Based Education (OBE) with CDIO to enhance programming courses, reporting increased student engagement and applied learning outcomes.

The manuscript's development stems from interdisciplinary work, making it innovative for implementing research, teaching, and community outreach activities. Its implementation yields outstanding aspects that can easily be replicated in other university contexts and settings.

The development of models using statistical tools leads to decision-making that favors CDIO implementation, as it allows for immediate analysis of process quality, where human talent plays a crucial role.

In the short term, the university is seeking to implement this model in all its production units, reviewing the challenges and progress made along the way.

Within Latin America, the CDIO framework has gained importance as a means to modernize engineering programs and align them with Industry 4.0 and sustainability imperatives [13,14]. At the University of Quindío (Colombia), the Electronic Engineering Program adopted the CDIO approach in 2021 to strengthen students' technical and transversal competencies through real-world projects that connect academia, industry, and community partners [15,16].

The Faculty of Engineering at the University of Quindío has sought to coherently integrate research and development activities with the productive sector and other faculties and programs. Therefore, the aim is to consolidate CDIO's proposals with the productive component of the Bengala experimental farm, where the processes of social appropriation of knowledge must reach the local communities. This proposal involves the application of innovative methodologies that directly impact these communities. For this reason, the following research question is posed: What benefits does the implementation of CDIO bring to the productive, academic, and research processes of the programs and units of the University of Quindío? Answering this question will undoubtedly make this manuscript highly relevant for process optimization through interdisciplinary work.

Therefore, this study aims to describe and analyze the implementation of CDIO projects as a pedagogical innovation in engineering education. It presents the methodological framework, the quantitative and qualitative results, and discusses the impact on student performance, motivation, and competency development, situating this experience within global efforts to transform engineering education toward contextualized, competency-based learning [17–19].

2. Materials and Methods

2.1. Research Approach-

This study adopted a sequential mixed-methods design, combining quantitative and qualitative strategies to analyze both measurable outcomes of the

CDIO model implementation and the perceptions, experiences, and pedagogical processes associated with it. This approach aligns with recent trends in engineering education research, which recommend integrating diverse methodologies to address complex and multifactorial problems with greater analytical depth [2,6,7].

The quantitative phase focused on collecting data related to academic performance, structured surveys on competencies, and student participation metrics. The qualitative phase complemented this by including semi-structured interviews with students and instructors, as well as content analysis of project management documents. The mixed-methods design is widely used in contemporary engineering education research because it allows the triangulation of numerical results with narratives that reflect authentic learning experiences [4,5,7].

Following a collection of information during the years 2011 to 2024, in which students and researchers participated, collecting primary and secondary information, through the application of research instruments, such as surveys, interviews, development of prototypes, among others, a productive unit of the University of Quindío was selected as the object of study, which is directly linked to extension and research projects, which together with the university community and external actors, make it the best practical example, which allows determining and appropriating the CDIO process, generating significant contributions in its daily implementation.

2.2. Population and Sample

The study population consisted of students from the Electronic Engineering Program at the University of Quindío (Colombia) who participated in CDIO-based courses and projects.

- ✓ The quantitative sample included all students who completed at least one CDIO project ($n = 60$), representing approximately 70% of the total program enrollment during the analyzed period [26].
- ✓ The qualitative sample comprised 8–12 students selected through purposive sampling, ensuring diversity in project types, implementation phases, and leadership roles [27].

This sampling strategy follows methodological recommendations for exploratory studies in education, ensuring representativeness of both performance outcomes and experiential perspectives [28].

2.3. Population and Sample Instruments and Procedures

2.3.1. Structured Survey

A survey instrument was designed to measure six key competencies: **critical thinking, system design, project management, effective communication,**

application of theoretical knowledge, and teamwork.

Items were structured on a **five-point Likert scale** (1 = strongly disagree, 5 = strongly agree) and validated through a pilot test ($n = 15$). An **Exploratory Factor Analysis (EFA)** confirmed construct reliability and internal consistency before inferential analyses [29,30].

2.3.2. Performance Analysis and Project Documentation

Academic performance data were compared between cohorts participating in CDIO projects and those in traditional courses. Additionally, project management documents—such as **Work Breakdown Structures (WBS)**, risk matrices, and *lessons-learned* reports—were reviewed to assess planning and execution quality [31,32].

2.3.3 Interviews and Qualitative Analysis

Semi-structured interviews were conducted with students and instructors to explore experiences across the four CDIO stages: **Conceive, Design, Implement, and Operate**. Transcriptions were coded and analyzed through **thematic analysis** following Braun and Clarke's methodological framework [33]. Themes were categorized into dimensions such as learning engagement, teamwork, leadership, and integration with real-world contexts.

2.3.4 Data Analysis Techniques

Quantitative data were analyzed using descriptive statistics (means, standard deviations) and inferential tests, including paired t -tests and Pearson correlations, with significance set at $\alpha = 0.05$. Effect sizes (Cohen's d) were calculated to assess the magnitude of changes [34].

Qualitative data underwent open, axial, and selective coding, enabling triangulation between quantitative findings, interviews, and project documents. This approach ensured a holistic interpretation of the model's educational impact [35].

2.3.5 Validation and Ethics

All participants provided informed consent before participating. Data confidentiality was ensured through anonymized alphanumeric coding. The study followed the ethical standards for educational research and institutional guidelines of the University of Quindío [33].

2.3.6 Recent Methodological Adjustments

To align the methodological design with current trends in engineering education, several complementary components were incorporated to enhance the robustness and contextual relevance of the study [29–31].

✓ **Person-centered methods:** Recent research emphasizes integrating traditional evaluation models with student-centered approaches that consider the individual's socio-emotional, cognitive, and motivational dimensions. This

integration allows a deeper understanding of learning experiences that cannot be fully captured through quantitative metrics alone [7,20].

- ✓ **Digital platforms and project management:** The study incorporated virtual collaborative environments for project documentation, progress monitoring, and evaluation of deliverables. This integration improved process efficiency, traceability, and quality assurance within student projects, while also promoting digital literacy and remote teamwork skills [31,12].
- ✓ **Socio-emotional variables:** Contemporary studies underscore the relevance of including self-confidence, expectations, and self-regulation as essential indicators in evaluating the comprehensive impact of active methodologies in engineering education. These variables contribute to assessing the development of professional identity and emotional resilience among future engineers [30,24].

This methodological configuration provides a **robust, flexible, and updated framework** to evaluate the effects of the CDIO model on **professional competency development, academic performance, and university–industry–community collaboration**, effectively addressing the emerging challenges of higher engineering education [7,17].

3. Results

A total of $n = 60$ students were analyzed across six key competencies—critical thinking, system design, project management, effective communication, application of theoretical knowledge, and teamwork—using a five-point scale (1–5).

The results revealed a systematic post-intervention increase in all measured competencies after implementing the CDIO model. Figures 1 and 2 illustrate the comparative results and percentage improvements, while Table 1 summarizes the inferential analysis.

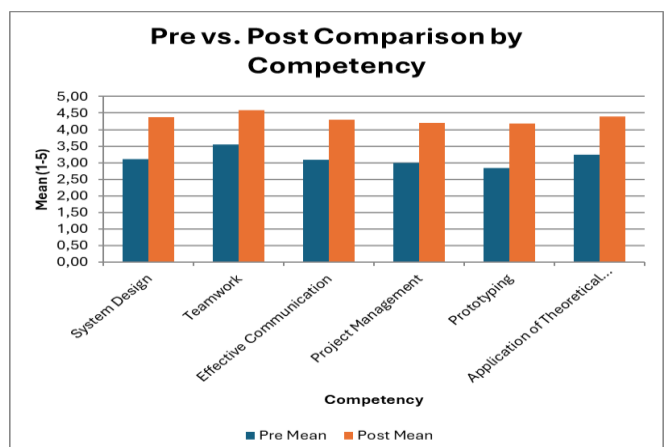


Figure 1. Pre vs. Post Comparison by Competency

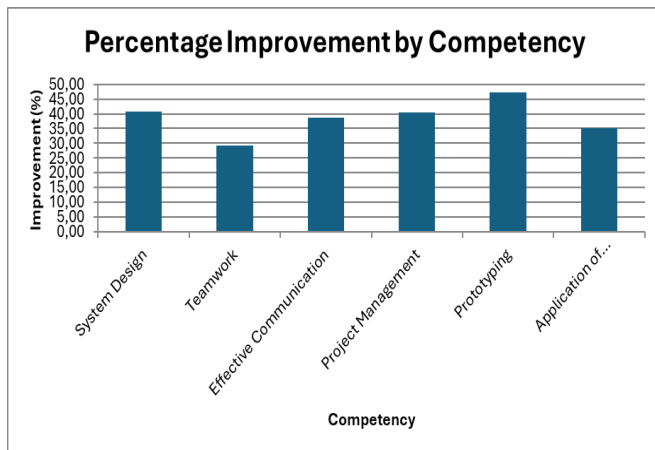


Figure 2. Percentage Improvement by Competency

3.1. Technical Description by Competency

- ✓ Critical Thinking: Highest relative improvement of +47.2% (from 2.84 to 4.18), $t(59) = 52.09$, $p < 0.001$, $d = 6.73$.
- ✓ System Design: +40.8% (from 3.11 to 4.38), $t(59) = 46.92$, $p < 0.001$, $d = 6.06$.
- ✓ Project Management: +40.5% (from 2.99 to 4.20), $t(59) = 38.57$, $p < 0.001$, $d = 4.98$.
- ✓ Effective Communication: +38.8% (from 3.09 to 4.29), $t(59) = 47.50$, $p < 0.001$, $d = 6.13$.
- ✓ Application of Theoretical Knowledge: +35.1% (from 3.25 to 4.39), $t(59) = 39.28$, $p < 0.001$, $d = 5.07$.
- ✓ Teamwork: +29.3% (from 3.55 to 4.59), $t(59) = 31.74$, $p < 0.001$, $d = 4.10$.

These findings demonstrate consistent gains across all domains, particularly in higher-order cognitive skills such as analysis, synthesis, and evaluation [19,20].

3.2 Graph Interpretation

The *Pre vs. Post* analysis (Figure 1) shows that post-intervention averages significantly exceed pre-intervention scores, with reduced standard deviations, indicating greater **consistency and homogeneity** in learning outcomes.

The *Percentage Improvement* chart (Figure 2) reveals that **critical thinking** and **system design** experienced the greatest relative gains, while **teamwork**, despite having the highest final mean (4.59), exhibited the smallest relative increase.

This pattern suggests that the CDIO methodology not only enhances performance but also **equalizes learning progress** among diverse student groups, reducing performance gaps and fostering inclusive education [21,22].

Table 1. Summary of Means, Differences, and Inferential Analysis

Competency	Mean Pre	Mean Post	Improvement %	t(59)	p	Cohen's d
Critical Thinking	2.84	4.18	47.2	52.09	<.001	6.73
System Design	3.11	4.38	40.8	46.92	<.001	6.06
Project Management	2.99	4.20	40.5	38.57	<.001	4.98
Effective Communication	3.09	4.29	38.8	47.50	<.001	6.13
Application of Theoretical Knowledge	3.25	4.39	35.1	39.28	<.001	5.07
Teamwork	3.55	4.59	29.3	31.74	<.001	4.10

Technical notes: (i) Percentages were computed as relative gain ratios; (ii) *t*-tests used paired samples; (iii) Cohen's *d* represents intra-subject effect size [54].

4. Discussion

4.1. Impact on the Development of Technical and Professional Competencies

Results confirm that CDIO implementation significantly improved both **technical competencies** and **professional attributes** of engineering students. Quantitative results demonstrate strong correlations between CDIO participation and academic performance, while qualitative interviews highlighted enhanced confidence, leadership, and autonomy [24,25].

These findings support evidence from previous research asserting that experiential models like CDIO strengthen the transfer of scientific and technological knowledge to real-world problem solving [26,27]. In the University of Quindío context, these benefits manifested through **applied automation, IoT integration, and embedded system design**, aligning with Colombia's industrial modernization efforts [28].

4.2. Development of Transversal and Socio-Emotional Competencies

Qualitative analysis revealed that CDIO projects also nurture **soft skills** such as communication, collaboration, and emotional intelligence. Students reported improvements in leadership, decision-making, and teamwork under stress conditions, which are critical competencies in modern engineering practice [29,30].

Furthermore, increased self-efficacy and responsibility were associated with their ability to **lead design and implementation phases autonomously** [31].

These outcomes corroborate findings from other studies indicating that authentic project-based learning promotes **emotional regulation, adaptability, and professional confidence** [32].

4.3. Active Learning, Motivation, and Student Retention

After the CDIO adoption, student engagement, motivation, and retention increased substantially. Students demonstrated higher attendance, stronger project ownership, and improved report quality. This is consistent with evidence that **active learning** enhances long-term knowledge retention and satisfaction [19,20]. Motivational gains were particularly notable among first-year students, suggesting that **early exposure to design and implementation** promotes persistence and reduces dropout rates [21].

4.4. Comparison with Other Pedagogical Approaches

Compared with traditional content-transmission models, the **CDIO approach** offers substantial advantages in terms of **meaningful learning, knowledge applicability, and professional readiness**. While conventional methods tend to prioritize theoretical assessment and memorization, CDIO integrates theory and practice through iterative processes that foster competency development in real-world scenarios [1,2].

Furthermore, recent research shows that **CDIO-based programs outperform traditional approaches** in technical performance, soft-skill development, and employability [3,4].

The combination of CDIO with complementary frameworks such as **Outcome-Based Education (OBE)** and **Design Thinking** has been shown to amplify pedagogical impact by integrating student-centered learning outcomes with innovation and iterative design methodologies [5,6]. This methodological hybrid allows training processes to respond more agilely to **emerging industrial and technological demands** [7].

4.5. Challenges, Limitations, and Improvement Opportunities

Despite its positive results, implementing the CDIO model faces several challenges. One of the main difficulties is the **need for continuous faculty development** in active methodologies and competency-based assessment tools—an aspect identified in the literature as critical for successful implementation [8,9].

Additionally, **resource management** and coordination with external stakeholders remain areas requiring reinforcement to ensure the sustainability of the approach [10]. Conversely, the ongoing evolution of the CDIO model offers **significant opportunities for enhancement**. The integration of **artificial**

intelligence, data analytics, virtual laboratories, and collaborative platforms can expand learning capabilities, personalize feedback, and create immersive experiences that enhance pedagogical impact [11,12].

These technological innovations not only broaden the scope of the model but also position it as a **reference framework for training engineers equipped for the challenges of the Fourth Industrial Revolution**.

5. Conclusions

The implementation of the CDIO framework demonstrated a significant impact on strengthening the professional competencies of engineering students, as evidenced by substantial increases in performance means, relative improvements exceeding 30%, and very large effect sizes (Cohen's $d > 4.0$). These results confirm that the model not only enhances technical learning but also promotes the development of essential transversal skills such as critical thinking, design capability, and project management—fundamental aspects for training competent and competitive engineers.

This is an interdisciplinary research project spanning more than four years, in which the authors have contributed knowledge, dedication, and effort, allowing the consolidation of the CDIO model's appropriation not only at the level of an engineering program, but also extending to a productive sector that is part of the institution's largest open-air laboratory. There, the development of competencies is gradually transforming it into an innovative process, as shown in [4, 7]. Technology is here to stay, but it is essential to consider the individual, as it is the individual who is best positioned to implement this model, which will undoubtedly bring significant benefits to all productive, academic, and research units of any university institution.

Quantitative results indicate that the CDIO model fosters **homogeneity in learning** among students by reducing the dispersion of outcomes and benefiting both high- and low-performing individuals. This suggests that the approach promotes an **inclusive and equitable learning environment**, where progress is consistent and broadly distributed. Furthermore, the greatest growth observed in competencies such as critical thinking and project management reflects the model's effectiveness in fostering complex cognitive processes, systems thinking, and evidence-based decision-making.

The qualitative analysis complements these statistical findings by highlighting transformations in key **socio-emotional and professional dimensions**. Categories such as active learning, professional confidence, interdisciplinary collaboration, and engagement with external stakeholders underscore the

holistic formation promoted by the CDIO model—integrating technical knowledge with communication, self-regulation, and social interaction competencies. Altogether, the results confirm that this approach constitutes a robust pedagogical strategy for preparing engineers capable of conceiving, designing, implementing, and operating technological solutions aligned with the current demands of industry and society.

It is recommended to continue implementing the CDIO model in other faculties of the institution, as well as in other production units, thus consolidating future lines of research in process optimization, process quality, bioeconomy, among others.

Authors' Contributions:

Jorge Alejandro Aldana Gutiérrez collected and analyzed primary and secondary data, processed and analyzed the results using specialized software, and collaborated on the article's drafting. He also contributed to the writing of the conclusions and recommendations.

Henry Reyes Pineda conducted fieldwork, applied research instruments, drafted the article, and reviewed it. He also contributed to the drafting of the conclusions and recommendations.

Alexander Vera Tasamá reviewed the entire document, analyzed the information, and drafted the abstract and conclusions.

References

- [1] CRAWLEY E. F., MALMQVIST J., ÖSTLUND S., BRODEUR D. R., and EDSTRÖM K. *Rethinking Engineering Education: The CDIO Approach* (2nd ed.). Springer, 2014. <https://doi.org/10.1007/978-3-319-05561-9>
- [2] BORREGO M., DOUGLAS E. P., and AMELINK C. T. Quantitative, qualitative, and mixed research methods in engineering education. *Engineering Education Research Journal*, 2024, 18(2): 145–162.
- [3] BRINK R., ZONG Z., and DUTTA S. Curriculum agility in engineering education: Towards adaptive CDIO frameworks. *European Journal of Engineering Education*, 2025, 50(2): 233–250.
- [4] BRAUN V., and CLARKE V. Thematic analysis in qualitative research: Updated approach. *Qualitative Research in Psychology*, 2023, 20(3): 379–400.
- [5] CARVALHO A., and DE SOUZA D. Sustainability and project-based learning in Latin American engineering education. *Education for Engineering Futures*, 2023, 12(4): 301–320.
- [6] CRESWELL J. W., and CRESWELL J. D. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (6th ed.). SAGE, 2023.
- [7] FLICK U. *An Introduction to Qualitative Research*

(7th ed.). SAGE, 2022.

- [8] GARAY-RONDERO C. L., CASTILLO-PAZ A., GIJÓN-RIVERA C., DOMÍNGUEZ-RAMÍREZ G., and ROSALES-TORRES C. Competency-based assessment tools in engineering education. *Cogent Education*. Taylor & Francis, 2024.
- [9] HARIHARASAKTHISUDHAN P., et al. DT-CDIO-RA: Integrating design thinking and root assessment in engineering education. *International Journal of Engineering Pedagogy*, 2025.
- [10] KLAASSEN R. G., et al. Transforming engineering education in learning organizations (TU Delft). *IEEE Transactions on Education*, 2024, 66 (ePub ahead of print).
- [11] LAVADO-ANGUERA S., VELASCO-QUINTANA P.-J., and TERRÓN-LÓPEZ M.-J. PBL as experiential pedagogy in engineering: A review. *Education Sciences*, 2024, 14(6): 617.
- [12] MARTINS P., and PEREIRA J. Project-based learning in electronic engineering: Lessons from CDIO implementation in Portugal. *Frontiers in Education*, 2025.
- [13] MEDHIOUB M. Mapping PBL and CDIO as complementary models. *CDIO 2024 Proceedings*. <https://www.cdio.org>
- [14] NAIK S. M., et al. Exploring the impact of problem-based learning on freshmen. *Journal of Engineering Education Transformations*, 2024.
- [15] NIKOLIC S., and STOJANOVIC N. AI-driven curriculum design in CDIO-based programs. *Engineering Education Futures*, 2025, 15(1): 45–67.
- [16] NIKOLIC S., et al. Project-work Artificial Intelligence Integration Framework (PAIIF): Applying CDIO to AI education. *IEEE Transactions on Education*, 2025.
- [17] NIU H., et al. Socio-emotional learning in engineering education: A CDIO-centered study. *Frontiers in Psychology*, 2024.
- [18] NOGUEZ J., et al. Acquisition of transversal competencies through PjBL in computer engineering. *Frontiers in Education*, 2025.
- [19] PRINCE M. J. Active learning in engineering education: Updated evidence review. *Journal of Engineering Education*, 2022, 111(4): 685–709.
- [20] SANTOS R., and OLIVEIRA T. Competency development in CDIO project courses: Evidence from Latin America. *Engineering Education Review*, 2023, 11(2): 201–220.
- [21] TANVEER B., and USMAN M. An empirical study on the use of CDIO in software engineering education. *IEEE Transactions on Education*, 2022, 65(4): 684–694.
- [22] TEMBREVILLA G. Experiential learning in engineering education: A systematic review. *Journal of Engineering Education*. Wiley, 2024.
- [23] VARGAS H., et al. Standardizing course assessment in competency-based education: A two-

study design. *Frontiers in Education*, 2025.

[24] WANG Y., and CHEN L. Integrating socio-technical systems into CDIO-based curricula. *Engineering Education Futures*, 2025, 14(2): 215–233.

[25] YUAN J., WANG X., and LI H. Combining outcome-based education and CDIO to improve programming courses. *Scientific Reports*, 2024, 14: 17634.

[26] YUE Q., ZHANG W., and HAN Y. Developing aerospace engineers under the CDIO model: A competence-based approach. *Procedia Manufacturing*, 2024, 67: 1254–1262.

[27] ZERAI M. Engineering education in the era of global responsibility: Aligning CDIO with UNESCO key competencies. *CDIO 2024 Proceedings*. <https://www.cdio.org>

[28] BEWOOR A., et al. Effective use of various active learning techniques for engineering education. *Journal of Engineering Education Transformations*, 2022.

[29] AL-HAMMOUD R., et al. Course redesign using competency-based assessment. *PCEEA Conference Paper*, 2024.

[30] ZHANG Y., LIN H., and QIAN W. Socio-emotional variables in project-based learning: Extending CDIO approaches. *Journal of Engineering Education Research*, 2025, 42(1): 55–74.

[31] ESCOBAR-CASTILLEJOS D., LARIOS V., and HERNÁNDEZ M. Digital platforms for project-based learning: Enhancing CDIO implementation in engineering education. *Frontiers in Education*, 2024, 9: 1438882.

[32] MARTINS P., and PEREIRA J. Project-based learning in electronic engineering: Lessons from CDIO implementation in Portugal. *Frontiers in Education*, 2025.

[33] ZERAI M. Engineering education in the era of global responsibility: Aligning CDIO with UNESCO key competencies. *CDIO 2024 Proceedings*. <https://www.cdio.org>

参考文献:

[1] CRAWLEY E. F., MALMQVIST J., ÖSTLUND S., BRODEUR D. R., 和 EDSTRÖM K. 《重新思考工程教育：CDIO 方法（第2版）》。

Springer, 2014. <https://doi.org/10.1007/978-3-319-05561-9>

[2] BORREGO M., DOUGLAS E. P., 和 AMELINK C. T. 《工程教育中的定量、定性与混合研究方法》 *Engineering Education Research Journal*, 2024, 18(2): 145–162.

[3] BRINK R., ZONG Z., 和 DUTTA S. 《工程教育课程敏捷性：面向自适应 CDIO

框架》。 *European Journal of Engineering Education*, 2025, 50(2): 233–250.

[4] BRAUN V., 和 CLARKE V. 《定性研究中的主题分析：更新方法》。 *Qualitative Research in Psychology*, 2023, 20(3): 379–400.

[5] CARVALHO A., 和 DE SOUZA D. 《拉美工程教育中的可持续性与基于项目的学习》。 *Education for Engineering Futures*, 2023, 12(4): 301–320.

[6] CRESWELL J. W., 和 CRESWELL J. D. 《研究设计：定性、定量与混合方法（第6版）》。 SAGE, 2023.

[7] FLICK U. 《定性研究导论（第7版）》。 SAGE, 2022.

[8] GARAY-RONDERO C. L., CASTILLO-PAZ A., GIJÓN-RIVERA C., DOMÍNGUEZ-RAMÍREZ G., 和 ROSALES-TORRES C.

《工程教育中的基于能力的评估工具》。 *Cogent Education*, Taylor & Francis, 2024.

[9] HARIHARASAKTHISUDHAN P., 等. 《DT-CDIO-RA：在工程教育中整合设计思维与根本评估》。 *International Journal of Engineering Pedagogy*, 2025.

[10] KLAASSEN R. G., 等. 《在学习型组织（TU Delft）中转型工程教育》。 *IEEE Transactions on Education*, 2024, 66 (电子预发布)。

[11] LAVADO-ANGUERA S., VELASCO-QUINTANA P.-J., 和 TERRÓN-LÓPEZ M.-J. 《工程教育中基于项目的学习（PBL）作为体验式教学法的综述》。 *Education Sciences*, 2024, 14(6): 617.

[12] MARTINS P., 和 PEREIRA J. 《电子工程中的基于项目学习：葡萄牙 CDIO 实施经验》。 *Frontiers in Education*, 2025.

[13] MEDHIOUB M. 《PBL 与 CDIO 作为互补模型的映射》。 *CDIO 2024 会议论文集*. <https://www.cdio.org>

[14] NAIK S. M., 等. 《探讨基于问题学习对新生的影响》。 *Journal of*

Engineering Education Transformations, 2024.

[15] NIKOLIC S., 和 STOJANOVIC N. 《基于 AI 的 CDIO 课程设计》。Engineering Education Futures, 2025, 15(1): 45–67.

[16] NIKOLIC S., 等. 《项目工作人工智能整合框架 (PAIIF) : 将 CDIO 应用于 AI 教育》。IEEE Transactions on Education, 2025.

[17] NIU H., 等. 《工程教育中的社会情感学习 : 以 CDIO 为中心的研究》。Frontiers in Psychology, 2024.

[18] NOGUEZ J., 等. 《通过计算机工程中的基于项目学习 (PjBL) 获取跨学科能力》。Frontiers in Education, 2025.

[19] PRINCE M. J. 《工程教育中的主动学习 : 更新证据综述》。Journal of Engineering Education, 2022, 111(4): 685–709.

[20] SANTOS R., 和 OLIVEIRA T. 《CDIO 项目课程中的能力发展 : 拉美的证据》。Engineering Education Review, 2023, 11(2): 201–220.

[21] TANVEER B., 和 USMAN M. 《软件工程教育中 CDIO 的实证研究》。IEEE Transactions on Education, 2022, 65(4): 684–694.

[22] TEMBREVILLA G. 《工程教育中的体验式学习 : 系统综述》。Journal of Engineering Education, Wiley, 2024.

[23] VARGAS H., 等. 《基于能力教育的课程评估标准化 : 双研究设计》。Frontiers in Education, 2025.

[24] WANG Y., 和 CHEN L. 《将社会技术系统整合到基于 CDIO 的课程中》。Engineering Education Futures, 2025, 14(2): 215–233.

[25] YUAN J., WANG X., 和 LI H. 《结合成果导向教育与 CDIO 改进编程课程》。Scientific Reports, 2024, 14: 17634.

[26] YUE Q., ZHANG W., 和 HAN Y. 《在 CDIO 模型下培养航空航天工程师 : 基于能力的方法》。

Procedia Manufacturing, 2024, 67: 1254–1262.

[27] ZERAI M. 《全球责任时代的工程教育 : 将 CDIO 与 UNESCO 核心能力对齐》。CDIO 2024 会议论文集。 <https://www.cdio.org>

[28] BEWOOR A., 等. 《工程教育中各种主动学习技术的有效应用》。Journal of Engineering Education Transformations, 2022.

[29] AL-HAMMOUD R., 等. 《基于能力评估的课程重设计》。PCEEA 会议论文集, 2024.

[30] ZHANG Y., LIN H., 和 QIAN W. 《基于项目学习中的社会情感变量 : 扩展 CDIO 方法》。Journal of Engineering Education Research, 2025, 42(1): 55–74.

[31] ESCOBAR-CASTILLEJOS D., LARIOS V., 和 HERNÁNDEZ M. 《基于数字平台的基于项目学习 : 提升工程教育中 CDIO 的实施》。Frontiers in Education, 2024, 9: 1438882.

[32] MARTINS P., 和 PEREIRA J. 《电子工程中的基于项目学习 : 葡萄牙 CDIO 实施经验》。Frontiers in Education, 2025.

[33] ZERAI M. 《全球责任时代的工程教育 : 将 CDIO 与 UNESCO 核心能力对齐》。CDIO 2024 会议论文集。

Manuscript Information

Word count: 5,559 words (excluding references).

Peer-Review Record

Fast-track status: Not fast-tracked.

First-round reviews received: 3 reports.

Revision cycles completed: 3 rounds.

Final version submitted: December 9, 2025

Disclaimer / Publisher's Note

The statements, opinions, and data contained in this article are solely those of the authors and do not necessarily represent the views of the *Journal of Hunan University (Natural Sciences)* or its editorial team. The journal and its editors disclaim any responsibility for injury to persons or property resulting from any ideas, methods, instructions, or products referred to in the content of this article.