Research on the Integration of Engineering Culture Introduction Course and Innovation and Entrepreneurship Education

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Abstract: As the core carrier of general education for engineering majors, the Engineering Culture Introduction course plays an irreplaceable role in inheriting the engineering spirit and shaping professional literacy. However, the traditional curriculum model has such problems as the disconnection between theory and practice and the lack of cultivation of innovation and entrepreneurship capabilities. This paper integrates service-learning with the 5E (Engage, Explore, Explain, Elaborate, Evaluate) teaching model to develop an integration framework for the Introduction to Engineering Culture course and innovation and entrepreneurship education. Through the reconstruction of curriculum objectives, optimization of the content system, innovation of teaching models and improvement of the evaluation mechanism, this framework achieves the synergistic development of engineering culture inheritance and innovation and entrepreneurship capability cultivation. This integrated model enhances students' problem-solving ability, knowledge application ability, empathy and social responsibility, thereby offering a feasible path for the reform of innovation and entrepreneurship education in engineering general education courses.

Keywords: Engineering Culture; Innovation and Entrepreneurship Education; Service-Learning; 5E Teaching Model; Curriculum Integration

1. Introduction

Engineering culture is a collection of values, ways of thinking, behavioral norms, and technical systems formed by the long-term accumulation of engineering practice. Its core spirits of innovation, craftsmanship, and collaboration serve as an important cultural foundation for innovation and entrepreneurship education. As a bridge connecting engineering technology and humanistic literacy, the Engineering Culture Introduction course is not only a key component of the engineering education system, but also the core carrier for engineering education to achieve the training goal of "value guidance, competence-oriented, and knowledge-based". It meets the needs of cultivating students' professional ethics and cultural identity in engineering education, makes up for the shortcomings of traditional engineering professional education that focuses on technical skills while neglecting humanistic heritage and value shaping, and provides important support for the transformation of engineering education towards "compound talent training". This course undertakes the important mission of cultivating students' engineering ethics, social responsibility, and professional literacy, and its teaching quality directly affects the comprehensive effect of talent training in engineering education.

However, most engineering education courses in current universities have obvious limitations: the teaching content focuses on the theoretical teaching of engineering history and ethical provisions, which is disconnected from innovation and entrepreneurship practice; the teaching methods are dominated by one-way indoctrination, lacking the design of experiential and inquiry-based learning; the evaluation system focuses on knowledge memory, ignoring the comprehensive consideration of ability literacy and innovative practice [1,2]. Under the background of the

innovation-driven development strategy, integrating innovation and entrepreneurship education into the Engineering Culture Introduction course is not only an inevitable choice to respond to China's talent training needs, but also a practical path to solve the development dilemma of the course itself and improve the engineering education system [3]. A study by the Hong Kong Polytechnic University shows that integrating cutting-edge technologies with social entrepreneurship goals through the combination of service-learning and the 5E model can effectively improve students' core competencies such as problem-solving ability, empathy, and social responsibility [4]. This experience provides important enlightenment for curriculum reform: engineering culture is not only "static" knowledge inherited from history, but also a "dynamic" resource that drives innovation and solves social problems [5]. Based on this, this paper constructs a service-learning-oriented curriculum integration framework to realize the deep coordination of engineering culture inheritance and innovation and entrepreneurship ability training, providing support for cultivating compound engineering talents who "understand culture, are good at innovation, and dare to start businesses".

2. Theoretical Basis and Core Objectives of Curriculum Integration

2.1 Theoretical Basis

Service-Learning (SL) Concept: It organically combines community service with academic learning, enabling students to deepen their understanding and application of knowledge in the practice of meeting social needs, while cultivating their social responsibility and practical ability, which is highly consistent with the core connotation of engineering culture of "serving society" [6]. The 5E Teaching Model includes five links: Engage, Explore, Explain, Elaborate, and Evaluate, providing a step-by-step inquiry-based teaching process for the course and supporting the iterative learning process required for innovation and entrepreneurship. Combining technical education with social values, guiding students to use professional skills to solve real social problems, provides a core orientation for the integration of engineering culture and innovation and entrepreneurship education. The social entrepreneurship theory is adopted, which takes solving social challenges as the core goal, focuses on the unity of social value and economic sustainability, and provides a practical direction and value coordinate for curriculum integration [7].

2.2 Core Objectives

Knowledge Objectives: Students need to master the core connotation, historical evolution, and era characteristics of engineering culture, understand key concepts such as craftsmanship spirit and engineering ethics; at the same time, master the basic principles, processes, and methods of innovation and entrepreneurship, and clarify the internal connection between engineering culture and innovation and entrepreneurship. Ability Objectives: Cultivate students' ability to identify and solve engineering problems, innovative thinking and design ability, knowledge application and technology transformation ability, team cooperation and community communication ability, so as to realize the transformation of engineering culture knowledge into innovation and entrepreneurship ability. Literacy Objectives: Shape students' social responsibility, engineering ethics literacy, empathy, and innovation and entrepreneurship spirit, establish the values of "serving society with engineering and leading development with innovation", and lay the foundation for becoming responsible engineering entrepreneurs [8,9].

3. Reconstruction of the Content System for Curriculum Integration

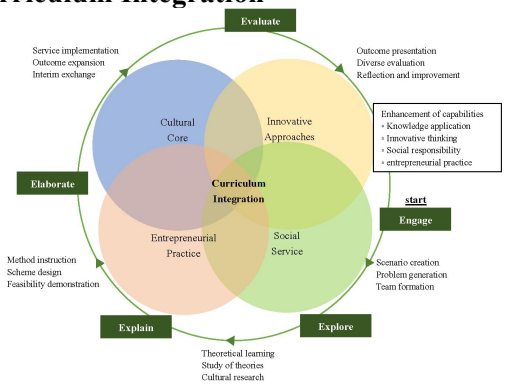

Figure 1. Proposed Teaching and Learning Cycle

Based on the core logic of service-learning and the 5E model, the traditional linear content structure is broken, and a four-in-one curriculum content system of "cultural core - innovation method - entrepreneurial practice -

social service" is constructed to realize the organic connection between engineering culture and innovation and entrepreneurship education [10], as shown in Figure 1.

3.1 Core Connotation and Innovation Genes of Engineering Culture

Core Elements of Engineering Culture: Systematically explain engineering values, craftsmanship spirit, collaborative culture, ethical norms, etc., focus on analyzing the core role of the innovation spirit in the development of engineering, and reveal the internal connection between engineering culture and innovation by combining classic engineering cases at all times and in all over the world (such as traditional water conservancy projects and modern aerospace projects) [11]. Era Evolution of Engineering Culture: Discuss the changes of engineering culture under the background of Industry 4.0, artificial intelligence, and sustainable development, analyze the emerging cultural characteristics such as green engineering and digital engineering, and clarify the era direction of innovation and entrepreneurship. Cultural Foundation of Social Entrepreneurship: Interpret the integration points between engineering culture and social entrepreneurship, such as the unity of craftsmanship spirit and entrepreneurial quality, the correlation between collaborative culture and team entrepreneurship, and the consistency between ethical culture and sustainable entrepreneurship [12].

3.2 Innovation Method Practice Based on Service-Learning

Engineering Innovation Thinking and Tools: Introduce innovative methods such as design thinking, reverse engineering, and cross-border integration, analyze their application scenarios combined with engineering culture cases, such as integrating craftsmanship spirit into product iteration and optimization [13]. Social Demand Identification and Analysis: Drawing on the concept of service-learning, guide students to conduct in-depth community research, identify the engineering needs of vulnerable groups (such as the disabled and the elderly), and cultivate demand insight ability [14]. Technological Innovation and Cultural Integration: Combine cutting-edge technologies such as AI, virtual reality, and computer vision to design innovative solutions that meet social needs, such as auxiliary engineering technologies for special groups and environmental protection engineering solutions based on green culture.

3.3 Entrepreneurial Practice from the Perspective of Engineering Culture

Core Logic of Social Entrepreneurship: Explain the characteristics, processes, and key links of social entrepreneurship, focus on analyzing core issues such as technology transformation, market positioning, and sustainable operation, and emphasize the leading role of engineering culture in entrepreneurship. Business Plan Design: Guide students to form teams to design social entrepreneurship plans based on community needs and engineering culture concepts, covering project background, technical solutions, social benefits, operation modes, etc [15]. Engineering Entrepreneurship Ethics and Responsibility: Discuss the ethical dilemmas in engineering entrepreneurship, such as technical application risks, intellectual property protection, and fulfillment of social responsibilities, and guide students to establish the concept of compliant entrepreneurship and responsible innovation [16].

3.4 Practical Application Oriented by Service-Learning

Community Service Project Implementation: Organize students to connect with community needs, transform business plans into small-scale service projects, such as developing auxiliary tools for the disabled and designing energy-saving engineering schemes for communities, so as to test the feasibility of innovative schemes in practice. Achievement Iteration and Optimization: Based on community feedback and practical reflection, iteratively optimize innovative schemes and business plans, and cultivate students' reflective ability and awareness of continuous improvement. Engineering Culture Dissemination and Promotion: Disseminate engineering culture and innovation and entrepreneurship concepts through achievement exhibitions and community lectures, and improve students' expression ability and social influence.

4. Innovation of the Teaching Model for Curriculum Integration

Drawing on the experience of integrating service-learning and the 5E model, a five-stage

teaching model of "engagement - exploration - design - practice - evaluation" is constructed to realize the deep integration of theoretical learning and practical application, classroom teaching and community service.

4.1 Stage 1: Situation Introduction and Problem Generation (Engage)

Situation Creation: Create real teaching situations through engineering entrepreneurship case documentaries, community demand sharing sessions, entrepreneur lectures, etc., such as playing documentaries on the living difficulties of special groups and inviting social entrepreneurs to share their experiences [17]. Problem Generation: Guide students to put forward problems combined with the situation, such as "How to improve the home safety of the elderly through engineering technology?" and "What are the possible community environmental protection entrepreneurship projects based on green engineering culture?" to stimulate their desire for exploration. Team Formation: Students form learning teams according to their interests and professional strengths, clarify team goals and division of labor, and lay the foundation for subsequent exploration and practice.

4.2 Stage 2: Cultural Exploration and Demand Analysis (Explore)

Theoretical Learning: Adopt a mixed online and offline teaching method, students learn the basic theories of engineering culture and innovation and entrepreneurship through MOOCs and micro-courses online, and deepen their understanding through special lectures and group discussions offline. Cultural Research: Organize students to carry out engineering culture research, such as visiting traditional engineering enterprises and investigating modern science and technology entrepreneurship parks, to deeply understand the practical forms and innovative applications of engineering culture. Demand Mining: Teams conduct field research in the community, identify real needs through interviews, observations and other methods, and clarify the core demands and potential expectations of service objects.

4.3 Stage 3: Scheme Design and Method Acquisition (Explain)

Method Teaching: Teachers explain key contents such as innovative methods, business plan writing, and technology transformation paths, and analyze the integration mode of engineering culture in scheme design combined with cases. Scheme Design: Based on the results of demand research, teams design innovative schemes and business plans, clarify technical routes, implementation steps, expected effects and social benefits, and teachers provide targeted guidance. Feasibility Argumentation: Organize scheme demonstration meetings, invite teachers, industry experts, and community representatives to comment on the technical feasibility and social value of the schemes, and put forward improvement suggestions.

4.4 Stage 4: Practical Application and Achievement Expansion (Elaborate)

Service Implementation: Teams put the schemes into practice and carry out community service projects, such as developing and testing auxiliary tool prototypes and implementing small-scale engineering services, so as to flexibly apply the learned knowledge to solve practical problems in practice. Achievement Expansion: Encourage students to participate in competitions such as the "Internet +" College Student Innovation and Entrepreneurship Competition and Engineering Innovation Design Competition, promote learning and innovation through competitions; connect with enterprises and incubator resources to promote the landing and transformation of excellent projects [18]. Mid-term Exchange: Organize mid-term report meetings, where each team shares practical progress, problems encountered and solutions, promoting communication and cooperation between teams.

4.5 Stage 5: Evaluation Reflection and Iterative Optimization (Evaluate)

Achievement Display: Each team displays learning achievements through product demonstrations, entrepreneurial roadshows, research report presentations, etc., such as displaying intelligent auxiliary equipment prototypes and conducting social entrepreneurship plan roadshows. Diversified Evaluation: Adopt a diversified evaluation method combining student self-evaluation, team mutual evaluation, teacher evaluation, and community feedback, and conduct a comprehensive evaluation from the dimensions

of knowledge mastery, ability improvement, and social value. Reflection and Improvement: Guide students to conduct critical reflection, summarize the experiences and lessons in practice, analyze the advantages and disadvantages of the scheme, and carry out iterative optimization combined with evaluation feedback to form an improved scheme or plan.

5. Improvement of the Evaluation System for Curriculum Integration

Breaking the traditional evaluation model dominated by examination results, a trinity diversified evaluation system of "process evaluation + achievement evaluation + developmental evaluation" is constructed to comprehensively reflect the actual effect of curriculum integration.

5.1 Process Evaluation (40%)

Focus on evaluating students' participation and performance in the course learning process: Classroom Participation: Online learning completion, offline classroom discussion speeches, special lecture interactions, etc. (10%); Practice Performance: Community research participation, service project contribution, team cooperation performance, etc. (15%); Reflection Records: Learning logs, practical reflection reports, scheme iteration records, etc. (15%).

5.2 Achievement Evaluation (40%)

Focus on students' learning achievements and practical outputs: Stage Achievements: Research reports, demand analysis reports, innovative scheme drafts, etc. (15%); Final Achievements: Innovative product prototypes, business plans, service project summary reports, achievement display and roadshow performance, etc. (25%), focusing on evaluating the innovation, feasibility, social value, and engineering culture integration of the achievements.

5.3 Developmental Evaluation (20%)

Focus on students' personal growth and long-term development: Ability Improvement: Evaluate students' improvement in problem-solving, knowledge application, empathy, social responsibility and other dimensions through pre-test and post-test comparison (using the S-LOMS scale) (10%); Development Potential: Evaluate the development trend of students' innovative thinking, entrepreneurial intention, and engineering culture literacy through comprehensive assessment by teacher observation and team feedback (10%).

6. Conclusion

The integration of the Engineering Culture Introduction course and innovation and entrepreneurship education under the orientation of service-learning realizes the deep coordination of engineering culture inheritance and innovation and entrepreneurship ability training by reconstructing the curriculum content, innovating the teaching model, and improving the evaluation system. This integration model takes service-learning as the carrier, the 5E model as the teaching framework, and social needs as the guide, effectively improving students' knowledge application ability, innovative thinking, social responsibility, and entrepreneurial practical ability, and breaking through the limitations of traditional courses. Practice shows that the integration of engineering culture and innovation and entrepreneurship education not only enriches the connotation and effectiveness of the Engineering Culture Introduction course, but also provides a feasible path for the innovation and entrepreneurship education reform of engineering general education courses. In the future, it is necessary to further optimize the curriculum system, strengthen resource integration, deepen the industry-university-community collaborative education mechanism, continuously improve the scientificity and practicality of the course, cultivate more high-quality engineering talents who understand engineering culture and have innovation and entrepreneurship capabilities, and provide strong support for the innovation-driven development strategy and the construction of a manufacturing power.

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