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Research on the Teaching Reform of Building Materials Courses Oriented Toward Innovation and Entrepreneurship

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ABSTRACT

With the advancement of green construction and the reform of innovation and entrepreneurship education in higher education, the teaching of building materials has gradually shifted from knowledge transmission to competence development. As a fundamental course in architecture and related disciplines, the teaching reform of building materials plays a crucial role in enhancing students' innovative thinking and practical abilities. This study explores the integration of innovation and entrepreneurship education into the teaching of building materials through literature analysis and case studies. It establishes a theoretical framework based on constructivism and experiential learning theory and proposes a three-level teaching system of "knowledge learning–practical application–innovative transformation." By employing project-based learning (PBL) and university–industry collaboration models, the study aims to cultivate students' systematic abilities from material cognition to innovative application. The research emphasizes that the transformation of the teacher's role and institutional support are key to successful implementation. The results demonstrate that this integrated model effectively promotes students' innovative thinking and practical competence, providing a feasible path for the deep integration of building materials education and innovation and entrepreneurship education.

KEYWORDS

Building materials teaching; Innovation and entrepreneurship education; Curriculum reform; Project-based learning; University-industry collaboration

1 Introduction

1.1 Research Background

Building materials, as a fundamental professional course for majors such as architecture, civil engineering, and environmental design, enable students to understand building performance, structural principles, and sustainable design. With the global development of the construction industry, the focus of building materials research has shifted toward green, intelligent, and sustainable materials. The continuous emergence of new materials places new demands on higher education: teachers must not only transmit knowledge but also cultivate students' comprehensive understanding of material application, innovative thinking, and practical capabilities.

The integration of professional education and innovation–entrepreneurship education primarily involves rethinking educational philosophy, curriculum design, and practical content, with the goal of cultivating interdisciplinary talents equipped with both professional expertise and entrepreneurial competence [1]. In engineering education, curriculum reform has evolved from traditional knowledge-based instruction to innovation-oriented and practice-centered education, and architectural programs are no exception. However, the teaching of building materials still suffers from outdated methods, weak innovation awareness among students, and limited hands-on opportunities.

Meanwhile, the construction industry, characterized by technological intensity and creative orientation, is inherently entrepreneurial—from material research to green construction and industrialization. Therefore, exploring the integration of building materials education with innovation and entrepreneurship training not only helps produce technologically innovative and application-oriented professionals but also injects educational vitality into the development of the industry.

1.2 Research Significance

1.2.1 Academic Significance

This study seeks to establish a cross-disciplinary teaching model that integrates building materials education with innovation and entrepreneurship education. By analyzing the knowledge structure of building materials courses and the competency orientation of innovation education, it fills a research gap between "curriculum content" and "innovation capability cultivation" in architectural education. Supported by educational theory, engineering pedagogy, and innovation management, this study contributes new perspectives and empirical evidence for future research on engineering education reform and applied talent cultivation.

1.2.2 Practical Significance

For teaching practice, this research provides valuable references for curriculum design in architecture-related programs. The integration of "building materials + innovation and entrepreneurship" facilitates the realization of the educational principle that "what is taught should align with industrial needs" and emphasizes the cultivation of students' innovative thinking, entrepreneurial awareness, and practical competence.

The findings can be extended to architecture, civil engineering, and environmental design programs, promoting the construction and enrichment of innovation and entrepreneurship education systems in higher education.

1.3 Research Status

In China, the teaching of building materials has long been dominated by knowledge delivery and experimental validation, with limited integration of innovation and entrepreneurship education. Although some universities have begun incorporating topics such as green materials and low-carbon construction, or introduced project-based competitions and innovation training, several issues remain:

(1) The update pace of teaching content lags behind technological advancement in material science.

(2) Teaching models still rely on "lecture + verification experiments," lacking problem-oriented learning.

(3) Teachers seldom receive systematic innovation – entrepreneurship training, resulting in limited classroom innovation.

(4) Entrepreneurship education is separated from professional courses, lacking mutual integration and synergy [2].

2 Theoretical Foundation

2.1 Knowledge System and Competency Requirements in Building Materials Education

The building materials course serves as a core foundational subject for majors such as architecture, civil engineering, and environmental design. Its teaching objectives go beyond the transmission of physical, chemical, and mechanical properties of materials; more importantly, they aim to help students understand the relationship between materials and architectural functions, aesthetics, structures, safety, and sustainability.

Within the context of the *New Engineering Education Initiative* proposed by China's Ministry of Education, the focus of engineering education has shifted from "knowledge transmission" to "competence cultivation" and "value formation." Therefore, the teaching of building materials must align with the overarching goal of cultivating innovative architectural talents.

2.1.1 Knowledge System Framework

The knowledge system of building materials typically includes the following dimensions [3]:

Material classification and basic properties: The composition and characteristics of inorganic binders, metals, wood, and polymer materials.

Material processing and application: The application and construction technologies of materials from laboratory research to engineering practice.

Sustainability and green performance: Life-cycle analysis, energy efficiency, and environmental performance of materials.

New and intelligent materials: Cutting-edge technologies such as nanomaterials, photoresponsive materials, and recycled concrete.

This knowledge framework requires students not only to understand theoretical principles but also to develop comprehensive capabilities in material selection, performance evaluation, and innovative design.

2.1.2 Competency-oriented Teaching

Under the framework of Outcome-Based Education (OBE), curriculum design must start with clearly defined learning outcomes [4]. For building materials education, three primary course-level learning outcomes are identified:

(1) Understanding material properties and engineering applications;

(2) Mastering material design, innovation, and modification skills;

(3) Developing fundamental competencies in material innovation and entrepreneurial application within construction contexts.

2.2 Theoretical Framework of Innovation and Entrepreneurship Education

2.2.1 Core Concepts of Innovation and Entrepreneurship Education

Originating in the United States in the 1960s, Innovation and Entrepreneurship Education (IEE) aims to cultivate students' creativity, risk-taking, and practical market orientation. Schumpeter's notion of innovation as "new combinations" — encompassing new products, technologies, markets, and organizations — highlights that IEE should guide students from "good ideas" to "good businesses," realizing the transformation from creativity to value creation.

2.2.2 Triple Helix Model

Etzkowitz and Leydesdorff's Triple Helix Model (2000) emphasizes the dynamic interaction among universities, industries, and governments as a driving force for innovation and knowledge transfer [5]. In the context of building materials education, this model can be operationalized through the establishment of university – industry joint laboratories, material innovation centers, and collaborative research projects, fostering a symbiotic relationship between education and industry and enabling students to translate innovation into practice [6].

2.3 Theoretical Foundations of Educational Integration

2.3.1 Constructivist Learning Theory

Represented by scholars such as Jonassen, the Constructivist Learning Theory [7] posits that learning is an active, self-constructed process rather than passive knowledge reception. Learners acquire knowledge through exploration, collaboration, and reflection in authentic contexts [8]. Applied to building materials education, this theory suggests that teachers should adopt project-based (PBL) or context-driven teaching methods, enabling students to construct their understanding through material experiments, architectural design, and innovation project practices.

2.3.2 CDIO Engineering Education model

The CDIO Model (*Conceive–Design–Implement–Operate*), initiated by the Massachusetts Institute of Technology (MIT) and Chalmers University of Technology, is one of the most internationally recognized standards in engineering education [9].Its core philosophy is to enable students to learn and apply knowledge throughout a complete engineering process rather than merely understanding theories.In building materials education, the CDIO approach can be reflected in the following four stages:

Conceive (C): Identify material-related problems and innovation needs.

Design (D): Develop innovative material solutions.

Implement (I): Validate solutions through experiments or prototyping.

Operate (O): Test and optimize results in real projects or competitions.

This model helps cultivate students' systematic engineering thinking, teamwork, and innovative execution skills.

3 Current Status and Problems in Building Materials Education

3.1 Overall Situation of Building Materials Teaching

3.1.1 Course Positioning and Teaching Objectives

At present, building materials courses in Chinese universities are commonly offered to undergraduates and postgraduates in programs such as architecture, civil engineering, urban planning, and environmental design. They are generally positioned as fundamental theoretical and experimental courses.The main teaching objectives are as follows:

To enable students to master the physical and chemical properties of commonly used building materials;

To understand the relationships among materials, structural systems, construction technologies, and architectural functions;

To cultivate students' abilities in material selection and engineering application.

However, such objectives often focus excessively on theoretical mastery, while neglecting creativity, problem-solving skills, and entrepreneurial awareness.

3.1.2 Teaching Content and Textbook Systems

The current textbook system for building materials remains outdated. Traditional materials—such as cement, concrete, steel, and wood—still dominate teaching content, while topics on green materials, intelligent materials, and new energy-based materials occupy only a small proportion.

Most teaching still follows a "material properties → experimental verification" framework, with limited inclusion of content related to industrial innovation, sustainability, or emerging technologies. This disconnection from contemporary industry development results in a significant gap between teaching content and real-world applications.

Cutting-edge areas such as 3D printing of construction materials, composite materials, renewable ecological materials, and biodegradable materials are rarely introduced in existing textbooks, reflecting a lag in the responsiveness of the curriculum to technological progress [10].

3.1.3 Teaching Methods and Assessment Models

Current instructional methods are predominantly based on lectures and verification experiments, supplemented by course papers or material reports. The practical component focuses on simple, closed experiments rather than open-ended or collaborative projects. Few opportunities exist for students to engage with real industrial cases or cross-disciplinary problem-solving.

Assessment methods also remain traditional, primarily relying on final written examinations and experimental reports. This evaluation approach fails to assess students' innovative thinking, project development abilities, teamwork, and entrepreneurial awareness. Consequently, students often cannot achieve the "knowledge – innovation – application" learning loop that integrated education aims to establish.

3.2 Analysis of Teachers' and Students' Perspectives

Drawing from surveys and interviews conducted among faculty and students from several architecture-oriented universities—such as Huazhong University of Science and Technology, Tongji University, and Harbin Institute of Technology—the following key observations were made:

3.2.1 Teacher Perspective

Most instructors possess strong expertise in material science and engineering fundamentals but often lack systematic understanding of innovation and entrepreneurship pedagogy. Their teaching responsibilities primarily center on theoretical instruction and scientific research, with limited engagement in cross-disciplinary collaboration or industry partnership. Furthermore, institutional incentive mechanisms emphasize research output and teaching hours over teaching innovation or entrepreneurial mentorship, resulting in a shortage of motivation and capacity for pedagogical reform.

3.2.2 Student Perspective

Students generally perceive the course as "highly theoretical, low in engagement, and weakly connected to architectural innovation." Common feedback includes the following:

"The course focuses too much on theory and lacks practical or design-related content."

"We have few opportunities for hands-on exploration or creative experimentation."

"Although we are interested in topics like green architecture and sustainable design, there is little guidance or support from instructors to explore these areas."

Such feedback reveals a mismatch between students' learning motivations and the course's teaching approach, leading to diminished engagement and limited innovation outcomes.

4 Integration Pathways Between Building Materials Education and Innovation – entrepreneurship Education

4.1 Overall Concept of Integration

The integration of building materials education with innovation and entrepreneurship should adhere to the concept of "innovation as the core, projects as the platform, and university – industry collaboration as the support." This approach aims to construct an educational model that combines professional knowledge, innovative thinking, project practice, and entrepreneurial transformation.

By redesigning and optimizing the teaching content, instructional methods, evaluation mechanisms, and learning environments, students can be guided to transition from material learners to material creators and entrepreneurs. The essence of this reform lies in transforming the course from a purely knowledge-based subject into a competence-oriented and practice-driven educational ecosystem.

4.2 Optimization and Integration of Teaching Content

4.2.1 Establishing a Four-level Curriculum Structure: "Foundation–frontier–application–entrepreneurship"

Foundation Level: Focuses on traditional materials' properties, processing techniques, and industry standards.

Frontier Level: Introduces the latest developments in green materials, smart materials, renewable energy-based materials, and digital construction materials.

Application Level: Centers on the analysis of innovative material applications in architectural design and construction.

Entrepreneurship Level: Involves product commercialization, patent transformation, and business model design, helping students link material innovation to industrial and entrepreneurial value creation.

This hierarchical structure builds a progressive system where students' learning evolves from theoretical understanding to innovative application and eventually entrepreneurial realization.

4.2.2 Incorporating Industrial Cases and Research Achievements

To bridge the gap between education and industry, the curriculum should include cutting-edge case studies from research institutions and enterprises.For instance, topics such as the application of carbon-fiber-reinforced composites in building structures or recycled concrete technologies can help students recognize the connection between material innovation and market potential. Such integration not only enriches classroom teaching but also reinforces students' awareness of how innovation contributes to industrial advancement and sustainability.

4.3 Innovation in teaching Methods

4.3.1 Project-Based Learning (PBL)

Under the PBL model, students form teams to investigate real-world architectural challenges, such as the design of sustainable materials or energy-efficient building systems.Through research, experimentation, and outcome presentation, students experience the full process from problem identification to solution implementation, thereby completing the knowledge – competence – innovation learning cycle. This method fosters hands-on learning, teamwork, and reflective practice, making it a powerful bridge between theory and innovation.

4.3.2 Design Thinking–oriented Instruction

Integrating Design Thinking into building materials teaching enables students to approach architectural problems from a human-centered perspective.Following the five stages—Empathize, Define, Ideate, Prototype, and Test—students are guided to explore users' needs and environmental contexts before developing creative solutions. For example, a project themed "Recycled Materials for Urban Regeneration" can encourage students to combine user experience, ecological awareness, and innovative material design, thereby enhancing both creativity and social responsibility.

4.3.3 Blended and Digital Learning Approaches

Blended learning integrates online digital resources (such as building materials databases, MOOCs, and virtual simulation labs) with offline practice-based instruction. By leveraging AIGC (AI-Generated Content) tools and BIM (Building Information Modeling) technologies, students can visualize material properties, simulate construction processes, and engage in interactive learning environments.Such digital empowerment not only enhances engagement and accessibility but also aligns architectural education with the emerging trend of intelligent construction [11].

4.4 Practical Teaching and University–industry Collaboration Mechanisms

4.4.1 Establishment of "Material Innovation Laboratories" and "Entrepreneurship Incubation Platforms"

To deepen the integration between education and industry, universities should jointly establish University – Industry Collaborative Laboratories and Material Innovation Centers with construction material enterprises and research institutions.These platforms provide students with authentic R&D environments and industry-based practical scenarios, allowing them to engage in the complete process of material innovation—from concept to testing and industrial application.

Furthermore, by relying on university innovation and entrepreneurship schools, an incubation mechanism for material innovation projects can be developed to connect classroom learning with real entrepreneurial resources. This mechanism enables students to transform research outcomes into viable innovations and startups.

4.4.2 Competitions and Project-Based Training

National-level competitions such as the "Internet+ College Students' Innovation and Entrepreneurship Competition" and the "Challenge Cup" offer effective platforms for integrating building materials education with entrepreneurial practice.Students are encouraged to transform course projects into innovation and entrepreneurship proposals, applying the knowledge and skills acquired from the course.Through mentorship and team-based project management, students can develop project planning, collaborative design, and execution capabilities, which are essential for bridging academic learning and real-world problem-solving.

4.4.3 Dual-mentor System: Academic and Industrial Guidance

Introducing a dual-mentor system, in which enterprise experts and designers co-teach with university instructors, ensures the effective combination of theoretical guidance and industrial practice. Teachers should also participate in enterprise innovation projects to enhance their own practical understanding and feed this experience back into classroom teaching. This dual mentorship structure creates a mutually reinforcing relationship between education and industry, strengthening the relevance and applicability of the curriculum.

5 Conclusions and Prospects

The core of teaching reform in building materials lies in achieving the three-dimensional transformation of "knowledge-ability-innovation." A three-tier framework system for the teaching content of building materials courses, guided by innovation and entrepreneurship, is constructed as "basic theory – application practice – innovation transformation." The shift in the role of teachers is key to achieving integration. The integrated teaching of "building materials + innovation and entrepreneurship" has a significant effect on ability cultivation. Teaching reform in building materials requires a multi-dimensional support system. Future research can be further deepened in the following directions: establishing a teaching evaluation system for innovation and entrepreneurship-oriented building materials courses. Based on educational evaluation and innovation management, an evaluation indicator system for innovation and entrepreneurship capabilities should be developed to assess students' innovative thinking, practical skills, and entrepreneurial abilities, serving as a reference for teaching assessment. Conduct interdisciplinary teaching research. Explore innovative teaching models that integrate building materials with architecture, environmental science, digital construction, and other disciplines, forming a multi-disciplinary collaborative innovation teaching ecosystem to promote architectural education reform. Vigorously promote the integration of industry, academia, and research education. Strengthen close collaboration with construction companies, building materials research institutions, and enterprise incubation bases to ensure that educational outcomes directly serve society and enterprises. Empower building materials teaching with AIGC and digital technologies. Technologies such as AIGC (AI-Generated Content), BIM (Building Information Modeling), and virtual simulation have broad application prospects in building materials and construction. Therefore, in future teaching, intelligent simulation, virtual experiments, data analysis, and other technologies can be used to enhance the visibility and interactivity of teaching, thereby empowering innovation and entrepreneurship education.

About the Author

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