 ISSN: 3078-4794; EISSN: 3106-4175

Issues and Solutions in Cultivating Innovative and Entrepreneurial Talents in Materials Chemistry for New Quality Productive Forces

Li Jia*, Zhang Guiling, You Jun, Wang Heng, Yu Yanchao

School of Materials Science and Chemical Engineering, Harbin University of Science and Technology, Harbin 150080, Heilongjiang, China

Abstract: Against the dual backdrop of educational digital transformation and the accelerated development of New Quality Productive Forces, the quality of innovative and entrepreneurial talent cultivation in materials chemistry - a core discipline underpinning high-tech, high-efficiency, and high-quality industrial development—directly influences industrial transformation and upgrading as well as the national innovation system. Based on the current state of domestic and international research on innovative and entrepreneurial education and combined with the practical experience in talent cultivation for materials chemistry, this paper systematically analyzes the core issues in current talent development and proposes targeted solutions. It aims to provide a reference for constructing a talent cultivation model that meets the demands of New Quality Productive Forces.

Keywords: Digital Transformation; New Quality Productive Forces; Materials Chemistry; Innovative and Entrepreneurial Education; Talent Cultivation Model

0. Introduction

The global economic landscape is undergoing a profound transformation, driven by a new wave of technological revolution and industrial transformation characterized by artificial intelligence, big data, biotechnology, and advanced materials. Within this context, the concept of "New quality productive forces" has emerged as a central tenet in China´s strategic development framework, particularly following its emphasis in the report of the 20th National Congress of the Communist Party of China. New quality productive forces are defined by innovation-led development, breaking away from traditional economic growth models and productivity paths. They embody high technology, high efficiency, and high quality, representing an advanced productive force aligned with the new development philosophy. This new paradigm is catalyzed by revolutionary technological breakthroughs, innovative allocation of production factors, and deep industrial transformation and upgrading. Its essence lies in the qualitative leap of laborers, means of labor, objects of labor, and their optimal combination, with a core indicator being the substantial enhancement of total factor productivity.

Higher education institutions, as the primary incubators of advanced knowledge and skilled professionals, face an urgent imperative to align their missions with this national strategic shift. The cultivation of talent must evolve to not only possess deep disciplinary expertise but also the innovative capacity, entrepreneurial agility, and cross-domain integration skills necessary to drive and adapt to these new productive forces. This alignment is not merely an economic necessity but a fundamental educational responsibility in the 21st century.

Materials Chemistry stands at the very heart of this transformation. As a foundational and interdisciplinary field bridging chemistry, physics, and engineering, it is the cornerstone for developing new materials that enable breakthroughs in sectors ranging from renewable energy (e.g., perovskite solar cells, solid-state batteries) and microelectronics (e.g., next-generation semiconductors) to biomedicine (e.g., targeted drug delivery systems) and sustainable manufacturing. The innovation cycle in materials—from fundamental discovery to scaled production and commercial application—is inherently complex and risky. It demands professionals who are not just competent laboratory researchers but also possess a systemic understanding of the innovation value chain, including intellectual property management, techno-economic analysis, scale-up challenges, and market dynamics.

However, a significant gap persists between the emerging needs of industries propelled by New quality productive forces and the traditional output of materials chemistry programs. Prevailing educational models often remain siloed, theory-heavy, and disconnected from the rapid pace of industrial innovation and digital integration. While "mass entrepreneurship and innovation" has been a national policy priority, its integration into the core fabric of specialized engineering disciplines like materials chemistry has been inconsistent and often superficial.

Concurrently, the global acceleration of Educational Digital Transformation offers unprecedented tools and methodologies to bridge this gap. Digital technologies—such as virtual and augmented reality (VR/AR) for immersive lab simulations, big data analytics for materials discovery, online collaborative platforms, and AI-driven personalized learning—can fundamentally reshape how materials chemistry is taught and learned. They can make the invisible world of atoms and molecules tangible, simulate high-cost or hazardous industrial processes safely, and connect classrooms seamlessly with global research and industrial networks.

Therefore, the central research question this paper addresses is: How can materials chemistry programs systematically reform their talent cultivation models by deeply integrating educational digital transformation with innovative and entrepreneurial education to effectively meet the demands of New quality productive forces? This paper systematically diagnoses the key challenges in the current paradigm, proposes a holistic and actionable framework for reform, and discusses the implementation pathways and potential impact of such a transformation [1].

1. Main Issues in Current Innovative and Entrepreneurial Talent Cultivation for Materials Chemistry

Despite strong national advocacy for "mass entrepreneurship and innovation" and numerous explorations in innovative and entrepreneurial education by universities, significant issues remain within the specific engineering field of materials chemistry:

1.1. Vague Positioning of Talent Cultivation Objectives

Traditional training objectives for materials chemistry often focus on imparting foundational knowledge, lacking responsiveness to the "high-tech, high-efficiency, high-quality" characteristics demanded by New quality productive forces. Insufficient emphasis on cultivating students' innovative thinking, cross-disciplinary integration capabilities, and ability to solve complex engineering problems in training objectives results in graduates struggling to meet the advanced demands of new materials R&D and industrial upgrading [2].

1.2 Low Level of Digital Integration in the Curriculum System

Firstly, core courses show low integration with innovative and entrepreneurial education, failing to incorporate cutting-edge technologies, industry pain points, and entrepreneurial processes into the curriculum [3]. Secondly, the curriculum structure lacks sufficient modularity, with poor organic connection between general education, foundational professional courses, and specialized courses, and a notable absence of interdisciplinary offerings. Thirdly, practical courses are underrepresented. Traditional experimental teaching primarily consists of verification experiments, lacking comprehensive and innovative components such as literature review, experimental design, data processing, and industrialization simulation, which hampers the cultivation of students' practical and innovative abilities [4].

1.3 Monotonous Teaching Methods and Lack of Practical Support

The teaching mode remains largely traditional, teacher-centered lecture-based, with superficial application of digital teaching tools. Firstly, interactive teaching methods such as flipped classrooms, case-based teaching, project-driven learning, and O2O blended learning are underutilized, leading to passive knowledge reception and stifled innovative thinking [5]. Secondly, digital resources like virtual simulation and online teaching platforms are not fully integrated, making it difficult to simulate real-world scenarios like materials R&D and chemical production, thereby reducing the intuitiveness and practicality of teaching. Thirdly, instructors' proficiency in applying digital teaching tools is limited, hindering the deep integration of teaching content with technological means [6].

1.4 Rigid Evaluation Mechanisms and Lack of Continuous Improvement

Current assessment methods predominantly rely on final written exams, neglecting the evaluation of students' innovation process, practical skills, and teamwork spirit [7]. Furthermore, there is a lack of mechanisms for assessing the appropriateness of training objectives based on graduate tracking feedback and employer evaluations. This makes it challenging to dynamically adjust talent cultivation programs according to industry needs.

2. Solutions and Implementation Pathways

To transition from the current state to a future-ready model, a systemic and integrated reform framework is proposed, addressing each identified issue through interconnected interventions.

2.1. Reconstructing Training Objectives: Anchored in New quality productive forces

The starting point must be a fundamental redefinition of the "graduate profile." This involves a collaborative, evidence-based process:

Stakeholder-Coordinated Objective Setting: Program objectives must be co-created and regularly validated through structured engagements with a "Program Advisory Board" comprising senior industry leaders from cutting-edge materials companies, successful alumni entrepreneurs, and representatives from national research institutes focused on strategic materials. This ensures objectives are forward-looking and market-relevant.

Competency-Based Objective Formulation: Move from vague statements to specific, measurable competency frameworks. Objectives should explicitly target:

Advanced Technical Mastery: Deep understanding of core and frontier materials chemistry.

Innovation Capacity: Ability to formulate research questions, design experiments, analyze data, and propose novel material solutions.

Entrepreneurial Agility: Skills in opportunity assessment, business model canvas development for materials-based products, and understanding of funding mechanisms for deep tech startups.

Digital Fluency: Proficiency in using digital tools for simulation, data analysis, collaboration, and communication.

Systems Integration & Sustainability: Ability to consider the life-cycle, environmental impact, and ethical implications of materials development.

Dynamic Mapping and Review: These competency-based objectives should be mapped onto individual courses and experiences. A formal review cycle (e.g., every two years) should be mandated, using data from graduate destination surveys, employer satisfaction reports, and analysis of technological trends to update the objectives.

2.2 Optimizing the Curriculum System: Designing a "Digital & I&E" Infused Matrix

The curriculum must be restructured as a flexible, interconnected matrix rather than a linear sequence of courses.

Spiral Curriculum Design: Implement a spiral approach where core concepts of I&E and digital tools are introduced early (e.g., "Introduction to Materials Innovation" in Year 1) and revisited at increasing levels of complexity and application in later, specialized courses (e.g.,"Entrepreneurship in Nanotechnology" or "Digital Tools for Battery Design" in Year 3/4).

Core + Module Structure: Establish a solid core of fundamental materials science and chemistry. Around this, create a suite of elective "innovation modules" that students can combine based on their interests.

Module: Materials Informatics & AI: Covers data-driven materials discovery, machine learning for property prediction.

Module: Scaling & Manufacturing: Covers process engineering, techno-economic analysis, green chemistry principles.

Module: Innovation Ecosystem & Commercialization: Covers IP strategy, venture capital for hard tech, regulatory affairs for materials.

Project-Based Learning as Curriculum Spine: Introduce a mandatory, multi-semester "Capstone Innovation Project" that runs parallel to coursework. Student teams, ideally interdisciplinary (e.g., combining materials, chemical engineering, and business students), work on a real-world challenge posed by an industry partner or based on faculty research with commercial potential. This project becomes the integrative experience where technical knowledge, entrepreneurial skills, and digital tools are applied in concert.

Digital Content Integration: Mandate the inclusion of digital learning objects in every core course syllabus. This could be a VR walkthrough of a semiconductor fab, an online simulation of a polymerization reactor, or an AI-powered tutor for phase diagram problems.

2.3 Reforming Teaching Methods: Championing Active and Blended Learning

Faculty must be empowered and incentivized to adopt new pedagogical roles as facilitators and coaches.

Faculty Development Programs: Institute mandatory training workshops on active learning strategies (PBL, case method, flipped classroom), effective use of digital teaching tools, and basics of technology commercialization. Create incentives (teaching awards, consideration in promotion) for excellence in innovative teaching.

Industry Practitioner Involvement: Systematically invite industry engineers, R&D managers, and materials startup founders as guest lecturers, project mentors, and adjunct faculty. This brings real-world context and credibility into the classroom.

Hybrid Makerspace-Laboratories: Transform traditional teaching labs into "Innovation Labs" or makerspaces. Equip them not only with analytical instruments but also with rapid prototyping tools (3D printers for device housings), basic materials processing equipment, and high-performance computing terminals for simulation work. These spaces should encourage tinkering, prototyping, and iterative design.

Leverage Online Platforms for Scale and Collaboration: Use MOOCs or specialized online platforms (e.g., Coursera's materials science courses, Kadenze's digital fabrication content) to supplement core learning. Use collaborative software (like GitHub for code/data, Notion for project management) to manage team projects, fostering digital collaboration skills.

2.4 Revolutionizing Evaluation: Implementing a Multidimensional Assurance System

Assessment must evolve to measure what truly matters for innovation.

Diversified Assessment Portfolio: Replace or heavily supplement final exams with a portfolio of assessments: technical reports on lab projects, pitches for a material-based startup idea, reflective journals on the design process, peer assessments of teamwork, and public presentations of capstone projects to an expert panel.

Competency Rubrics: Develop detailed, transparent rubrics for assessing competencies like "experimental design," "ethical reasoning," or "communication." These rubrics should be shared with students at the outset of assignments, making expectations clear and assessment objective.

Institutionalized Feedback Loops: Establish an Office of Educational Data and Analytics. Its mandate is to annually collect, analyze, and report on:

Graduate Outcomes: Employment status, job roles, employer type, further studies, entrepreneurial activities (tracked at 1, 3, and 5 years post-graduation).

Employer Surveys: Systematic feedback on the strengths and weaknesses of graduates.

Current Student Experience Data: Course evaluations focused on skill development and engagement.

Closed-Loop Continuous Improvement: This data must feed directly into a formal curriculum committee review process. The committee's task is to answer: Are our graduates achieving the objectives? Where are the gaps? What curricular or pedagogical adjustments are needed? This creates a responsive, data-driven system for perpetual alignment with the needs of New quality productive forces.

3. Conclusion

Cultivating innovative and entrepreneurial talents in materials chemistry capable of driving and thriving within the era of New quality productive forces is a complex yet imperative systemic undertaking. It requires moving beyond piecemeal initiatives like occasional guest lectures or business plan competitions. The transformation demands a fundamental re-imagining of the educational ecosystem—its goals, its content, its methods, and its metrics for success.

The holistic framework proposed in this paper advocates for such a systemic shift. By reconstructing objectives in partnership with industry, redesigning the curriculum into a dynamic digital-I&E matrix, reforming pedagogy towards active and blended learning, and reinventing evaluation around competencies and continuous feedback, materials chemistry programs can bridge the existing gap. This approach leverages educational digital transformation not as an add-on, but as an enabling backbone for deeper, more contextualized, and more accessible learning.

The successful implementation of this model hinges on strong institutional commitment, investment in faculty development and digital-physical infrastructure, and the cultivation of deep, sustained partnerships with the materials industry and entrepreneurial community. Future research should focus on longitudinally tracking the impact of such integrated reforms on graduate career trajectories, their propensity for innovation, and their contribution to the materials-based industries central to New quality productive forces. By embracing this challenge, universities can ensure that materials chemistry education remains a vibrant source of talent and innovation, providing the essential human capital to power sustainable and high-quality economic development in the decades to come.

Funding:

This work was supported by the 2022 Key Entrusted Project of Higher Education Teaching Reform Research in Heilongjiang Province (Grant No. SJGZ20220081)

References:

[1]LU Yuzheng. Impacts, Challenges and Responses of the Emergence of New Quality Productive

Forces on Undergraduate Level Vocational Education Talent Cultivation Model. Contemporary Vocational Education. 2024，3: 14-22.

[2]Jiang Wenkui. Research on the Practical Path of New Quality Productivity Leading Education Innovation. Journal of Qiqihar University (Phi & Soc Sci). 2024，5: 60-63.

[3]Zhang Hongrui，Xiao Mingxing. Exploration and Practice on the Integration of Pharmacy Educationwith Entrepreneurship in the Era of Original Innovation. University Chemistry. 2024，12: 23-31.

[4]WANG Dan，KANG Yaqi，TAN Ya，LIU Xuemei，HU Ge. A Discussion on the Cultivation of Innovative and Entrepreneurial Talents Based on Discipline Competition and the Integration of Industry and Education. Higher Education in Chemical Engineering. 2024，2: 104-109.

[5]HUANG Junliang. Research on the Path of Cultivating Innovative and Entrepreneurial Talents in Universities in the Era of Digital Intelligence. Journal of Chinese College Student Employment. 2024，4: 11-15.

[6]HAN Ping，YAO Zhilong. Research on Education and Teaching Reform Based on the Concept of Innovation and Entrepreneurship Education. The Theory and Practice of Innovation and Entrepreneurship. 2024，8: 31-34.

[7]SHEN Jian，LIU Dejiang，XUE Chunmei，CONG Huiying，TIAN Lijuan. Research on the Cultivation Path of Applied Talents for Biotechnology Major with the Improvement of Innovation and Entrepreneurship Ability as the Orientation. 2024，6: 91-93.