

Exploring Curriculum Teaching Reform for New Energy Materials and Devices Major in Newly Established Local Undergraduate Universities: A Case Study of Taishan University

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Abstract:

Driven by the dual imperatives of Emerging Engineering Education (New Engineering) reform and the national “carbon peaking and carbon neutrality” strategy, the new energy materials and devices (NEMD) major faces an urgent need for a paradigm shift in talent cultivation. In 2026, Taishan University began enrolling its first cohort of undergraduate students for the NEMD major. As a newly established program within a local application-oriented university, it faces phased challenges, including limited pedagogical experience, curriculum systems that remain under development, and experimental platforms that are still being progressively improved. Based on a systematic analysis of the program’s positioning and current teaching status, this study integrates the three vertical and three horizontal empowerment frameworks from the National New Energy Materials and Devices Professional Development Alliance with Outcome-Based Education (OBE) principles. Accordingly, we propose curriculum teaching reforms across four dimensions: (1) refining teaching objectives to better align with regional industrial needs; (2) constructing a “Three-Tier, Four-Dimensional” modular curriculum system; (3) advancing blended and project-driven teaching models; and iv reinforcing research-informed teaching alongside industry-education collaborative mechanisms. This study aims to offer practical insights for curriculum development in similar newly established NEMD programs at local undergraduate institutions

Keywords:

Emerging Engineering Education, New Energy Materials and Devices, Curriculum Teaching Reform, OBE Concept, Local Application-Oriented Universities

1. Introduction

The deep advancement of the new round of technological revolution and industrial transformation has positioned the new energy industry as a critical engine driving high-quality economic development. Since 2017, the ministry of education has actively promoted emerging engineering education construction, successively issuing

the “Fudan Consensus,” “Tianjin Action,” and “Beijing Guidelines,” which mark a systematic reshaping of engineering education talent cultivation paradigms.[1] Concurrently, the proposal of the “carbon peaking and carbon neutrality” strategic goals imposes higher demands on the knowledge structures, engineering competencies, and innovation capabilities of professionals in the new energy sector. In July 2025, the Fourth National Teaching and Discipline Development Forum for New Energy Materials and Devices Majors was held in Chengdu, where the “New Energy Materials and Devices Professional Development Alliance” was formally established. This alliance directly addresses three core challenges currently facing the major, i.e., disconnection between disciplines and industry, weak practical capabilities, and dispersed teaching resources, by constructing a “Three Vertical and Three Horizontal” empowerment system.[2] This national platform provides directional guidance and resource-sharing channels for curriculum development across universities, particularly for newly established programs.

The new energy materials and devices (NEMD) major (National Standard Code: 080414T), as a New Engineering discipline oriented toward national strategic emerging industries, is characterized by deep interdisciplinary integration, rapid knowledge updates, and strong practice dependence. taishan university began enrolling undergraduate students for this major in 2026, making it a newly approved program hosted by the college of chemistry and chemical engineering. As a newly established program within a local university, the new energy materials and devices major at Taishan University possesses distinctive features: it boasts a faculty of 21 full-time instructors, all holding doctoral degrees, including 7 professors, 7 associate professors, and 7 lecturers, with one Taishan Industrial Leading Talent. The program focuses on two frontier directions, namely electrochemical energy storage and photoelectric conversion, and has established a comprehensive experimental platform offering full-chain practical training in material synthesis, structural characterization, device assembly, and performance testing. Graduates are primarily oriented toward three major career tracks: lithium batteries, photovoltaics, and energy storage systems.

As a newly established program in a local application-oriented university, the NEMD major at Taishan University faces both significant opportunities and pressing challenges. The former includes the ability to incorporate New Engineering concepts and OBE principles from the start of program construction, whereas the latter encompasses insufficient teaching experience, curriculum systems still being shaped, and experimental platforms undergoing progressive improvement. How to effectively operate this major in a local application-oriented university, ensuring alignment with the common requirements of New Engineering talent cultivation while reflecting regional characteristics and institutional positioning, constitutes a pressing practical issue. Based on the actual program construction at Taishan University, this paper integrates the frontier concepts of the national new energy materials and devices professional development alliance with OBE educational philosophy to explore curriculum teaching reform pathways suitable for newly established local undergraduate institutions.

2. Current Challenges in Curriculum Teaching

2.1. Disconnect Between Multidisciplinary Knowledge Integration and Student Cognitive Foundations

The NEMD major encompasses multidisciplinary content spanning materials science, physics, chemistry, electronics, and mechanical engineering. The curriculum system includes core courses such as solid state physics, semiconductor physics and devices, applied electrochemistry, and fundamentals of materials science and engineering. As documented in existing educational research, new energy materials courses exhibit pronounced interdisciplinary characteristics, and integrating fragmented knowledge across broad disciplinary boundaries has become a significant pedagogical challenge [3]. For students in local application-oriented universities, mathematical and physical foundations vary considerably, making the integration of multidisciplinary knowledge a potential source of cognitive overload. Furthermore, the rapid iteration of technologies in this field, combined with the lag between textbook content and industrial development, poses additional challenges in effectively incorporating cutting-edge research outcomes and industry trends into classroom instruction.

2.2. Experimental Teaching System in the Construction Phase

As a newly established program, Taishan University has developed a full-chain practical training platform encompassing “material synthesis-structural characterization-device assembly-performance testing,” enabling students to complete hands-on projects including lithium-ion coin cell assembly and charge-discharge testing, as well as perovskite solar cell fabrication and photoelectric conversion efficiency measurement. However, from the perspective of new program development, the hierarchical design of experimental projects, validation of credit allocation rationality, and compilation and refinement of experimental teaching materials all require gradual exploration through teaching practice. At the national level, since the NEMD major was only established in Chinese universities from 2010 onward, most institutions remain in preliminary stages of program development. Incomplete experimental curriculum systems and the lack of specialized experimental teaching materials are widely recognized challenges [4,5]. How to leverage the experience of pioneering institutions to shorten the “ramp-up period” of practical teaching is a critical issue that new programs must address.

2.3. Teaching Models and Curriculum Ideological-Political Integration Require Deepening

Traditional teaching models predominantly rely on lecture-based instruction, with students passively receiving knowledge, which fails to stimulate learning interest and innovative thinking. As a newly established program, Taishan University is in the early stages of exploring innovative teaching models. From the perspective of curriculum ideological and political education (IPE), the NEMD major is highly aligned with the national “dual carbon” strategy and possesses natural advantages for ideological and political cultivation. However, systematically integrating awareness of patriotic scientific dedication and “bottleneck” technology breakthroughs into classroom instruction requires deliberate design at the pedagogical level. The professional development alliance emphasizes OBE curriculum reform and virtual teaching and research section construction, promoting the dissemination of national first-class program achievements, all of which provide referable pathways for teaching model innovation in newly established programs.

2.4. Industry Demand-Oriented Teaching Objectives Require Precise Alignment

The new energy industry encompasses multiple subsectors including lithium batteries, photovoltaics, and energy storage systems, each with significantly different job competency requirements. Taishan university has established the cultivation positioning of producing application-oriented innovative talents with “Mountaineer” characteristics, focusing on electrochemical energy storage and photoelectric conversion directions. However, at the curriculum teaching level, how to refine this cultivation positioning into operational and evaluable teaching objectives, and how to effectively align course content and teaching methods with industry job competencies, requires further exploration. Particularly in talent cultivation program design, it is essential to ensure that “foundation-tier” courses provide adequate disciplinary groundwork, “core-tier” courses achieve precise alignment with industry positions, and “expansion-tier” courses maintain adaptability to frontier directions.

3. Pathways for Curriculum Teaching Reform

3.1. Anchoring to Regional Industrial Demands to Restructure Teaching Objectives

Curriculum teaching reform must first address two fundamental questions: for whom are we cultivating talent, and what competencies are we cultivating? To this end, a progressive mechanism involving industry demand investigation, cultivation objective refinement, and course objective decomposition is recommended.

First, establish a long-term mechanism for industry demand investigation. Leveraging the new energy industry layout of Shandong Province, particularly energy storage materials and lithium battery supporting enterprises in tai'an and surrounding areas, regular investigations of industry talent demands should be conducted to map job competency profiles. Taishan university has joined the national new energy materials and devices professional development alliance, providing access to industry talent demand data and program construction resources through the alliance platform, thereby shortening the new program's accumulation cycle in industry cognition. Second, refine cultivation objectives into evaluable course objectives. In accordance with the talent cultivation program's “objectives to be achieved five years after graduation,” theoretical teaching objectives should be positioned to consolidate core knowledge in electrochemistry fundamentals, materials science, and semiconductor physics. Practical teaching objectives should target full-chain skills in “material synthesis-device assembly-performance testing.” Competency objectives should focus on cultivating patriotic dedication and “dual carbon” awareness. Third, integrate the “dual carbon” concept into the course objective system. In alignment with the “carbon peaking and carbon neutrality” goals, dedicated “dual carbon” modules should be established in courses such as introduction to new energy materials and devices and fundamentals of electrochemistry, cultivating students' low-carbon awareness and sustainable development perspectives. Drawing on existing educational reform experience, students' low-carbon awareness and conservation consciousness should be consciously strengthened in experimental teaching, nurturing them into innovative and practical professionals [10].

3.2. Constructing a “Three-Tier, Four-Dimensional” Modular Curriculum System

To address issues of fragmented knowledge and the theory-practice disconnect, an OBE-oriented “Three-Tier, Four-Dimensional” curriculum module is proposed (see Figure 1). Three-Tier Curriculum Structure: (1) Foundational disciplinary modules-covering advanced mathematics, college physics, inorganic and analytical chemistry,

physical chemistry, and fundamentals of materials science. particular attention must be paid to the logical sequencing of course offerings, ensuring that foundational courses such as physical chemistry are scheduled before core specialized courses. (2) Core specialized modules-including principles and applications of electrochemistry, semiconductor physics and devices, new energy materials preparation technology, energy conversion materials and devices, and materials research methods. This tier adopts an integrated “theory + in-class laboratory” delivery approach, synchronizing knowledge transmission with competency development. (3) Comprehensive innovation modules comprising comprehensive new energy materials laboratory, comprehensive electrochemistry laboratory, comprehensive new energy devices practice, as well as graduation thesis/project and innovation and entrepreneurship training programs, facilitating the transformation from knowledge to competency.

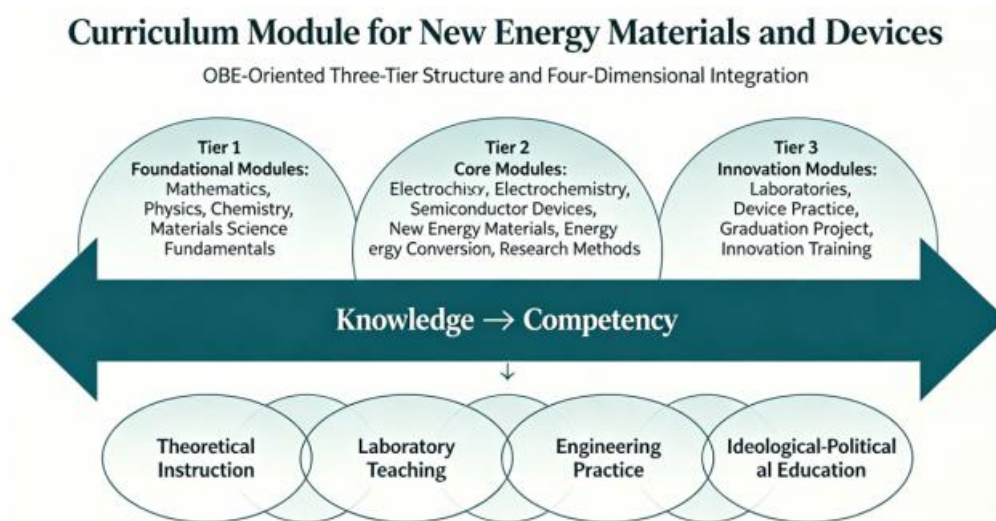


Figure 1. The Schematic diagram of the “Three-Tier, Four-Dimensional” curriculum module.

Four-Dimensional Content Integration refers to the organic integration of four dimensions, including theoretical instruction, laboratory teaching, engineering practice, and ideological-political education. For ideological-political education integration, it is important to guide students in understanding the “bottleneck” technological challenges in China’s new energy sector, thus inspiring their sense of responsibility to advance the nation’s scientific and technological capabilities. With respect to curriculum content renewal, platforms such as the shandong provincial engineering research center for green synthesis and new energy materials creation serve as key resources for converting faculty research outputs into pedagogical cases, ensuring that course content remains at the forefront of the field.

3.3. Advancing Blended and Project-Driven Teaching Models

Given the new major still-developing online and offline teaching resources, a phased approach to teaching model reform is recommended. Phase I (Construction Period): Leveraging the university's online teaching platform, develop micro-lecture videos and exercise banks for foundational specialized course modules, enabling students to engage in pre-class autonomous learning and in-class focused clarification. The Professional Development Alliance has signed agreements for over 20 university-enterprise joint laboratories and promotes virtual teaching and research section construction. Taishan University can access high-quality online teaching resources through the alliance platform to compensate for its own resource accumulation gaps.

Phase II (Refinement Period): Promote flipped classrooms, case-based teaching, and project-driven instruction. For example, in the Lithium-Ion Battery Technology course, a project theme of “From Material Design to Battery Assembly” can be adopted, with student teams completing the full workflow of material synthesis, coin cell assembly, performance testing, and data analysis. This teaching approach has achieved positive outcomes in various institutions—through project-based team collaboration, students develop innovative thinking, achieve multidisciplinary knowledge integration, and cultivate competencies for addressing complex engineering problems [6].

Simultaneously, an assessment system combining “formative assessment + summative assessment” should be established. Laboratory operation standards, project report quality, and teamwork performance should be incorporated into regular grades, with reduced weight on final examinations, emphasizing the assessment of practical competencies and innovative thinking. Drawing on practices in domestic institutions, assessment scores can be divided into three components: regular performance (including attendance, classroom interaction, and research competition participation), project presentation, and final assessment, achieving diversified evaluation.

3.4. Strengthening Research-Feeding-Teaching and Industry-Education Collaborative Education Mechanisms

The College of Chemistry and Chemical Engineering at Taishan University possesses notable advantages in research platforms, including the Shandong Provincial Engineering Research Center for Green Synthesis and New Energy Materials Creation and the Provincial University Key Laboratory for Green Synthesis and Functional Materials. All full-time faculty members hold doctoral degrees, including one Taishan Industrial Leading Talent. These research resources should be fully leveraged to establish effective mechanisms for research-feeding-teaching.

First, a research mentorship system should be implemented. The program has explicitly established that the mentorship system will operate throughout the entire four-year undergraduate period. This institutional design should be effectively executed by encouraging undergraduates to join faculty research groups for scientific training, thereby cultivating scientific thinking and experimental skills in authentic research contexts. Second, a competition-driven learning approach should be adopted. Competitions such as the “Challenge Cup,” “Internet+,” and the National College Students Metallographic Skills Competition should be integrated with curriculum teaching by translating competition requirements into course project tasks. Discipline competitions have been demonstrated to be effective vehicles for deliberately exercising students’ practical abilities, promoting their further mastery of theoretical knowledge, and cultivating scientific thinking and innovation awareness. Third, industry-education collaboration should be deepened. Leveraging the platform resources of the Professional Development Alliance that the program has joined, efforts should be made to expand university-enterprise cooperation channels by inviting industry engineers to participate in practical teaching and organizing student visits to new energy enterprises for internships and site visits. The construction of joint university-enterprise laboratories should be actively promoted to build a closed-loop ecosystem integrating the education chain, talent chain, and industry chain, thereby opening a pathway for the translation of classroom knowledge into industrial competencies.

4. Conclusions

Under the context of Emerging Engineering Education, the curriculum teaching reform of the New Energy Materials and Devices major constitutes a systematic project. For newly established local undergraduate universities like Taishan University, it is necessary to acknowledge the phased challenges, such as limited teaching experience and experimental platforms that remain under development. Nevertheless, these institutions should seize their “latecomer advantage” by incorporating New Engineering philosophies and OBE orientations at the early stage of program construction, while also benefiting from the platform resources of the National Professional Development Alliance, thus avoiding the conventional trajectory of “tradition first, reform afterward.” By aligning teaching objectives with industrial demands, developing a modular curriculum framework, innovating pedagogical approaches, and reinforcing the synergy between scientific research, education, and industry, the program is expected to evolve into a New Engineering talent cultivation base that not only meets the demands of the regional new energy industry but also embodies the characteristics of application-oriented education, ultimately contributing talent support to the realization of the national "dual carbon" goals.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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