World Journal of Educational Studies
Print ISSN: 2959-9989
Online ISSN: 2959-9997
DOI: https://doi.org/10.61784/wjes3176

AI-EMPOWERED INDUSTRY-EDUCATION INTEGRATION: TEACHING REFORM EXPLORATION IN LITHIUM-ION BATTERY MANUFACTURING TECHNOLOGY

Lei Wang[1], BinBin Xin[1*], Chen Pan[2], Jun Yang[1*]
[1]School of Chemical Engineering, Guangdong University of Petrochemical Technology, Maoming 525000, Guangdong, China.
[2]Architecture and Civil Engineering Institute, Guangdong University of Petrochemical Technology, Maoming 525011, Guangdong, China.
[*]BinBin Xin and Jun Yang are both the corresponding authors.
Corresponding Authors: BinBin Xin, Jun Yang

Abstract: The intelligent transformation of the new energy lithium-ion battery manufacturing industry has created an urgent demand for the cultivation of emerging engineering talents. In response to prominent issues in traditional curricula—such as the disconnect between course content and industrial technology, the fragmentation of practical teaching from engineering scenarios, insufficient depth in industry-education integration, and the misalignment of teaching evaluation with competency-based outcomes—this paper proposes a trinity curriculum reform model centered on “AI empowerment, industry-education integration, and interdisciplinary cross-pollination.” By reconstructing an integrated “AI + battery manufacturing” technology curriculum module, designing a “four-in-one” collaborative education mechanism, establishing a five-dimensional digital support system for educational mapping, and forming a trinity teaching model of “AI + micro-projects + engineering case studies,” this reform systematically addresses the structural challenges of traditional curricula. Practical results show that this approach significantly enhances students’ job competency and industrial adaptability, providing a replicable paradigm for the development of emerging engineering programs in new energy-related fields.

Keywords: Artificial intelligence; Industry-education integration; Lithium-ion battery manufacturing; Curriculum reform; New quality productivity

1 INTRODUCTION

Currently, as the global energy structure accelerates its transition toward clean and low-carbon sources, lithium-ion batteries—core components of new energy vehicles and energy storage systems—have emerged as a strategic focal point in technological competition among major powers. According to the International Energy Agency, global demand for power batteries will exceed 3 TWh by 2030, with the industry experiencing exponential growth [1]. In parallel, battery manufacturing technologies are undergoing a profound transformation from "experience-driven" to "data-driven" approaches. Next-generation information technologies such as artificial intelligence (AI) [2], digital twins [3], and the Industrial Internet are reshaping the entire industrial chain—including material screening, cell manufacturing, intelligent inspection, and process optimization. As a result, there is an explosive demand for interdisciplinary talents who understand batteries, master AI, and can work across domains.

In China, accelerating the development of new quality productive forces, particularly in new energy, has been established as a core strategy. The government has successively issued policy documents such as the New Energy Vehicle Industry Development Plan (2021–2035) and the Guidelines on Accelerating Scenario Innovation to Promote High-Quality Economic Development through High-Level AI Applications, which explicitly call for deep integration of AI with new energy battery manufacturing technologies and the cultivation of high-caliber technical talent suited for the era of intelligent manufacturing.Beyond China's domestic policies, a global wave of AI regulation is taking shape. As Tóth comprehensively reviews, jurisdictions including the European Union (EU AI Act), the United States (Executive Order on Safe, Secure, and Trustworthy AI), and China (Interim Measures for Generative AI) have established regulatory frameworks that impose specific compliance requirements for high-risk applications, including those in critical infrastructure and energy sectors [4]. These regulatory developments necessitate that engineering education not only teach AI application skills but also cultivate awareness of responsible AI governance [5]. However, traditional talent cultivation models struggle to meet the urgent demands of industrial intelligent transformation, making curriculum reform imperative [6]. As a core course in disciplines such as new energy, materials science, and intelligent manufacturing, "New Energy Lithium-Ion Battery Manufacturing Technology" faces several prominent challenges in teaching: First, there is a serious disconnect between course content and industrial technological advancements [7]. Instruction remains largely focused on explaining conventional processes, with limited systematic introduction of cutting-edge technologies such as AI-assisted process design and machine vision inspection. Textbook updates lag significantly behind the pace of enterprise technology iteration, resulting in a clear "technological gap." Second, practical teaching is detached from real-world engineering scenarios, relying mainly on confirmatory experiments, leaving students insufficiently trained to handle complex, ill-defined problems. Third, industry-education integration remains shallow, with university-industry collaboration often limited to superficial forms such as co-building internship bases. Empirical studies confirm that shallow university-industry collaboration remains a critical issue in engineering education [8]. Fourth, teaching evaluation is misaligned with competency-based learning outcomes, still emphasizing final theoretical examinations while neglecting assessment of core competencies such as AI tool application and engineering problem-solving.

In response to these challenges, this paper systematically investigates curriculum reform based on the fundamental approach of deep industry-education integration, with AI empowerment as the core strategy. The reform encompasses four dimensions: curriculum system restructuring, design of industry-education integration mechanisms, development of a digital and intelligent support system, and innovation in teaching models.

2 Curriculum System Restructuring: A Four-Dimensional Collaborative Top-Level Design

The curriculum restructuring is guided by the overarching framework of "AI empowerment as the central theme, OBE as the driving force, industry-education integration as the pathway, and interdisciplinary support as the foundation." Through a four-dimensional collaborative approach, a curriculum system tailored to the demands of intelligent manufacturing is established, as illustrated in Figure 1.

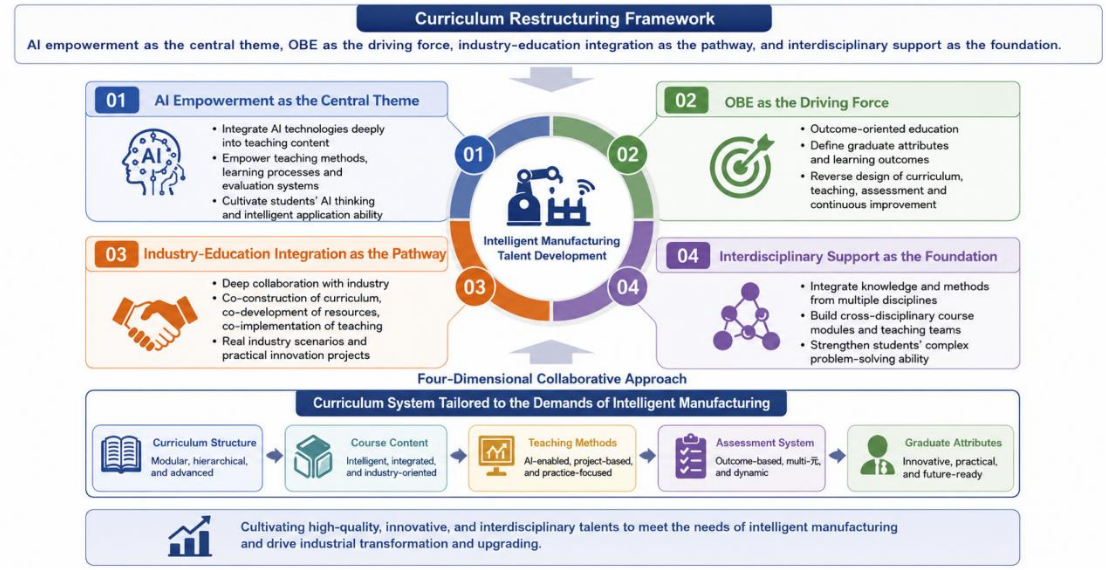

Figure 1 Framework of Curriculum Restructuring for Intelligent Manufacturing

2.1 AI Empowerment: Building "AI + Battery Manufacturing" Technology Integration Modules

Focusing on the entire lithium-ion battery manufacturing process (electrode preparation, cell assembly, formation and aging, and module integration), three technology integration modules are developed. The first is the AI-assisted process design module, which employs machine learning to optimize coating process parameters and predict roll pressure and uses genetic algorithms to solve cutting and nesting problems. The second is the intelligent inspection and fault diagnosis module [9]. This module integrates computer vision for electrode surface defect detection and cell alignment inspection and utilizes time-series anomaly detection algorithms for predictive maintenance of equipment. The third is the digital twin and intelligent control module, which builds a virtual simulation production line on a digital twin platform [10]. This platform supports virtual trials of complex tasks, including process debugging, capacity simulation, and energy efficiency optimization [11].

2.2 OBE as the Driving Force: Reverse Design of Course Objectives and Assessment System

Guided by the outcome-based education (OBE) concept and adhering to the principle of "reverse design [12], forward implementation," the reform first defines core learning outcomes, including four types of competencies: technical application ability, engineering practice ability, problem-solving ability, and collaborative innovation ability [13]. Course content and teaching activities are then designed backward from these outcomes, with competency goals broken down into knowledge units, hands-on projects, and assessment checkpoints.

Finally, a diversified assessment system is established, adopting a weighted formula of 30% project presentations, 20% corporate evaluations, 20% skills certification, and 30% theoretical examinations, with a focus on evaluating students' actual performance in completing representative engineering tasks.

2.3 Industry-Education Integration Pathway: Building a Collaborative University-Industry Education Community

Based on a framework featuring dual stakeholders (university and enterprise) and full-chain collaboration, four mechanisms are established. The course co-development mechanism involves forming a joint curriculum committee with leading enterprises to co-establish curriculum standards. The co-teaching mechanism implements a “one course, two instructors” system, where corporate engineers deliver over 30% of case-based teaching and project guidance. The platform sharing mechanism promotes the co-construction of modern industrial colleges and intelligent manufacturing training bases, integrating enterprise-level Manufacturing Execution System (MES) systems and digital twin platforms. The outcome recognition mechanism facilitates the exchange of credits and the integration of vocational skill certificates.

2.4 Interdisciplinary Support: Design of Multidisciplinary Integrated Course Clusters

Lithium-ion battery manufacturing draws on multidisciplinary knowledge, including materials, mechanics, electrical engineering, control systems, computer science, and management. Three types of interdisciplinary modules are constructed. The foundational interdisciplinary module offers prerequisite courses such as Fundamentals of Electrochemistry and Fundamentals of Mechanical Design. The core interdisciplinary module features integrated courses such as Intelligent Manufacturing System Integration for Batteries and Machine Vision and Its Applications. The cutting-edge interdisciplinary module offers seminar-style electives on topics such as solid-state battery manufacturing and AI-driven process innovation.

3 DESIGN OF THE INDUSTRY-EDUCATION INTEGRATION MECHANISM: “FOUR SYNERGIES” FOR COLLABORATIVE EDUCATION

As shown in Figure 2, this paper constructs a collaborative education mechanism based on “Four Synergies”—jointly developing courses [14], co-cultivating talent, sharing resources, and co-developing projects—to facilitate the evolution of industry-education integration from shallow cooperation to deep synergy through a closed loop of dynamic iteration.

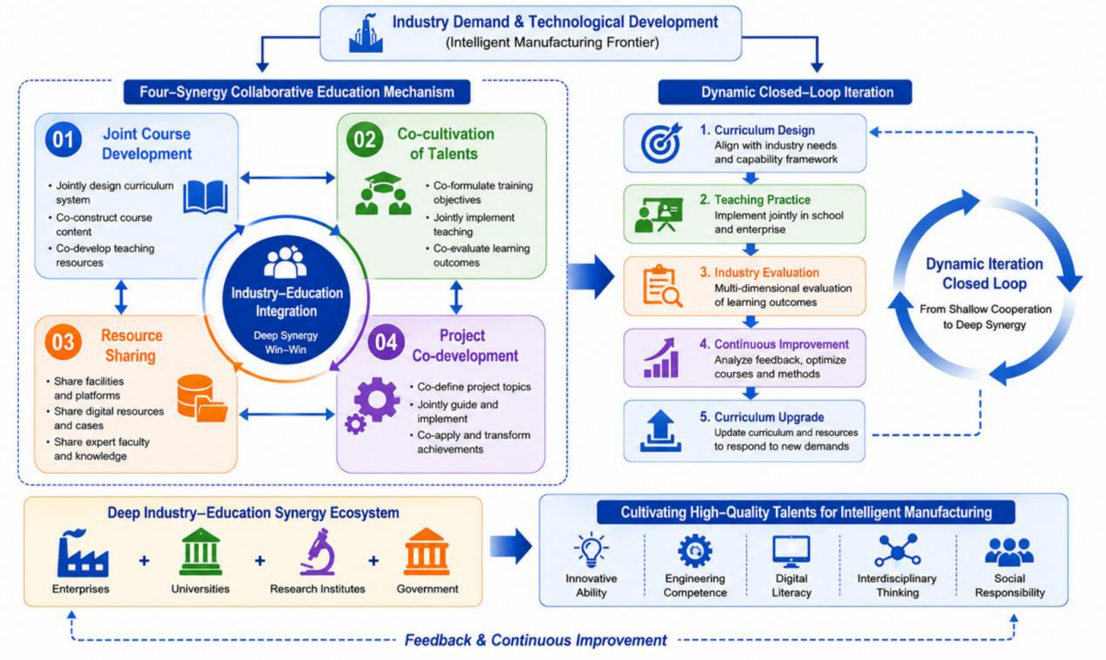

Figure 2 Schematic Illustration of Design of the Industry-Education Integration Mechanism

Joint Curriculum Development: Enterprise Engagement Throughout Curriculum Design

A joint curriculum development committee, co-chaired by the university’s program lead and the enterprise’s technical director, is established. The enterprise contributes raw materials such as typical task analysis forms, process specification documents, quality anomaly case libraries, and equipment alarm logs, which are then transformed by university instructors into teaching projects, case libraries, and hands-on training task sheets. The university and enterprise jointly develop loose-leaf and workbook-style teaching materials, which are revised every 18 months to ensure timely integration of cutting-edge technologies.

3.1 Collaborative Talent Development: University-Enterprise Dual-Path Education Model

A segmented training model is implemented [15], in which students sequentially complete general education and discipline-specific foundational courses, enterprise cognitive internships, and rotational hands-on training, core specialized courses, and finally on-the-job internships alongside their graduation projects. This ensures students engage with authentic tasks in real work settings. A dual-mentor system is adopted, with joint guidance meetings held every two weeks, and student growth portfolios are established. Upon completing required courses, students may apply for vocational competency certificates.

3.2 Shared Resources: Data and Platform Interoperability Between University and Enterprise

Under a confidentiality agreement and data desensitization framework, the enterprise provides production line operation data, quality inspection data, and equipment alarm data, which the university uses to develop teaching cases and training tasks. Enterprise-level platforms, including MES, QMS, and digital twins, are adopted as instructional tools within the university. Each year, full-time faculty are selected to undertake rotational assignments at the enterprise, while technical experts from the enterprise are appointed as adjunct professors on campus, creating a virtuous cycle of “engineers in the classroom and faculty in the workshop.”

3.3 Collaborative Research Projects: Bringing Enterprise Projects into the Classroom

Each semester, the enterprise releases a “project pool” covering areas such as process optimization, equipment improvement, and quality enhancement, with difficulty levels categorized as basic, advanced, and challenging. Students form interdisciplinary teams and conduct project-based research under the joint guidance of university and enterprise mentors. Outstanding outcomes may be recommended for innovation and entrepreneurship competitions, patent applications, or further development through the enterprise’s technology incubation channel.

3.4 Dynamic Iteration Mechanism

A dynamic iteration mechanism is established, centered on “demand identification — content updating — feedback evaluation,” forming a six-step closed-loop process of “demand investigation → problem diagnosis → solution design → curriculum implementation → effectiveness evaluation → continuous improvement.” This ensures alignment between curriculum content and the evolution of industrial technology [15].

4 DIGITAL SUPPORT SYSTEM: FIVE-DIMENSIONAL EDUCATION MAPPING

Against the backdrop of AI and big data technologies deeply empowering education, a five-dimensional education map encompassing “Knowledge — Competence — Problem — Resource — Evaluation” has been constructed to enable visualized, quantifiable, and optimization curriculum instruction.

4.1 Architecture of the Five-Dimensional Education Map

Centered on student development, the five-dimensional education map establishes a new educational paradigm featuring “five-dimensional integration and closed-loop feedback” [10]. The knowledge map systematically presents the systemic interconnections and cognitive hierarchies of 186 knowledge points. The competence map comprises six dimensions (basic operations, process design, equipment debugging, quality control, intelligent applications, and system integration) with 18 competency indicators. The problem map constructs a problem tree derived from 120 typical engineering problems collected from partner enterprises. The resource map integrates over 500 teaching resources to enable personalized recommendations. The evaluation map establishes a four-dimensional indicator system encompassing “knowledge mastery, competency attainment, project practice, and innovative performance.”

4.2 Learning Profile Modeling and Application

By integrating multi-source data from online learning platforms, virtual simulation systems, training equipment sensors, and project review systems, comprehensive tracking of learning behaviors is achieved. Using learning analytic techniques, a “five-dimensional radar chart” is generated for each student, dynamically identifying their knowledge mastery status, competency attainment levels, and typical weaknesses. Personalized learning pathway recommendations are provided to students, while instructors receive class-wide learning overviews and precise teaching intervention suggestions, shifting the instructional process from “experience-driven” to “data-driven.”

5 TEACHING MODEL INNOVATION: THE “AI + MICRO-PROJECT + ENGINEERING CASE” TRINITY

This chapter constructs a trinity teaching model of “AI empowerment — micro-project driving — engineering case threading” to form a human-AI collaborative intelligent teaching ecosystem.

5.1 Blended Teaching Model

A teaching process of “five-stage progression, three-party interaction, and three-scene integration” is implemented. The five-stage progression consists of: case introduction → knowledge construction → simulation validation → micro-project execution → outcome presentation and iteration. Three-party interaction enables collaboration among instructors, students, and AI. Three-scene integration connects online, offline, and enterprise-based learning environments.

5.2 Three-Tier Micro-Project System

A three-tier micro-project system comprising “basic—advanced—challenge” levels has been developed. Basic-level projects are skill-verification oriented, completed within 1–2 weeks; advanced-level projects are comprehensive application oriented, completed within 3–4 weeks; challenge-level projects are innovation and inquiry oriented, completed within 6–8 weeks, requiring outcome defense and review by enterprise experts. A combination of “required + elective” approaches supports differentiated training and the identification of top-tier talent.

5.3 Engineering Case Library and Intelligent Toolchain

Eighty real-world cases have been collected from partner enterprises, covering five categories, including process optimization, quality improvement, and equipment troubleshooting, with 5–10 new cases added each semester. An intelligent toolchain covering the entire workflow of “design — simulation — inspection — optimization” has been integrated. All tools are deployed on a cloud-based laboratory platform, accessible to students at any time via a web browser.

5.4 Practical Outcomes

In a pilot reform conducted with the 2023 cohort of the New Energy Science and Engineering program, the experimental group demonstrated marked improvement in core competencies such as intelligent process design and data-driven decision-making compared to the control group. AI tool adoption surged, and the first pilot batch achieved high initial employment rate, major-related employment rate, and employer satisfaction. Students completed numerous micro-projects, with several outcomes adopted by enterprises, and also earned multiple provincial-level competition awards and patent filings.

6 CONCLUSION AND OUTLOOK

Targeting the dual demands of cultivating emerging engineering talents and facilitating the intelligent transformation of the new energy industry, this paper systematically conducts curriculum reform exploration and practice centered on the three core concepts of “AI empowerment, industry-education integration, and interdisciplinary convergence.” The study has established a top-level curriculum system design featuring “four-dimensional synergy,” designed a “four-common” collaborative education mechanism with dynamic iterative closed loops, developed a “five-dimensional education map” digital support system, and innovated the “AI + micro-project + engineering case” trinity teaching model. Empirical data demonstrate that this reform has achieved significant outcomes in enhancing students’ job competency, employment quality, and enterprise satisfaction.

Future curriculum reform will continue to deepen in the following directions: first, the deep application of generative AI, exploring personalized lesson plan generation and intelligent assessment based on large language models [2]; second, the upgrading of industry-education integration models, moving from “enterprise participation” to “university-enterprise symbiosis”; third, the intelligent evolution of the education map, introducing graph neural networks and other techniques to achieve more precise learning pathway planning, with further validation and dissemination across more institutions.

In this course, by integrating the ideological and civic education system into professional teaching, the teaching effectiveness has been significantly reflected in three aspects: knowledge acquisition, ability improvement and value shaping. The introduction of value guidance not only fails to diminish the depth of professional teaching, but also effectively enhances the ideological connotation, innovation level and practical value of design works by guiding students to form a clear cultural stance, social responsibility and ethical awareness, achieving an organic unity of professional education and value guidance.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] IEA. Global EV outlook 2023 catching up with climate ambitions. 2023.

[2] Johri A, Katz A S, Qadir J, et al. Generative artificial intelligence and engineering education. Journal of Engineering Education, 2023, 112(3): 572-577.

[3] Pajpach M, Pribiš R, Drahoš P, et al. Methodology and pilot implementation of modular educational-development platform for interoperable digital twin. Scientific Reports, 2025, 15(1): 28020.

[4] Cajueiro D O, Celestino V R R. A comprehensive review of artificial intelligence regulation: weighing ethical principles and innovation. Journal of Economy and Technology, 2026, 4: 77-91.

[5] Yan Yuyang, Liu Hui, Chau T. A systematic review of AI ethics in education. Journal of Global Information Management, 2025, 33(1).

[6] Hao Yijia, Liu Yushi, Liu Bo, et al. Integrating AI in engineering education: a comprehensive review and student-informed module design for U.K. students. IEEE Transactions on Education, 2025, 68(2): 173-185.

[7] Ayerbe Elixabete, Berecibar Maitane, Clark Simon, et al. Digitalization of battery manufacturing: current status, challenges, and opportunities. Advanced Energy Materials, 2021, 12(17): 2102696.

[8] Zhang Hua, Wu Libao, Wang Ji. Research on innovative models of industry-education integration to promote sustainable education in agricultural machinery majors. Sustainable Futures, 2025, 10: 101072.

[9] Kumar R S, Singh A R, Narayana P L, et al. Hybrid machine learning framework for predictive maintenance and anomaly detection in lithium-ion batteries using enhanced random forest. Scientific Reports, 2025, 15(1): 6243.

[10] Krauß J, Ackermann T, Kies A D, et al. Virtual experiments for a sustainable battery cell production//Kohl H, Seliger G, Dietrich F. Manufacturing driving circular economy. Cham: Springer International Publishing, 2023.

[11] Denisart Lucie, Zapata-Dominguez Diana, David Xavier, et al. Combining virtual reality with mixed reality for efficient training in battery manufacturing. Batteries & Supercaps, 2023, 7(1): e202300268.

[12] Che Maznah M I, Lian O C, Noor N A M. Bridging accreditation and SDGs through outcome-based education: pathways for transforming engineering curricula. Journal of Engineering Research and Education, 2026, 18: 287-299.

[13] Mishra A, Singh S S. Smart pedagogical learning and assessment methodologies—outcome based education: a novel quality assurance framework with attainment computation for Indian engineering higher education programs. Journal of Computers in Education, 2024, 12(4): 1231-1282.

[14] Shah R, Gillen A L. A systematic literature review of university-industry partnerships in engineering education. European Journal of Engineering Education, 2023, 49(3): 577-603.

[15] Wang Caidong, Xiao Yanqiu, Xiao Zhiling, et al. Exploration and practice of an inter-embedded engineering excellence talent cultivation mechanism with three dimensions and six stages. Frontiers in Education, 2025, 10: 1632525.