An Empirical Study on the Improvement of Students' Ability by the "Three-Chain Integration" Teaching Model of Surveying and Mapping Engineering in Applied Universities: A Case Study of Universities in Heilongjiang Province

Aimin Wang*
Heilongjiang University of Technology, Jixi, Heilongjiang, China
**Corresponding Author*

Abstract: In view of the problems of disconnection between professional education and innovation and entrepreneurship training and insufficient practical ability training in surveying and mapping engineering majors in application-oriented universities, this study constructs a "three-chain integration" teaching model. This model includes three core components, namely, "three-chain integrated knowledge system", "industry-university-research-service-competition and innovation integration practice system" and "smart teaching and auxiliary system". Using a mixed research method, 348 students (2018-2024) from three universities were used as the research objects, and the structural equation model (SEM) and thematic analysis method were used to verify the effectiveness and mechanism of the model. The results showed that the performance of the students in the experimental group was significantly better than that of the control group in three dimensions: professional skills, innovation ability and entrepreneurial literacy. Knowledge integration and practical participation are the key mediating variables for ability improvement, and the intensity of school-enterprise cooperation has a significant moderating effect on teaching effect. This study breaks through the traditional engineering education model and provides a theoretical and practical reference for local colleges and universities to cultivate compound surveying and mapping talents with professional technology, innovative thinking and entrepreneurial ability.

Keywords: Surveying and Mapping Engineering; Application-Oriented Universities; Three-Chain Integration; Innovation and Entrepreneurship Education; Teaching Reform

1. Introduction

In the context of global innovation and entrepreneurship-driven higher education reform, cultivating compound talents with both professional quality, innovative thinking, and entrepreneurial ability has become the core goal of the world's higher education reform [1]. Based on Boyer's "Academic Reflection Theory" and Kuratok's "Entrepreneurship Education Ecosystem Model", this study proposes a teaching model based on "three-chain integration" to solve the problem of disconnection between talent training and social needs [2]. At the same time, the internationally accepted CDIO (Ideation-Design-Implementation-Operation) engineering education framework emphasizes the integration of technical capabilities and innovative practices, providing theoretical support for the reform of engineering majors such as surveying and mapping engineering [3]. In the global context of engineering projects, the national innovation-driven development strategy and the rising global demand for high-quality technical talents have jointly promoted local application-oriented universities to become the forefront of talent training reform. As the main force in delivering applied talents for regional economic and social development, local applied universities shoulder the responsibility of bridging the gap between academic education and industrial demand, and the quality of their talent training directly affects regional competitiveness [4]. Surveying and mapping engineering is closely related to the fields of geospatial information, smart city construction and environmental monitoring, and is indispensable in the field of modern engineering technology. With the rapid development of new engineering and intelligent surveying and mapping technology, the industry's requirements for talents are increasing, and it is necessary not only to master core professional skills, but also to have the ability to transform technological advantages into innovative achievements and entrepreneurial practices [5]. This study adopts a mixed research method to systematically explore the effectiveness and mechanism of the specialized and integrated teaching mode of surveying and mapping engineering in local application-oriented universities. An interpretive sequential mixed study design was adopted, divided into two consecutive phases. The first stage is to construct and carry out teaching reform around the innovation and entrepreneurship knowledge system integrating the "three chains" and new engineering, and the second stage collects quantitative data to measure the overall effect of the teaching model, and quantifies the results through qualitative data interpretation and contextualization. This design facilitates a comprehensive understanding of "what works" and "why it works," navigating the complexities of educational intervention research.

2. Review of the Current Research Status at Home and Abroad

2.1 The Current Status of Integrated Education Research

The research of integrated education in China focuses on the exploration of multidisciplinary practice mode and localization reform. In the new energy science and engineering major, researchers have constructed a three-in-one teaching model of "curriculum-competition-scientific research" by integrating ideological and political elements, introducing competition projects and real enterprise topics, which effectively improves students' interdisciplinary application ability and industrial adaptability [6]. In the field of environmental engineering, TRIZ innovation theory is tried to be combined with professional courses, such as guiding students to solve technical problems through contradiction matrix analysis in "Air Pollution Control Engineering", which significantly improves students' ability to identify problems and design innovative solutions [7]. In view of the problems of disconnection between practice and market and the lack of practical experience of teachers in the "integration of specialization and innovation", the engineering management major proposes the "integration of theory and practice" model: using real projects such as comprehensive utilization of industrial solid waste as the carrier, through "virtual simulation + enterprise training" combined with competition-driven, to realize the talent training path of "integration of teaching, competition and research" [8]. In addition, school-enterprise cooperation has become an important breakthrough, and Hebei Polytechnic University has built a multi-party collaborative innovation and entrepreneurship ecosystem by updating the curriculum content and establishing a "dual-teacher" teaching team [9]. The integration of specialization and innovation in the field of surveying and mapping engineering is still in the exploratory stage, and most of the existing research focuses on the development of digital quality inspection tools, but there are still gaps in the deep integration of professional courses and innovation and entrepreneurship [10]. Internationally, specialized and creative integration education is oriented by interdisciplinary integration and industrial needs. In the case of civil engineering, Anhui University of Science and Technology combines innovative methods, intellectual property protection and underground space engineering technology, and increases students' participation in academic competitions by 40% through "online + offline" hybrid teaching and competition drive, which confirms the effectiveness of structured innovation education [11]. In developing countries, the core challenges faced by public higher education institutions include low innovation acceptance, insufficient technical infrastructure, and weak policy support, which provide a reference for the international adaptation of local application-oriented universities in our country [12]. The "dual system" model of European universities of applied sciences and the ABET certification system in the United States emphasize the connection between engineering education and industry standards, but there is still a lack of research on how to integrate geospatial technology with the entrepreneurial value chain in technical majors such as surveying and mapping engineering.

2.2 Current Research Status of Structural Equation Model (SEM) Application

SEM is mostly used in domestic education research for mechanism verification and path analysis. In the field of new engineering, Xinjiang Agricultural University took the School of Mechanical and Electrical Engineering as a sample to construct a multi-dimensional model of "school-enterprise cooperation-practical conditions-teacher ability-curriculum reform-ability training", and found that school-enterprise cooperation had the strongest direct effect on the ability training mechanism, which provided a quantitative basis for the optimization of the engineering education system [13]. In the blended teaching effect study, SEM analysis based on the Technology Acceptance Model showed that students' perceived ease of use of online platforms indirectly affected learning outcomes through learning motivation. In the field of entrepreneurship education, empirical studies in six universities in Fujian Province show that the influence of teaching methods and teaching content on student satisfaction is significantly higher than that of teaching conditions, which provides targeted suggestions for the reform of the general education curriculum for entrepreneurship. The international academic community focuses on the standardized application of SEM in educational decision-making. Dumas et al. proposed a five-stage analysis framework: clarifying the theoretical assumptions of latent variables→ constructing a complete model with covariates→ rigorously verifying fitting indicators→ replicating models across contexts→ integrating multi-study evidence to form practical suggestions, which provided methodological guidance for causal inference of educational interventions. In technology-integrated education, Nigerian scholars have verified the mediating pathways of "educational technology→ learning motivation → peer learning outcomes" through SEM, and found that the direct effect of technology application ability on learning effect is stronger than that of instructional design. In the field of AI education, multi-layered framework studies show that SEM models are well-fitted and can effectively capture the complex impact of AI on student achievement in open education. Although the integration of expertise and innovation is highly valued around the world, there are still obvious shortcomings in international and domestic research. Internationally, existing research is mainly focused on a single discipline such as research universities or business administration, and little attention is paid to engineering majors in applied universities, especially local universities. For example, although the European University of Applied Sciences has developed a mature "dual system" entrepreneurship education model, it lacks in-depth exploration of how to deeply integrate professional knowledge systems such as surveying and mapping engineering with the innovation and entrepreneurship value chain. Similarly, ABET-accredited American engineering education emphasizes the cultivation of innovation capabilities, but rarely involves the specific integration mechanism of engineering professional courses with intellectual property management and entrepreneurial practices. In China, since 2015, our country's universities have carried out the practice of integration of specialization and innovation under the promotion of policies, but the surveying and mapping engineering majors of local application-oriented universities still face outstanding challenges: rigid disciplinary barriers hinder the cross-integration of professional knowledge and management, law, business and other knowledge; Insufficient empirical support weakens the effectiveness of talent empowerment; Outdated teaching strategies are difficult to adapt to the digital transformation needs of the industry. In order to fill these gaps, this study focuses on the surveying and mapping engineering major of local application-oriented universities, aiming to construct a set of empirically supported and practical teaching model of specialization and innovation. This study not only responds to the call for global higher education reform, but also provides an empirical reference for bridging the gap in regional engineering education talent training, and ultimately helps improve the quality of talents to meet national strategic needs and international education trends.

3. The Process of Building a Teaching Reform System

3.1 The Construction of Innovation and Entrepreneurship Knowledge System Integrating "Three Chains" and New Engineering

Focusing on the innovation chain, intellectual property chain, and entrepreneurship chain, the whole life cycle of innovation and entrepreneurship is deeply integrated with the theoretical teaching of surveying and mapping engineering. Integrate knowledge elements of economics, management, law and other disciplines into professional courses and "entrepreneurship and entrepreneurship courses", carefully plan the course content, and establish a specialized and innovation integration course group.

3.2 The Construction of an Integrated Practice System of "Industry, University, Research, Service, Competition and Innovation"

Make full use of the advantages of the second classroom to build a full-process practice education and specialization integration practice system. With the integration of industry and education as the starting point, we cooperate with a number of surveying and mapping enterprises to build internship bases and provide project practice opportunities. In school-enterprise cooperation, students participate in projects under the guidance of enterprises and in-school mentors, and gain a deeper understanding of the application of professional knowledge. Relying on the integration of virtual teaching and research rooms, it integrates resources, breaks the limitations of time and space, and provides a platform for teachers and students to communicate and collaborate. With the help of the competition platform, organize students to participate, promote learning through competition, and enhance teamwork and innovation. In scientific and technological research and development and local services, students are encouraged to participate in scientific research and local service projects. Take employment practice as the foothold, track students' internship and employment, collect feedback from enterprises, test innovation and entrepreneurship achievements, and provide reference for teaching improvement.

3.3 The Construction of a Teaching Guarantee System Based on Smart Teaching Aids

In order to meet the demand for multidisciplinary knowledge in specialized and creative integrated education and adapt to the personalized development of students, the research team established a multidisciplinary integrated knowledge graph based on text data mining and graph database technology. Through the collection and processing of a large number of professional literature, industry materials and other data, key information is extracted and the nodes and relationships of the knowledge graph are constructed. On this basis, a personalized learning path recommendation system and a knowledge question and answer system are developed. According to students' learning progress, interests and knowledge mastery, we provide students with personalized learning suggestions and resource recommendations to help students quickly acquire the knowledge they need. The knowledge question and answer system answers the questions encountered by students in the learning process in a timely manner, realizes the wisdom empowerment of education and teaching, and promotes the development of new quality teaching productivity.

4. Sample Selection and Data Collection

4.1 Sample Selection and Data Collection

The research was carried out in three local application-oriented universities in northeast our country, all of which have four-year undergraduate surveying and mapping engineering majors, and all of them have a good tradition of school-enterprise cooperation with the industry and the enthusiasm to participate in entrepreneurship and entrepreneurship competitions. These institutions were selected for their representativeness: they serve similar regional economic needs and face similar challenges in the integration of specialization and innovation. Among them, the participants in the quantitative evaluation stage consisted of 286 undergraduate students majoring in surveying and mapping engineering, who experienced the integrated teaching mode of specialization and innovation. Participants participated in core courses and integrated practical activities of industry, university, research, service, competition and innovation, including enterprise internships and competition projects. The control group consisted of 252 students of the same major who received traditional teaching before the implementation of the model. To ensure comparability, propensity score matching was used to balance the two sets of baseline features.

The qualitative phase participants included 24 experimental group students, covering different achievement levels to capture diverse learning experiences and outcomes. 12 professional teachers involved in course design, teaching and project guidance, including senior professors and young lecturers with industry backgrounds. and 8 corporate mentors from 6 partner surveying and mapping companies to guide students in internships and evaluate project results.

4.2 Quantitative Data Collection and Processing

The questionnaire was developed based on the CDIO Engineering Education Framework and validated scales, including: Professional Skills Scale: 15 items, measuring technical manipulation and theoretical application competencies. Innovation Capacity Scale: 12 items, adapted from the Individual Innovation Behavior Scale, assessing problem-solving, idea generation, and technical improvement abilities. Entrepreneurial Literacy Scale: 10 items, based on Curatoko's concept of entrepreneurial self-efficacy, focusing on risk assessment, resource integration, and market awareness. A pre-survey of 50 students, among which professional skills Cronbach's α=0.89, innovation ability α=0.87, and entrepreneurial literacy α=0.85, confirmed that the reliability of the questionnaire was good and the structural validity was passed. The formal survey was conducted online through Qualtrics, with 538 valid questionnaires collected and a recovery rate of 92.3%. Students' core course scores and practical course scores are extracted from the university academic management system. The winning records of provincial/national surveying and mapping competitions and innovation and entrepreneurship competitions in 2018-2024 are verified through official documents and competition databases.

The questionnaire items in this study are partly adapted from the maturity scale and partly self-compiled. A total of 50 questionnaires were distributed and 45 valid questionnaires were collected, and the items were screened through project analysis. The critical ratio method was used to delete the CR<3.0 items; Through correlation analysis, the items with a correlation coefficient of < 0.3 were deleted, and the observed variables of each latent variable were finally determined. CFA analysis was performed on each latent variable, and the results showed that the combined reliability of "knowledge integration" = 0.89, the Cronbach α coefficient (α) = 0.87, and the mean amount of variance extraction = 0.62, and the square root of AVE (0.79) was greater than the correlation coefficient with "practice participation" (0.61), indicating good reliability and validity. Other latent variables such as "practice participation" and "personalized learning" also met the reliability and validity requirements. The common method bias test was performed using the Harman one-way test, and the explanation rate of the first factor variance in the exploratory factor analysis was 35.2% <40%, indicating that there was no serious common method bias.

4.3 Qualitative Data Collection

The interviews are conducted in a combination of online and offline, lasting 45-60 minutes each time, and the interview outline is customized according to the role of the participants, in which the student interview outline covers integrated course experience, project learning challenges, and changes in ability perception. The teacher's outline includes the curriculum design process, teaching method adjustment, and student development observation. The industry mentor outline includes students' practical project performance, matching skills with industry needs, and teaching mode feedback. All interviews were audio-recorded and transcribed verbatim to form 44 transcripts. 36 hours of classroom observation were conducted on 12 integrated courses, documenting teaching strategies, student engagement patterns, and teacher-student interactions. The documents analyzed included syllabi, project reports, competition results, and corporate feedback forms to triangulate interview and survey data.

4.4 Validity and Reliability Guarantees

The questionnaire was reviewed by 3 engineering education scholars and 2 senior surveying and mapping practitioners to ensure the validity of the content. Exploratory and confirmatory factor analysis confirmed construct validity. test-retest reliability was established by pre-surveys at 2-week intervals; For qualitative data, two researchers independently encode 20% of the transcript to ensure inter-coder reliability. All participants signed an informed consent form, and the data was anonymized to protect privacy.

5. Research Results and Discussion

5.1 Quantitative Results: Effectiveness of Teaching Models

Descriptive and inferential statistics showed that there were significant differences between the experimental group and the control group in terms of professional skills, innovation ability and entrepreneurial literacy. As shown in Table 1.

Table 1. The Core Competencies of the Experimental Group and the Control Group Were Compared

Capacity dimension	Constituencies	Mean ± standard deviation	t value	p value	Cohen coefficient d
Professional skills	Experimental group	4.23±0.58	12.36	<0.001	0.89
	Control group	3.51±0.62	9.23	0.005	0.82
Innovation ability	Experimental group	3.97±0.61	9.82	<0.001	0.72
	Control group	3.28±0.59	8.76	0.004	0.67
Entrepreneurial literacy	Experimental group	3.85±0.55	10.15	<0.001	0.76
	Control group	3.12±0.64	9.87	0.004	0.72

The experimental group scored significantly higher than the control group in all three dimensions, and the effect size was large, indicating that the teaching mode had a substantial impact. Specifically, the experimental group students performed stronger in technical operation and theoretical application, and had higher practical training scores.

Longitudinal analysis of the competition results showed a steady upward trend in the experimental group. From 2019 to 2024, students in the experimental group won 87 provincial/national awards in surveying and mapping competitions and innovation and entrepreneurship competitions, while the control group received only 32 awards in the pre-intervention period. Repeated measures analysis of variance showed a significant increase in the number of awards over three years, with the most significant increase in interdisciplinary projects.

The structural equation model verifies the hypothetical path of "ability improvement → mediating variables → teaching system". The model fit indexes were good: $\chi^2/df=2.31$, CFI=0.94, RMSEA=0.06, SRMR=0.05.The three-chain integrated knowledge system positively predicts knowledge integration, which in turn affects professional skills and innovation ability. The integrated practice system of industry, university, research, service, competition and innovation significantly improves practice participation, mediating the relationship between model and entrepreneurial literacy. The smart teaching and auxiliary system indirectly promotes the improvement of all abilities through personalized learning. GFI and AGFI were calculated at the same time, and the results showed that GFI=0.92 and AGFI=0.90, both of which were greater than the standard of 0.9, combined with the above results, showed that the model fit well.

5.2 Qualitative Results: Underlying Mechanisms and Situational Factors

Students and teachers reported that incorporating business management and intellectual property content into technical courses such as Engineering Surveying fostered interdisciplinary thinking. One senior student said, "Studying surveying and mapping techniques alongside project management helped me understand how to translate technical solutions into viable business plans." Industry mentors emphasized that this reduced the "knowledge silo effect."

The integrated system provides a real-world project experience, with 83% of students surveyed finding corporate internships transformative. "Working with companies on smart city mapping projects has taught me to strike a balance between technical accuracy and customer needs – something that textbooks can't cover." Teachers observe improved problem-solving skills among students: "Students now proactively identify market needs when designing surveying and mapping projects, rather than just focusing on technical compliance."

The personalized recommendations of the intelligent tutoring system improve learning efficiency. "The system recommended patent applications related to my drone project, which directly helped our team win the competition." Teachers noted that the administrative burden was reduced, allowing them to have more time to provide creative guidance.

Institutional policies and close industry cooperation enhance the model's effectiveness. However, universities with weak industry links face challenges: "limited business partnerships make it difficult to provide sufficient real projects", indicating that institutional support is a key moderator.

6. Conclusion

This study systematically explores the effectiveness and mechanism of the integrated teaching mode of surveying and mapping engineering in local application-oriented universities through mixed research methods. The main research findings and contributions are as follows:

The empirical results confirm that the teaching mode composed of "three-chain integrated knowledge system", "integrated practice system of industry, university, research, service, competition and innovation" and "smart teaching and auxiliary system" significantly improves students' comprehensive ability. Quantitative analysis shows that the performance of students in the experimental group in the three key dimensions of professional skills and entrepreneurial literacy is significantly better than that of the control group, and the effect size is large, indicating that this model has substantive practical value. The longitudinal data further shows that the number of student competition awards is steadily increasing, especially in interdisciplinary projects such as smart city surveying and mapping, agricultural monitoring system, etc., reflecting the role of this model in connecting technical expertise with real innovation needs.

The structural equation model verifies the specific action path: "three-chain integration" mediates the improvement of professional ability and innovation ability by promoting knowledge integration; the industry-university-research-service competition system promotes the development of entrepreneurial literacy by enhancing practical participation; and the smart teaching and auxiliary system indirectly promotes the improvement of abilities in various dimensions through personalized learning. The qualitative research results further complement the above findings, revealing how interdisciplinary curriculum design, real project experience and intelligent tutoring can jointly break down disciplinary barriers, strengthen practical skills, and optimize learning efficiency, effectively solving the core problems such as discipline islands and insufficient empowerment in talent training in local application-oriented universities.

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