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From Success Paradigms to Failure Post-Mortems: Paradigm Transformation and Path Reconfiguration in Experimental Teaching of New Energy Materials

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Abstract: Targeting long-standing practical dilemmas in experimental teaching of new-energy materials, including dominance of confirmatory experiments, result-oriented evaluation, uneven resource allocation, and disconnection between teaching and industry-university cooperation, this paper puts forward a teaching philosophy of transforming from the "success paradigm" to "failure post-mortems." By constructing a hierarchically-progressive experimental content system, a multiple process-oriented evaluation mechanism, an open and shared resource guarantee mode, as well as an industry-education-integrated collaborative talent-cultivation path, experimental failures are converted from teaching blind spots into learning resources. Students acquire authentic modes of thinking for materials research-and-development through controllable failure experiences, providing references for the reform of experimental teaching for new-energy-material majors in institutions of higher education.

Keywords: New energy materials; Experimental teaching; Paradigm transformation; Failure post-mortem; Industry-education integration

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1. Introduction

New-energy materials constitute the core foundation supporting the development of the new-energy industry, and their experimental teaching plays an irreplaceable role in cultivating practical capabilities and innovative literacy of students majoring in materials-related disciplines. Nevertheless, traditional experimental teaching has long adopted the success paradigm of "teacher demonstration-student repetition-report scoring." Students complete preset operations along predetermined paths and are poorly prepared for failures and uncertainties prevailing in real-world scientific research [1]. Based on the actual conditions of experimental teaching of new-energy materials in universities, this paper analyzes existing

dilemmas such as rigid content, single-dimensional evaluation, uneven resources, and disconnection between industry and education. It proposes the teaching concept of shifting from the "success paradigm" to "failure post-mortems," and reconfigures experimental-teaching content systems, evaluation mechanisms, resource allocation, and collaborative paths, so as to offer references for improving the talent-cultivation quality of new-energy-material majors.

2. Existing dilemmas in experimental teaching of new-energy materials

2.1. Rigid experimental contents: Dominance of confirmatory experiments and insufficient inquiry space

Traditional experimental teaching of new-energy materials mostly aims to verify known conclusions. Experimental procedures, reagent dosages, and process parameters are pre-specified in teaching materials. Taking the preparation experiment of lithium-ion electrode materials as an example, students follow established workflows to finish ball-milling, sintering, and testing. Obtaining performance data consistent with textbooks is regarded as success. Although such "recipe-following" experimental design guarantees stable teaching order, it reduces students to passive executors and deprives them of key links in materials R&D such as parameter exploration, condition optimization, and troubleshooting [2]. An excessively high proportion of confirmatory experiments and an insufficient number of design-oriented and comprehensive experiments cause students to form a mindset that "experiments must have standard answers." When confronted with real-research problems such as electrode-performance fluctuations and poor material repeatability, they lack capabilities for independent analysis and problem-solving. Rigidity of experimental content is also reflected in delayed updates: material systems in textbooks mostly remain at mature routes from years ago and fail to reflect cutting-edge directions including solid-state electrolytes, silicon-carbon anodes and high-nickel ternary materials. Students have no access to open-ended questions in current research hotspots [3].

2.2. Single-dimensional evaluation mode: Result orientation obscures processes and marginalizes failure experiences

Current experimental-teaching evaluation mainly takes accuracy of experimental-report data and result reproducibility as core indicators. Links such as operation procedures, anomaly handling, and failure analysis carry low weights or are even absent. To obtain "ideal data," students often selectively record qualified data, avoid abnormal phenomena, or even revise experimental results by copying textbook conclusions. Such evaluation orientation essentially encourages "worship of success" and discourages in-depth student exploration of experimental failures. R&D of new-energy materials itself features a high failure rate. Phenomena including battery capacity fading, catalytic-efficiency fluctuations, and uneven material morphologies are commonplace in research, yet they are treated as operational mistakes rather than learning resources in teaching [4]. Marginalization of failure experiences renders students psychologically vulnerable to experimental failures after they graduate and enter research institutes or enterprise-R&D posts. Meanwhile, they lack methodological training to extract valid information from failures. Simplified evaluation criteria also lead to templated experimental-report writing: students only need to fill in preset tables to finish assessment without in-depth discussion of the physicochemical mechanisms behind the data.

2.3. Uneven resource allocation: Structural gaps in hardware facilities and teachers' competence

Experiments on new-energy materials require high-precision instruments such as glove boxes, electrochemical workstations, LAND battery-testing systems, and scanning electron microscopes, whose purchase and maintenance incur high costs. Restricted by funding, local universities often suffer from insufficient equipment quantity, outdated models, and limited opening hours. Students can only take turns for group operations, which greatly cuts down per-capita hands-on operating time. Meanwhile, most teachers undertaking experimental teaching focus on theoretical scientific research and lack front-line enterprise R&D experience. They have limited understanding of process pain points, quality-control requirements, and safety specifications in the industrialization of new-energy materials [5]. Insufficient engineering-practice competence among teachers further prevents experimental-teaching content from extending toward real-world industrial scenarios. In terms of class-hour allocation, experimental class hours are frequently squeezed by theoretical courses, leaving students little time to conduct multi-variable parameter exploration. Furthermore, laboratory-safety-management systems remain imperfect. Insufficient safety training and emergency drills targeting high-risk experiments such as lithium-battery-material tests and electrochemical experiments also restrict the in-depth development of open-ended experimental projects.

2.4. Disconnection between industry and education: Teaching contents lag behind industrial-technology iteration

Technologies for new-energy materials iterate rapidly. Technical routes keep evolving from lithium-iron phosphate to high-nickel ternary materials, from graphite anodes to silicon-carbon anodes, and from liquid electrolytes to solid-state electrolytes. Nevertheless, university experimental textbooks generally feature long update cycles. Some experimental projects still adopt technical routes from five or even ten years ago, creating obvious gaps between what students learn and actual enterprise demands. In addition, stable experimental-teaching-cooperation mechanisms between universities and new-energy enterprises are absent. Real-world enterprise R&D projects can hardly be transformed into teaching cases. Systemic divergences exist in material systems, testing standards, and process conditions adopted in university laboratories versus industrial practices [6]. Such disconnection results in long adaptation cycles for new graduates after taking up posts. Enterprises commonly report that newly-recruited students "can run experiments but do not understand processes," "grasp principles yet cannot solve engineering problems." Industry-education disconnection is also manifested in evaluation criteria: university experimental assessments emphasize data reproducibility, whereas enterprise-R&D attaches greater importance to problem-solving efficiency and cost control. This gap further weakens the matching degree between talent cultivation and industrial demands.

3. Paths for paradigm transformation in experimental teaching of new-energy materials

3.1. From verification to inquiry: Construct a hierarchically-progressive experimental-content system

The primary task for transformation is to restructure experimental-content supply and break the monopoly of confirmatory experiments. It is recommended to build an experimental-project matrix consisting of three tiers: "basic verification-comprehensive design-inquiry-driven innovation." The basic tier retains necessary

confirmatory experiments to help students master fundamental operational specifications for material preparation and characterization, such as basic electrode-preparation workflows and routine testing methods using electrochemical workstations. The comprehensive tier sets multi-parameter-coupled experimental projects, for instance, the influence of electrolyte-formula optimization on battery rate performance and the regulation of catalytic-material morphologies by sintering temperature and holding time. Students are required to independently design experimental schemes, select variable intervals, predict potential outcomes, and analyze data dispersion [7]. At the innovation tier, authentic scientific-research topics or enterprise technical bottlenecks are introduced as open-ended experimental projects for student participation. Experimental "failures" are permitted, and failure-related data are incorporated into assessment.

In content design, a dedicated "failure-case module" shall be established. Typical failure cases from the research group or enterprise-R&D activities are converted into teaching materials, for example, abnormally low initial charge-discharge efficiency of a certain batch of electrode materials, sharp drop in catalytic-system activity during continuous testing, and abnormally elevated interfacial impedance of solid-state electrolytes. Students are guided to analyze failure causes, propose improvement hypotheses, and carry out verification just as researchers would do [8]. Each failure case shall be supplemented with complete raw-data records, characterization graphs, and literature comparisons, enabling students to experience the full reasoning chain from abnormal phenomena to mechanistic explanations. Through hierarchical progression, students shift from "repeating successes" to "embracing uncertainties." They acquire authentic scientific-research thinking within a controllable teaching environment and gradually build awareness of the complexity of material R&D.

3.2. From result-oriented to process-oriented: Establish a multiple process-oriented evaluation and failure-post-mortem mechanism

Transformation of evaluation modes serves as a critical lever for paradigm reconstruction. The evaluation inertia that solely relies on experimental-report data shall be broken, and a multi-dimensional evaluation system covering the whole experimental process shall be established. Specifically, experimental scores can be decomposed into four modules: pre-class preview and scheme design (20%), operation norms and safety awareness (20%), process records and anomaly analysis (30%), as well as result discussion and post-mortem reflection (30%) [9]. Among them, "anomaly analysis" and "post-mortem reflection" specifically target experimental-failure scenarios. When students obtain unexpected data, such outcomes shall not be treated as deduction items. Instead, assessment focuses on whether students can identify anomalies, trace root causes, and put forward revision ideas.

Teachers may set up the "failure post-mortem report" task. Students are required to compose post-mortem documents similar to research-group-meeting reports after experiments, covering experimental objectives, actual outcomes, deviation analysis, literature comparison, and follow-up improvement plans. Such evaluation conveys the message: experimental failure is not shameful; failing to learn from failure is. Meanwhile, peer review and defense-style assessment are introduced. Students present their failure experiences and lessons learned in group reports to cultivate academic expression and critical-thinking capabilities [10]. For students who obtain "perfect data" yet cannot interpret underlying mechanisms, teachers shall raise follow-up questions in discussion sessions regarding why parameters fall within such ranges and what would happen given altered conditions, preventing students from remaining at the mechanical-operation level. Through adjustment of evaluation guidance, students are guided to pursue "genuine understanding"

rather than "favorable data," making evaluation an organic component of the learning process.

3.3. From closed to open: Promote laboratory-resource sharing and teachers' competence upgrading

Against the constraint of uneven resource allocation, simultaneous efforts shall be made on both hardware platforms and teaching staff. On the hardware side, on the one hand, large-scale instruments shall be coordinated by university-level experimental-teaching centers. Online reservation, time-sharing, and inter-faculty opening mechanisms shall be implemented to boost equipment-utilization efficiency and avoid fragmented idle instruments. On the other hand, virtual-simulation experiments shall be adopted to complement physical experiments. Virtual-simulation modules shall be developed for high-cost, high-risk, and long-cycle experimental projects (e.g., power-battery thermal-runaway experiments, large-scale-material-synthesis processes, electrochemical tests under extreme conditions). Students conduct parameter exploration and failure pre-enactment in virtual environments before performing key validations in physical laboratories, so as to ease conflicts arising from equipment shortages and limited class hours [11].

On the teaching-staff side, a "dual-competency teacher" training program shall be carried out. Experimental teachers are dispatched to new-energy-material enterprises for at least six-month on-the-job practice, participating deeply in enterprise-R&D projects to accumulate engineering-practice experience and understand genuine industrial requirements for material performance, cost control and safety specifications. Meanwhile, senior enterprise engineers are engaged as off-campus supervisors to guide partial comprehensive experiments and innovative projects, bringing authentic industrial problems and cases into classrooms [12]. In addition, experimental teachers are encouraged to convert mature segments from their own scientific-research projects into teaching experiments, keeping teaching contents synchronized with research frontiers. In teacher assessment, the weight assigned to paper publications for experimental teachers shall be appropriately reduced. Contributions in experimental-teaching reform, student-innovation guidance and safety management shall be recognized to stabilize the experimental-teaching workforce. Open sharing and competence upgrading will gradually narrow resource gaps among universities as well as gaps between classrooms and industry [13].

3.4. From classroom to industry: Deepen industry-education integration and collaborative talent-cultivation mechanisms

The fundamental solution to disconnection between experimental teaching and industry lies in establishing deeply-collaborative talent-cultivation mechanisms. Universities shall co-build joint laboratories, practical-teaching bases, and industrial colleges with leading enterprises and specialized-refined-innovative enterprises along the new-energy-material industrial chain. Authentic enterprise-R&D projects are decomposed into experimental topics suitable for undergraduate teaching. Concrete paths include: first, co-develop experimental courses. Enterprise engineers provide process cases and technical requirements, while university teachers adapt them for teaching purposes, forming a closed-loop of "enterprise setting problems-classroom problem-solving-enterprise feedback" to ensure experimental topics originate from real-world industrial issues. Second, set enterprise-proposed graduation-design and innovation-entrepreneurship projects. Under joint guidance of enterprise and university supervisors, students conduct experimental research targeting practical enterprise problems, and research outcomes directly support enterprise-technology improvements, achieving win-win outcomes for talent cultivation and R&D [14].

Third, regularly hold new-energy-material experimental-skill competitions with industrial testing standards as competition criteria to drive alignment between teaching contents and industrial standards.

From safety and ethical perspectives, universities and enterprises shall jointly formulate experimental-safety codes and data-confidentiality systems, ensuring that industrial projects introduced into teaching systems protect enterprise commercial secrets while guaranteeing student-experiment safety. Desensitization or alternative schemes can be adopted for experiments involving core enterprise-technologies to preserve problem essence while safeguarding intellectual-property rights. Moreover, "order-oriented" experimental-teaching modes may be explored. Experimental-content modules are customized according to post requirements of cooperative enterprises, enabling students to receive preliminary training on core post competencies before graduation [15]. Deep-going industry-education integration expands experimental teaching from closed-campus contexts to open industrial ecosystems. Students build intuitive perceptions of real-world operations within the new-energy-material industry during their studies, shortening the adaptation period from classroom to workplace.

4. Conclusion

The transformation of experimental teaching for new-energy materials from the "success paradigm" to "failure post-mortems" essentially represents an in-depth reform shifting from knowledge transmission toward competence cultivation. Such transformation demands experimental-teaching content to evolve from verification toward inquiry, evaluation modes from result-orientation toward process-orientation, resource allocation from closure toward openness, and teaching scenarios from classrooms toward industry. Universities shall seize this opportunity to systematically reconstruct experimental-teaching systems. Students shall temper scientific thinking and engineering literacy through controllable failure experiences, so that high-quality innovative talents capable of tackling genuine challenges in the new-energy-material industry can be cultivated.

Disclosure statement

The authors declare no conflict of interest.

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