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Research on Teaching Reform of the "Powder Technology" Course in the Context of Cultivating Composite Applied Talents

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ABSTRACT

As a cross-industry enabling technology, powder technology urgently requires talent development to address new industrialization challenges. Based on an analysis of industry-education capability alignment, this paper reveals structural deficiencies in traditional curricula: fragmented knowledge modules hinder systematic thinking, disconnected practical components suppress technology transfer capabilities, and static evaluations lead to innovation deficits. Innovative reforms, grounded in typical engineering problems, implement core strategies: constructing a project-based content matrix that integrates process flows, equipment clusters, and product chains; adopting a teaching modality based on reverse fault analysis; and designing a competency-based evaluation system that covers process operation, solution optimization, and prototype innovation. This model facilitates the structured cultivation of engineering problem-solving capabilities through dynamic coupling between teaching content and industrial technological advancements.

KEYWORDS

Powder technology; Teaching reform; Multidisciplinary applied talent; Engineering education; Project-based learning

1 Introduction

Powder technology, as an engineering system handling specialized material forms, has become deeply embedded in the core processes of modern industries. From controlling the particle size of lithium battery cathode materials to managing phase transitions during ceramic powder sintering, and even enabling targeted delivery of pharmaceutical microparticles, the performance thresholds of high-end products are directly constrained by the level of powder processing technology. This cross-domain integration requires practitioners to possess multidisciplinary knowledge integration capabilities. Not only must they master the principles of unit operations, such as grinding, classification, and fluidized conveying, but they must also grasp the engineering mapping logic of technology chains in specific industrial settings to develop systematic solution-building capabilities for complex engineering problems. In contrast, current university curricula remain entrenched in discipline-centric teaching paradigms, exhibiting lagging issues such as disconnects in technological iteration, weak industry-education collaboration, and gaps in competency transfer. The widening gap between the supply of specialized talent and industrial demand makes curriculum reform imperative. This critical teaching and research challenge must be addressed by deconstructing the new landscape of competency development, diagnosing the deep-seated mechanisms of teaching bottlenecks, and designing pathways for scientific transformation.

2 New Requirements for the "Powder Technology" Course in Cultivating Multidisciplinary Applied Talent

2.1 Defining Core Competency Demands for Multidisciplinary Applied Talent in Modern Materials and Chemical Industries

The continuous advancement of modern materials and chemical industries demands a cohort of multidisciplinary professionals possessing both broad interdisciplinary perspectives and exceptional engineering practice capabilities. The core competitiveness of such talent is first manifested in their ability to integrate cross-disciplinary knowledge. They must synthesize principles of powder technology with expertise in materials science, chemical engineering, automatic control, and even data science to address challenges across the entire industrial chain—from raw material preparation to end-use applications—at a systemic level. Secondly, it lies in their practical ability to solve complex engineering problems [1]. Real-world industrial scenarios rarely offer standard solutions, demanding practitioners move beyond rote memorization of formulas. They must accurately pinpoint problem roots, propose innovative solutions, validate these through experimentation, and balance constraints across multiple dimensions—technical, economic, safety, and environmental. Finally, efficient team collaboration and communication skills are equally critical competencies. Within projects, they need to seamlessly coordinate with colleagues from diverse backgrounds while clearly articulating their technical concepts.

2.2 Analyzing the Limitations of Traditional Powder Technology Courses in Knowledge Systems and Competency Development

When measured against these competency requirements, the limitations of traditional Powder Technology courses become evident. In terms of knowledge structure, most courses still follow a disciplinary logic, dividing topics such as powder properties, preparation, characterization, and transportation into separate chapters. While this arrangement appears straightforward, it artificially disconnects the inherent relationships between technologies within real production processes. Students may memorize multiple particle size analysis methods but fail to grasp why even minute variations in Particle Size Distribution demand near-obsessive precision in lithium battery anode material production [2]. Regarding competency development, teaching priorities often lean toward imparting concepts, principles, and formulas, while training in higher-order skills, such as interdisciplinary integration and complex problem-solving, remains inadequate. Course designs rarely place students in simulated real-world engineering scenarios. Consequently, graduates may possess solid theoretical knowledge but struggle with knowledge transfer when confronted with practical engineering challenges, revealing significant gaps in their hands-on and innovative capabilities.

2.3 Argumentation: Engineering Problem-Driven Curriculum Reconstruction as the Key Pathway to Talent Development Goals

To break free from traditional course models and achieve a genuine leap from knowledge transmission to competency development, the critical shift lies in fundamentally transforming the logic of curriculum construction—moving from a discipline-knowledge-centered approach to one driven by solving real-world engineering problems. This implies that course organizational units are no longer isolated knowledge points but rather representative projects or case studies sourced from the industrial frontlines. Knowledge acquisition itself is no longer the endpoint but rather a necessary tool for solving engineering problems. For instance, teaching could be structured around a project focused on preparing novel catalyst carriers and optimizing their performance. Throughout this process, students would proactively explore relevant theories—such as powder preparation, modification, and characterization—driven by specific questions to achieve project objectives. This model inherently links knowledge acquisition with real-world applications, most effectively fostering simultaneous growth in knowledge integration and problem-solving skills. It represents the pathway to cultivating versatile applied talents.

3 Prominent Issues in Current Teaching Practices of Powder Technology Courses in China

3.1 Disconnect Between Course Content and Industrial Demands and Knowledge System

The primary issue is the significant disparity between course content and the rapidly evolving demands of the industrial sector and modern knowledge systems. Many textbooks, which have been in use for years, continue to focus on traditional powder technologies. They devote considerable attention to classic processes, such as ball milling and screening, while barely touching upon—or even glossing over—cutting-edge techniques, including fluid energy milling, spray drying, and plasma-based nanopowder synthesis. Particularly concerning is the near-total absence of content on digital transformation areas, such as intelligent online detection and simulation optimization for powder processes. This obsolescence creates a significant generational gap between what students learn and the work scenarios they will encounter in high-end manufacturing. Furthermore, course content often fails to integrate effectively with subsequent courses, lacking a macro-level examination of powder technology's role within the entire product lifecycle. Consequently, students' knowledge systems appear fragmented, hindering the development of the systemic perspective necessary for solving complex problems [3].

3.2 Teaching Methods Overemphasize Theoretical Instruction and Lack Engineering Problem-Oriented Practical Training

In terms of teaching methods, the vast majority of Powder Technology classrooms remain stuck in one-way theoretical indoctrination. Instructors meticulously dissect concepts at the lectern while students passively absorb information below. This teaching model severely stifles students' initiative and critical thinking. Classrooms critically lack teaching segments driven by real, complex engineering problems, leaving students with few opportunities to engage in simulated engineering practices such as equipment selection, process design, or production fault diagnosis. Even when experiments are conducted, they often involve formulaic, verification-based procedures that students can complete by following instructions step-by-step, leaving little room for independent design, analysis, or innovation. Under this model, students fail to learn how to handle unexpected experimental outcomes and are unable to grasp the decisive role of parameter optimization in determining the final product's performance. This scarcity of practical training directly results in weak engineering application skills, preventing students from effectively translating theory into problem-solving strategies and competencies.

3.3 Rigid Assessment Methods Fail to Evaluate Comprehensive Application and Innovation

As the guiding force of teaching activities, inflexible and singular assessment methods constitute another significant obstacle to curriculum reform. Currently, most universities evaluate learning outcomes in Powder Technology courses primarily through a single closed-book final exam, which predominantly focuses on concept recall and formula calculations. At best, this method tests students' memorization of isolated knowledge points but fails to measure their more critical, comprehensive application and innovation abilities. A student might score high on an exam but struggle when tasked with designing a reasonable process flow for a specific powder product and drafting a preliminary feasibility report that incorporates both technical and economic analysis [4]. This evaluative bias misguides students, directing their efforts toward rote memorization for exams rather than genuine skill internalization. It also neglects the assessment of critical engineering competencies, such as teamwork, technical documentation, and oral presentations—directly contradicting the goal of cultivating versatile, applied professionals.

4 Reform Pathways for the "Powder Technology" Course Aimed at Cultivating Composite Applied Talents

4.1 Reconstructing a Modular, Project-Based Curriculum System Integrating Knowledge Across the Industrial Chain

To fundamentally resolve content disconnect issues, a thorough structural overhaul of the existing curriculum system is imperative. The core of the reform lies in dismantling traditional chapter divisions to establish a new modular system oriented toward projects and spanning the entire industrial chain. This system can be designed around several typical powder products or technology domains, such as teaching modules for new energy material powders or advanced ceramic powders. Within each module, teaching activities are driven by a real, complete engineering project. Taking the new energy material powder module as an example, the project could encompass the entire process chain, from precursor preparation to high-temperature calcination, ultrafine grinding, surface coating, and final evaluation of electrochemical performance. This approach organically integrates knowledge points previously scattered across different chapters into a unified engineering context. Through project completion, students naturally develop a systematic understanding of the entire industrial chain.

4.2 Implementing a Problem-Oriented Teaching Model Combining Real Engineering Cases with Virtual Simulation

To transform traditional theory-focused teaching methods, a comprehensive shift to a new teaching model centered on problem-solving is essential. The key to this model lies in deeply integrating real engineering cases with virtual simulation technology. During instruction, the teacher's role shifts from knowledge lecturer to project designer and process facilitator. Numerous real-world cases sourced from partner enterprises—such as equipment fault diagnosis and process parameter optimization—can be introduced, guiding students to conduct group discussions and propose solutions. To compensate for the limited experimental equipment available in universities, the introduction of virtual simulation technology is particularly crucial. By constructing a highly realistic virtual platform for powder production lines, students can repeatedly practice process design, equipment operation, and parameter adjustments in a simulated environment. This integration of online simulations with offline discussions provides valuable, immersive engineering experiences at a low cost, high efficiency, and enhanced safety.

4.3 Establishing a Diversified Academic Assessment Mechanism Integrating Formative and Summative Evaluation

To ensure the direction and effectiveness of teaching reforms, it is essential to systematically reform single-method assessment approaches and establish a new, diversified mechanism that comprehensively evaluates students' integrated application and innovation capabilities. The core of this mechanism is shifting the focus of evaluation from end-of-term summative knowledge assessments to a comprehensive review of the learning process and project outcomes. First, the weight of end-of-term closed-book exams should be significantly reduced; replacing traditional summative exams with project reports and defenses should even be considered. Second, process-based assessments should be vigorously promoted, incorporating students' performance in literature research, design planning, experimental operations, data analysis, and teamwork throughout project execution into formative evaluations. Evaluation stakeholders should also diversify by introducing mechanisms such as industry expert input, peer assessments, and student self-evaluations [5]. Only through such comprehensive, multidimensional assessment reforms can students be genuinely guided to shift their learning focus from rote knowledge memorization to competency development.

5 Conclusion

To meet the demands of cross-disciplinary engineering competency development, the reform of the Powder Technology curriculum requires systematic breakthroughs. Current teaching challenges stem from a knowledge-centric paradigm that leads to disconnects, including a gap between theory and practice that weakens technology transfer capabilities, a mismatch between industry and educational resources that hinders the development of industrial cognition, and evaluation standards that deviate from competency development objectives. Reform must achieve a fundamental paradigm shift: construct a comprehensive industrial chain project system integrating tasks across material preparation, process optimization, and product development to reshape students' engineering systems thinking; implement dual-track fault diagnosis teaching combining industrial case studies with process simulation to stimulate complex problem-solving abilities; establish a competency-stage assessment matrix providing precise feedback based on operational standardization, solution innovation, and benefit achievement. Transform course formats into engineering practice platforms to effectively cultivate cross-domain integration capabilities in powder technology.

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