

# Exploring the Education Model of “Innovation and Research Integration” for Cultivating Compound Talents in Communication Engineering

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**Abstract:** This paper focuses on the challenge of synergistic training of innovation and entrepreneurship and research capabilities for students majoring in information and communication engineering. Based on the professional positioning of the School of Information Engineering at Tianjin University of Commerce and the demands of regional industries, a training system of "integration of innovation and research, mutual promotion of competition and research, deep integration of industry and education, and three-stage progression" is constructed. Based on the OBE concept and CDIO framework, the study designs a four-stage curriculum and practice system including "basic literacy-applied practice-research advancement-entrepreneurship incubation", along with a multi-dimensional process evaluation mechanism. Through two years of pilot construction, significant achievements have been made in curriculum reform, project-based study Tours, subject competitions, and industry-education integration. The results show that the innovation-research collaboration strategy can significantly enhance professional core competence and innovation awareness without increasing the academic burden. The educational model and resource allocation scheme proposed in the paper have replicable value for the transformation of new engineering in local universities.

**Keywords:** Research Training; Innovation and Entrepreneurship Education; OBE; CDIO; Industry-Education Integration

## 1. Introduction

Domestic and foreign research shows that innovation and entrepreneurship education has moved from the edge to the mainstream. Since 2011, Gibb, A[1] and Rae, D[2] have explored a

range of conceptual and practical challenges faced in delivering an innovative programme targeted at staff of UK higher Education (HE) and further education (FE) institutions. The domestic research, such as cited literature [3-5], mainly focuses on the curriculum reform, and the integration of engineering majors is insufficient. There are few application cases for communication engineering.

In the context of serving "coordinated development of the Beijing-Tianjin-Hebei region", "Digital China", "Intelligent Computing Tianjin" and the local communication and Internet of Things ecosystem, the School of Information Engineering of Tianjin University of Commerce has explored a teaching reform path with "integration of innovation and research" as the key point, which is a response to this era proposition. By integrating innovative practices, interdisciplinary collaboration and ideological and political education in the curriculum, a systematic training framework has been constructed, including the curriculum system, teaching methods, practical platforms and evaluation mechanisms. The model is project-driven, embedding real research projects throughout the teaching process and introducing the CDIO engineering education model to strengthen students' complete engineering thinking training from demand analysis to system implementation. Build a training system of "integration of innovation and research, mutual promotion of competition and research, deep integration of industry and education, and three-stage progression", aiming to break down the barriers between professional foundation, scientific research training and innovation and entrepreneurship, and build an open education ecosystem centered on students, driven by projects, and coordinated by industry, academia and research.

The significance of this study lies in three aspects: Theoretically, it enriches and develops

the theory of engineering education, especially in the practical application of project-driven teaching, interdisciplinary integration and research-based learning theories, providing empirical support for the construction of a theoretical system for the cultivation of compound talents in the context of new engineering. In practice, it provides an operational and replicable model of teaching reform for communication engineering and related electronic information majors. Through the design of specific curriculum systems, teaching methods, implementation strategies and evaluation mechanisms, it offers a systematic solution for universities to address the core issue of "how to cultivate innovative talents". Strategically, this study will directly serve China's competitiveness and sustainable development in key technology fields such as 5G/6G, industrial Internet, and artificial intelligence by cultivating a large number of high-quality, compound talents to meet the demands of future industrial development, and has significant strategic value for promoting the organic connection between the education chain, talent chain and industrial chain, innovation chain.

## 2. Related Research and Theoretical Basis

### 2.1 Bloom's Taxonomy

Drawing on both domestic and international macro education reform policies—specifically, China's National Medium and Long-Term Education Reform and Development Plan Outline (2010-2020) [6] and the international framework for Entrepreneurship Education in Higher Education (2002–2022) [7]—this study constructs the "Innovation and Research Integration" education model based on Bloom's Taxonomy [8, 9], which is a hierarchical framework that categorizes educational objectives into six cognitive levels—from foundational knowledge recall to higher-order skills like analysis, evaluation, and creation—guiding the design of learning outcomes, instruction, and assessment. It offers a structured approach to fostering progressive cognitive development and aligning teaching practices with targeted learning goals.

### 2.2 Theory of Innovative Education

The core of innovative education theory lies in stimulating students' innovative consciousness,

cultivating their innovative ability and enhancing their innovative practice level through systematic knowledge imparting and practical training. The theory emphasizes that the educational process should break the boundaries of traditional disciplines and focus on the integration of interdisciplinary knowledge and the cultivation of creative thinking, especially in the field of communication engineering, where the characteristics of rapid technological iteration and complex and changeable demands make innovative education a key path for cultivating compound talents [10].

In terms of the practical path, the reform of the curriculum system oriented towards innovation and entrepreneurship provides effective support for the cultivation of compound talents. To sustainably nurture innovative talents with interdisciplinary capabilities for emerging fields like artificial intelligence and quantum communication, communication engineering programs must further deepen the "innovation and research integration" model. This entails constructing an innovation ecosystem spanning curriculum, practice, and industry, while embedding the development of knowledge processing capabilities throughout the entire talent cultivation process.

### 2.3 Research-based Learning Theory

Research-based Learning (RBL)[11] theory provides the core methodology for the integrated innovation and Research model. It encourages students to think and work like scientists, to construct knowledge through independent inquiry, cooperative discussion and hands-on practice, and to transform from passive recipients of knowledge to active explorers of knowledge. The core of RBL in communication engineering talent development is to place students in real research or technical breakthrough situations and guide them through the complete research process of "identifying problems - analyzing problems - designing solutions - implementing verification-evaluating reflection", thereby systematically cultivating their scientific spirit and research ability.

In recent years, with the practical advancement of the "integration of creation and research" education model, the application of research-based learning theory has been deeply integrated with innovative practices, forming a teaching paradigm that is problem-oriented and project-based. At the implementation level, task-driven

teaching has been proven to effectively activate students' innovative potential by breaking down research projects into specific task units and guiding students to master key technologies such as communication system design and signal processing in the process of completing the tasks. This model has been successfully applied to the construction of innovation and entrepreneurship practice courses.

## 2.4 OBE and CDIO Framework

OBE (Outcome-Based Education)[12] emphasizes learning outcome-oriented, detailing graduation requirements to course objectives and evaluation metrics.

The CDIO (Conceive-Design-Implement-Operate)[13] engineering education concept, which emphasizes the integration of the entire life cycle of engineering practice into the curriculum system, has been adopted by more than 100 universities worldwide. The theory emphasizes breaking away from the traditional single model of knowledge transmission in education and constructing a "knowledge-ability-quality" trinity training system through project-based teaching, interdisciplinary curriculum design and other means. Some scholars, from the perspective of knowledge management, pointed out that traditional teaching models have problems such as one-way knowledge transmission and disconnection of practical links, and proposed to build a "learning chain" based on knowledge advantages, combining disciplinary theories with the latest industry dynamics to form a dynamic adaptive knowledge system.

Therefore, this study, based on the absorption of advanced concepts at home and abroad, couples the output indicators of OBE with the engineering context of CDIO, aiming to construct and validate a systematic, full-process "innovation-research integration" education model, with the expectation of providing a more forward-looking and effective solution for the cultivation of compound talents in communication engineering.

## 3. Design of the Integrated Innovation and Research Capability Architecture System

### 3.1 Graduation Competency Profile

Based on Bloom's educational theory, this framework aims to cultivate students of information and communication science with a

complete chain of abilities from basic knowledge to advanced innovative practice through systematic curriculum design, and incorporate entrepreneurial thinking, so that they can not only have solid professional skills, but also become compound talents with innovative spirit and research ability.

According to the capability classification of graduation requirements in engineering education accreditation[14] and the OBE concept, the professional capability portrait formed from engineering foundation and mathematical modeling capabilities, system design and experimental verification capabilities, scientific research literacy, innovation and entrepreneurship awareness, collaborative communication, project management, lifelong learning, and self-motivation is shown in Figure 1.

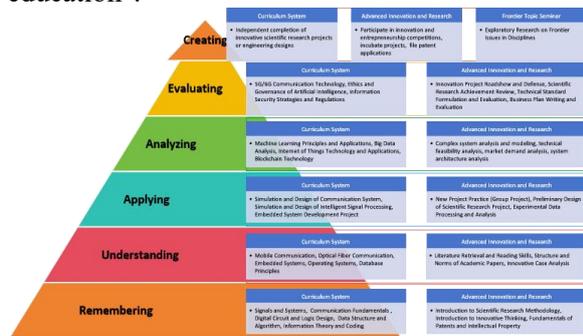


Figure 1. Competency Profile of Communication Engineering Students

### 3.2 Training System Architecture design

The framework of the system is based on Bloom's taxonomy of educational Objectives' six-dimensional cognitive hierarchy and incorporates the cultivation of innovation and scientific literacy, forming a progressive path: The "memory" hierarchy combines professional basic courses with scientific enlightenment content to assist students in basic retelling and knowledge recognition, and to build a solid disciplinary foundation; The "comprehension" level, through the core professional courses combined with literature retrieval and case analysis, achieves the interpretation of knowledge connotations and the sorting out of connections, deepening understanding; The "Application" level relies on professional practice courses and innovative projects, focusing on practical implementation and problem-solving, and cultivating product thinking and practical skills; The Analysis level uses elective courses and technical and market

analysis content to train the ability to disassemble and integrate and identify relationships, and to explore business opportunities; The "Evaluation" level combines advanced professional courses with project review and plan evaluation to enhance the comprehensive evaluation literacy of value judgment and standard application; The "Creation" level promotes integrated innovation and technology transfer through graduation design and innovation and entrepreneurship practice, facilitating frontier exploration. Each cognitive level unfolds from two dimensions: curriculum design and innovation and research ability development (as shown in Figure 2), forming a training system of "three stages and four segments, undergraduate and postgraduate integration, competition and research mutual promotion, and deep integration of industry and education".



**Figure 2. Framework Diagram of the "Integrated Innovation and Research" Training System**

- (1) First Stage (Freshman-sophomore first semester) : Basic Literacy Stage The goal of this stage is to solidify students’ mathematical and physical foundations and engineering science thinking. In addition to the public basic courses such as Advanced Mathematics and College Physics, we have transformed the subject basic courses such as Circuit Analysis, Signals and Systems, and Digital Signal processing with a "research and innovation" orientation.
- (2) The second stage (sophomore-junior year): Application Practice section This stage focuses on the core knowledge system of communication engineering. The courses include Principles of Communication, Information Theory and Coding, Mobile Communications, Computer Networks, etc. Each core course is embedded with 1-2 "research-oriented" course projects.
- (3) The third stage (junior-senior year): Research

Advancement and Entrepreneurship Incubation This module is the most open and interdisciplinary, aiming to broaden students’ horizons and stimulate their innovative potential. It consists of three parts: Frontier Technology Course Cluster: Students can choose courses such as "Artificial Intelligence and Communication", "Internet of Things Engineering", "Cybersecurity", and "Introduction to Quantum Communication" based on their interests, and the courses will be conducted in the form of small- class discussions. Innovative Methods and Tools courses: "Soft skills" courses such as Innovative thinking and Methods and Research Paper Writing and Academic Norms are offered. Comprehensive Innovation practice credits: Students earn them by participating in subject competitions (such as the Challenge Cup, Electronic Design Competition), the College Students’ Innovation and Entrepreneurship Training Program (the "Big Innovation" project), mentor research projects, and publishing papers/patents. This part of the credits is a "hard requirement" to ensure that each student has in-depth innovation practice experience.

**3.3 Curriculum Module Reconstruction**

The curriculum system is modularized to form a three-level framework of "theoretical foundation-professional core-innovation expansion". The basic modules cover core courses in mathematics, physics, circuits and other disciplines, strengthening the ability to model and analyze engineering problems; The professional core module includes courses in directions such as signals and systems, principles of communication, signal processing, and communication network technology, and deepens theoretical understanding through case teaching; The Innovation and expansion module introduces emerging fields such as 5G/6G communications, Internet of Things, and the integration of artificial intelligence and communications, guiding students to grasp the development trends of the discipline through special topic discussions, case analyses, etc., and cultivating the ability of technology foresight. In terms of curriculum integration, a virtuous cycle is formed by setting up course clusters, where theoretical courses support practical courses, practical courses nourish theoretical deepening, and innovative courses stimulate knowledge expansion. This curriculum system

design not only strengthens the organic unity of knowledge imparting and ability development, but also, through the deep integration of creative and research elements, builds a leap path for students from knowledge learning to technology application and from imitative innovation to original innovation, effectively aligning with the goal of cultivating compound talents.

### 3.4 Teaching Evaluation Mechanism

A scientific teaching evaluation system is the key link to test the implementation effect. It is necessary to build a multi-dimensional assessment mechanism that covers both process and outcome evaluation: Process evaluation focuses on students' innovative thinking, teamwork and engineering ethics performance in project practice, and dynamically tracks learning progress through phased achievement reports, technical document writing, etc. Result-oriented evaluation, on the other hand, uses "outcome-based" standards, incorporates patent applications, paper publications, competition awards, etc. into assessment indicators, and introduces industry experts to participate in the review to enhance the industry adaptability of the evaluation.

The teaching evaluation system incorporates "credit transfer+process evaluation+outcome orientation" at the institutional level, introduces multi-dimensional measurement indicators including project completion, innovative contribution, team collaboration performance, etc., and conducts systematic assessment of students' research capabilities through means such as periodic achievement exhibitions, academic paper writing, and patent applications.

## 4. Teaching Implementation Process and Evaluation

### 4.1 Development of Innovation and Entrepreneurship Capabilities

To enhance the practicality of professional education, this major integrates the concept of innovation and entrepreneurship education with core business theories into the entire teaching process. Meanwhile, classroom teaching is closely linked to the actual situation of the communications industry, with the addition of practical content. Adhering to the "student-centered" teaching philosophy, it fully stimulates students' enthusiasm and initiative in learning professional theories, cultivates their critical

thinking ability and problem-discovery capability, and helps them clarify the direction of their future career development.

Previously, the innovation and entrepreneurship education of this major mainly relied on the 32-class-hour compulsory course Innovation and Entrepreneurship Education for College Students and the National College Students' Innovation and Entrepreneurship Training Program (NCSET Program, i.e., professional competitions). Considering the differences in students' individual characteristics, the course Innovation and Entrepreneurship Education for College Students was optimized to form a demonstrative curriculum chain of "Cognitive Practice – Mobile E-commerce Technology – Innovation and Entrepreneurship Education for College Students – NCSET Program".

As the core course in the demonstrative curriculum chain, Mobile Commerce Technology plays a crucial connecting role. It undertakes students' expectations for professional education formed during the cognitive practice and provides ideological and technical support for subsequent innovation and entrepreneurship practices. Through semester-long team workshop activities, students are guided to pay attention to practical problems in daily life and society, and innovation and entrepreneurship projects are generated based on the orientation of solving "pain points". This enables students to learn the course content with actual project needs, realizing the in-depth integration of theory and practice.

With the help of the "Lean Canvas", the course establishes a close connection with the course Innovation and Entrepreneurship Education for College Students, and the technical scheme part of the innovation and entrepreneurship project (Modules 1-4 of the "Lean Canvas") is completed in the Mobile Commerce Technology course. The end time of the team workshop in this course is consistent with the application time of the NCSET Program in the following year, laying a solid foundation for students to apply for the NCSET Program. Furthermore, to better align with the "Internet+" College Students' Innovation and Entrepreneurship Competition, the project approval scope of innovation and entrepreneurship projects refers to the track settings of the competition, which improves the practicality and competitiveness of the projects. Centered on team workshops, the innovation and entrepreneurship curriculum chain carries out the

learning of innovation and entrepreneurship projects. It takes lean startup theory as the methodology, uses the "Lean Canvas" tool to assist teaching, and introduces entrepreneurial games to stimulate students' innovative thinking and improve their comprehensive innovation and entrepreneurship capabilities.

**4.2 Development of Research Capabilities**

By setting up a reasonable curriculum system and project practice, students' research literacy and ability to solve complex engineering problems can be effectively enhanced. Set up a 5G network optimization course group, guide students to study key technologies such as spectrum allocation and signal transmission optimization of 5G networks, simulate the actual network environment, analyze the impact of different parameter Settings on network performance, and cultivate students' understanding and optimization ability of complex communication systems. Set up a course group for Internet of Things (iot) system design, covering iot architecture, sensor technology, data transmission protocols, etc. Students are required to design an Internet of Things (iot) node that performs data collection, processing, and upload functions, as well as network deployment and debugging, thereby mastering the full life cycle development process of iot systems.

A new compulsory course module is added to develop comprehensive qualities. New Research Methods and Academic Norms (0.5 credits) will enable students to master the basic methods and steps of scientific research, understand the writing norms of academic papers and the requirements of academic ethics. This helps to cultivate students' rigorous research attitude and good academic literacy. The addition of Engineering Ethics (1 credit) aims to cultivate students' awareness of engineering ethics, enabling them to comply with relevant laws, regulations and industry standards in project practice and ensure the legality and safety of projects. Three new project- based courses have been added to help students understand the commercial value and business model of technological innovation through case analysis and practical exercises, and enable students to actively learn relevant knowledge in the process of problem-solving. Table 1 shows the teaching implementation process of engineering cases in the project-based course.

**Table 1. The Teaching Implementation Process of Engineering Cases in the Project-based Course**

Teaching Cases	OFDM Link simulation and Hardware-in-the-loop-verification
Teaching Objectives	Complete the design of OFDM transceiver systems and compare the BER and throughput of different channel estimation algorithms on multipath Rayleigh channels
Implementation process	Students first master the basic principles of OFDM, including modulation and demodulation, channel estimation and other related knowledge. Under teachers' guidance, they conduct link simulation with MATLAB or Python, design different channel estimation algorithms and compare their performance. Meanwhile, a hardware-in-the-loop verification platform is built to compare and analyze simulation results with actual hardware output.
Results Submission	Students submit code repositories, technical reports, and poster presentations, some of which have won awards in provincial competitions, demonstrating the effectiveness of project-driven learning

At the same time, workshops on technology transfer (patent writing, technology roadshow) are held to help students convert research results into actual productive forces and social value.

**4.3 Industry-education Integration and Resource Allocation**

The establishment of a mechanism for resource integration and sharing is equally crucial. It is necessary to establish a collaborative platform for resources both within and outside the university to enable cross-departmental and cross-institutional sharing of resources such as laboratory equipment, research data, and industry cases. As shown in Figure 3, by jointly building "innovation practice stations", "three channels" of project sources, "1+N" mentor structure, and multi-dimensional university-enterprise resource pools, resources such as algorithm libraries and standard test datasets of in-house research teams, as well as industrial white papers and technical documents provided

by enterprises, are integrated to form an open knowledge service system. At the same time, it is necessary to improve the evaluation and incentive mechanism for the use of resources, and encourage teachers and students to participate in the co-construction and optimization of resources through management methods such as points system and project system. In addition, establishing regional resource sharing alliances with similar institutions can prevent redundant construction and improve resource utilization efficiency.



**Figure 3. Implementation Plan for School-enterprise Cooperation and Industry-Education Integration**

#### 4.4 Implementation Effects and Evaluation

This study systematically analyzed the implementation effect of the "innovation and research integration" education model through multi-dimensional evaluation methods, with a focus on empirical research on the degree to which curriculum reform has achieved the goal of cultivating compound talents. In the evaluation of the implementation effect, the research team used a combination of quantitative and qualitative analysis methods to obtain data through multiple channels such as questionnaires, student works display, and enterprise internship feedback. A total of 136 valid samples were collected from the questionnaire survey, covering two batches of undergraduate students majoring in communication engineering who implemented the model. The data showed that the students' satisfaction with the curriculum system was 89.7%, and 85% of the students believed that project-based learning significantly enhanced their ability to solve complex engineering problems. In terms of practical achievements, students have completed a total of 28 innovation and entrepreneurship projects in the past three years. Among them, 12 have won awards in provincial-level or above subject competitions, 7 have obtained software copyright certification, and the related achievements have been practically applied and

transformed in industry- university-research cooperation enterprises.

From the perspective of ability cultivation, this model effectively promotes the coordinated development of students' engineering practice ability and innovation ability. The questionnaire data shows that 92.3% of students believe that the project-driven teaching approach has enabled them to have a deeper understanding of the complete process of communication system design, and 83.5% of students say that they have mastered the ability to integrate interdisciplinary knowledge through participating in real engineering projects. In the enterprise internship feedback, the partner specifically pointed out that the students cultivated by this model have a strong ability to analyze engineering problems and can quickly adapt to the collaborative environment of the R&D team.

#### 5. Conclusions

The "integration of innovation and research, mutual promotion of competition and research, deep integration of industry and education, three stages and four stages" training system proposed in this paper has effectively enhanced students' research capabilities and innovation and entrepreneurship capabilities in the communication engineering major, achieving a closed-loop linkage of courses, projects and achievements. The practice of this educational model shows that by systematically reconstructing the talent cultivation chain, the compound ability of communication engineering professionals can be effectively enhanced.

Overall, the "innovation and research integration" education model, by reconstructing the spiral ascending cultivation path of "foundation-project-competition-industry", has initially formed a model of compound talent cultivation with demonstration effect, and its achievements have shown significant advantages in engineering practice ability, innovation consciousness cultivation and industry-university-research collaborative education.

Despite the remarkable achievements, there is still room for improvement in the implementation of this model. First, the matching of project resources with the teaching sequence needs to be further improved. Some courses have embedded research projects that are too long in cycle or do not match the technical difficulty. Secondly, the construction of interdisciplinary teaching teams needs to be

strengthened.

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