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A PTF FRAMEWORK FOR UNDERGRADUATE INNOVATION EDUCATION: INTEGRATION WITHIN THE MODERN EMERGING ENGINEERING EDUCATION

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Abstract: In response to the reform imperative of engineering education under modernization, a novel education model named PTF (one-Pyramid, Two-axis, Four-driving) learning ecosystem is proposed and validated. The model comprises a Pyramid-style, hierarchical sequence of four types of innovation and entrepreneurship competitions—foundation, professional fundamentals, professional integration, and top comprehensive—along with a progression of projects from college-level scientific innovation to national-level innovation and entrepreneurship initiatives. Two platforms are established: an Innovation Education-Service-Platform and an Integrated-Practice-Platform, which enable sustained positive attention and growth in project activity, thereby enabling qualitative change. Four driving elements are identified: Cultural Driver, which builds an immersive environment for innovation; Institutional Driver, which provides structured guidance and motivation; Resource Driver, which supplies the physical and intellectual infrastructure; and Outcome Driver, which ensures practical validation and value creation. The PTF model offers a viable paradigm for the reform of modern engineering education to cultivate adaptable and innovative talents with in-depth thinking abilities who can tackle future complex challenges.
Keywords: Innovation education; Modernized education; Engineering practice

1 INTRODUCTION

Currently, technological advancement has emerged as a decisive factor in economic development, and the strength of science and technology has become a crucial indicator for measuring a nation's comprehensive national power. The demand for scientific knowledge and outstanding talents in national undertakings is more urgent than ever before [1]. Against this backdrop, as the forefront of scientific and technological innovation and the cradle of talent cultivation, universities are in an urgent need to carry out localized education reform and model innovation. Therefore, new engineering education, which emphasizes interdisciplinary integration, focuses on innovation ability, and promotes in depth industry university research cooperation, is bound to become an important part of modern education [2-3].
This research proposes an educational framework called the "PTF" model (a "one-Pyramid, Two-axis, Four-driving" ecosystem) (see Figure 1). It focuses on constructing an undergraduate talent cultivation model with professional characteristics, interdisciplinary integration, and industry academia cooperation, led by students' scientific and technological innovation [4-5].

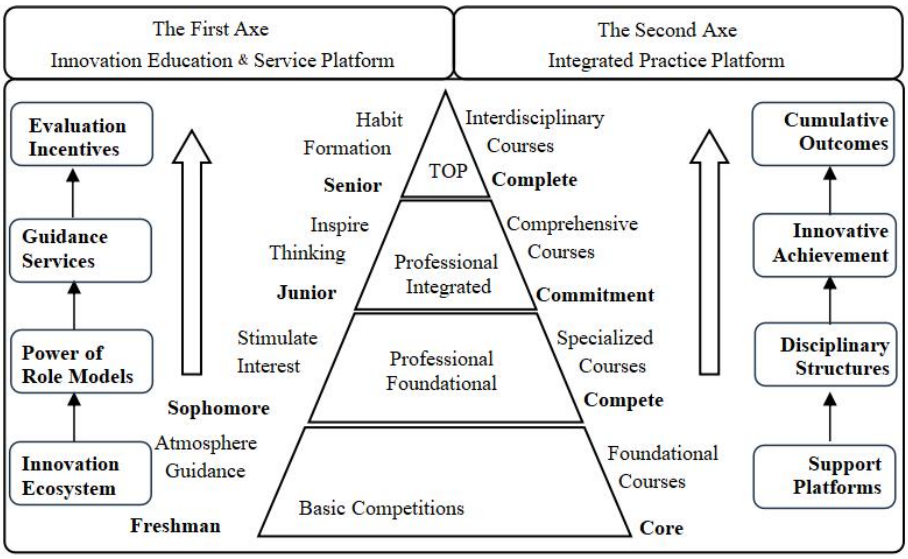

Figure 1 "PTF" Innovative Education Model (The "One Pyramid, Two Axes, Four Drives" Innovative Education Model) Diagram

In comparison with international mainstream models such as CDIO, OBE, and PBL, the PTF model demonstrates unique systematic integration advantages. This model does not simply transplant existing concepts. Instead, it takes the "pyramid-style" competition system as a prominent means to deeply integrate CDIO's whole cycle engineering thinking, OBE's output-oriented logic, and PBL's project driven method, thus constructing a "dual axis, four drive" collaborative ecosystem. Its innovation lies in the seamless connection of competitions, courses, projects, and industrial needs through an institutionalized management service platform and a physicalized practice incubation platform. It not only realizes a quantifiable and phased ability achievement path under the OBE concept but also breaks through the limitations of traditional PBL courses. It forms an educational mechanism that runs through the entire talent cultivation chain and supports the whole process of "innovation creation entrepreneurship," providing an operational systematic solution for the localization practice of engineering education.
The question "How to cultivate compound talents capable of addressing modern engineering challenges?" This paper aims to elaborate on the theoretical basis, structural design, and implementation effectiveness of this model, hoping to provide some insights for global higher education institutions to innovate engineering talent cultivation models and deepen the integration of innovation education.

2 ESTABLISHING A HIERARCHICAL MASTERY FRAMEWORK: BUILDING A “PYRAMIDSTYLE” COMPETITION SYSTEM FOR INNOVATION CAPACITY TRAINING

The " Pyramid " (see Figure 2) refers to a "pyramid-style" dual innovation ability training system in the PTF model that features hierarchical progression and step by step improvement. This system takes competitions as the carrier, integrates dual innovation education throughout the entire process of talent cultivation, and systematically encompasses four levels of competition types: "Basic Competitions; Professional Foundational Competitions; Professional Integrated Competitions; and Top Comprehensive Competitions" [6]. It also promotes the gradual advancement of project practice from entry-level academic training to national level innovation and entrepreneurship projects, thereby achieving systematic and sustainable growth in students' abilities [7].

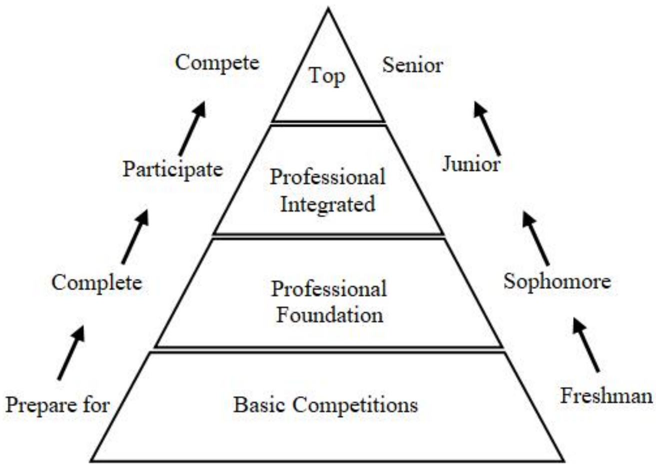

Figure 2 The "Pyramid-Style" Competition System for Cultivating the Innovation Ability of College Students in Higher Education Institutions

2.1 Pyramid-style Competitions System-The Foundation Type

At the fundamental level, the system conducts academic paper competitions, creative design contests, and presentation events to primarily stimulate the innovative interests and entrepreneurial awareness of lower grade students [8]. These competitions have flexible topics and moderate thresholds, focusing on enlightenment and experience, aiming to guide students to complete the entire process training from conception to practice. The organizational strategy emphasizes extensive mobilization, process guidance, and completion guarantee. The purpose of these competitions is to stimulate students' interest in innovation and entrepreneurship, cultivate their awareness, and are mainly targeted at lower grade students (freshmen and sophomores). The professional knowledge involved in the submitted works is relatively simple and superficial. The main function is to cultivate students' interest in participating in innovation and entrepreneurship. The evaluation of the projects mainly focuses on the completion of the project and the successful conclusion. Therefore, the approach to organizing such competitions is mainly to encourage participation through extensive mobilization, pay attention to the selection of topics for guidance, and continuously follow up to ensure progress.

2.2 Pyramid-style Competitions System-The Professional Foundation Type

At the fundamental professional level, the system leverages various types of competitions, including engineering skills competitions, mathematical and physical contests, experimental design competitions, and cultural and creative contests, to promote the extension and application of the professional knowledge from the first classroom in the second classroom. These competitions emphasize the practical transformation of basic knowledge and the inspiration of interdisciplinary thinking, facilitating the shift of students' learning mode from "passive acceptance" to "active exploration." Such competitions represent a continuous extension and content expansion of the basic professional knowledge from the first classroom in the second classroom. They provide students with a means to practice their basic professional knowledge and constitute a process of active relearning and rethinking through heuristic discussions, in contrast to the passive indoctrination-based teaching model.

2.3 Pyramid-style Competitions System-The Professional Integrated Type

On senior professional level, the curriculum system includes high level professional contests like electronics information, intelligent manufacturing, mechanical innovation, mathematical modelling and industrial design. Through these competitions, the students can fully use the advanced mathematics, essential professional courses, and interdisciplinary knowledge to deal with the engineering problems, thus training their systematic thinking, integrated design and team work abilities. This kind of competitions enable senior students' basic course (higher mathematics, college English, college physics) integrated learning and skillfully applying, as well as student professional courses learned during in their college studies.

2.4 Pyramid-style Competitions System-The Top Level

At the TOP level are comprehensive competitions, with representative events such as the national innovation and entrepreneurship competitions like the "Internet +" and the "Challenge Cup." These competitions comprehensively assess students' overall qualities in aspects such as professional knowledge, innovative practice, market insight, team management, and communication skills. This type of competition places greater emphasis on the improvement of students' all-around development in terms of morality, intelligence, physical fitness, aesthetics, and labor. It not only requires students to have strong abilities in learning, applying, and innovating in comprehensive professional knowledge but also demands that participating students possess high resilience, a positive mindset, and good communication skills. This has played a positive role in promoting the all-around development of students [9].

It is a well-designed pyramid system, with obvious goals. This is a systematic design scheme, which creatively implements the practice of "innovating innovative qualities" to achieve "developing comprehensive qualities". The PTF model offers a systematic system path to help engineering colleges replicate and apply the mode and implement the innovation and entrepreneurship education.

3 SERVICE-ORIENTED ACTIVE GUIDANCE: BUILDING A DUAL PLATFORM OF "TWIN AXES AND FOUR DRIVES" FOR INNOVATION

In the PTF framework, the "Two Axes" are the Innovation Management and Service Platform (management and service axis) and the Integrated Practice Platform (practice incubation axis). These axes are deeply coupled and mutually reinforcing, forming a closed-loop enabling process from awareness to outcomes [10].

3.1 The first axe: innovation education management and service platform

3.1.1 The first driving factor of the PTF educational model is the atmosphere created to stimulate students' innovative consciousness and the exemplary power that boosts students' confidence in innovation

In the implementation of the "PTF" education model, creating an innovative atmosphere and leveraging the leading role of role models are the two core strategies for stimulating students' innovation awareness and building their confidence in innovation. The effectiveness of these strategies has been repeatedly verified in practice [11-13].

To systematically create an innovative atmosphere, the model relies on the "Innovation Management and Service Platform" to build a multidimensional and immersive innovation culture ecosystem. The platform integrates teaching staff from both inside and outside the school, corporate mentors, and outstanding senior students to form a structured mentoring team. It provides full process project registration and management, competition coordination, innovation and entrepreneurship training, and achievement transformation services. Additionally, a series of innovation practice courses are offered to fully integrate innovation education into the talent cultivation process. The atmosphere creation emphasizes "early enlightenment and strong immersion" to cultivate students' knowledge application and technological innovation abilities and form a cultural atmosphere centered around campus academic and technological innovation activities. For example, during the freshman enrollment period, professional awareness and innovation kickoff activities are carried out. Through various means such as lectures by academicians and experts, industry frontier lectures, exhibitions integrating science and technology with art, and low threshold creative competitions, students are exposed to a strong innovative environment from the very beginning of their college life. This subtly stimulates their curiosity and exploration drive, allowing freshmen to immerse themselves in a strong technological innovation atmosphere and experience the joy brought by rich practical activities from the day they enter the campus, thereby stimulating their innovation awareness.

The power of role models is infinite and represents boundless positive energy. Role models are like flags that represent the direction; they are also resources that gather strength. By learning from and promoting the noble characters and advanced deeds of role models, students can use role models as a mirror to clarify their direction, recognize their gaps, purify their souls, and elevate their spiritual realm in learning and practice. In leveraging the power of role models, it is believed that special attention should be paid to the creation and dissemination of "approachable role models". Regular activities such as science and technology innovation project reports, excellent achievement exhibitions, experience sharing by award winners, and cross grade exchanges can be organized to enable students to directly access the success stories of their peers or senior students. They can learn from their failures and realize that innovation is not exclusive to the elite. These real narratives from "people around them" can greatly enhance students' self-efficacy and convey a positive belief that "with dreams, a willingness to try, perseverance, and success will follow"(see Figure 3). By ignoring the burden of "judging heroes by results", students can view innovation as a practical and achievable process, effectively dispelling their fear of innovation and inspiring more students to take the first step in innovation practice.

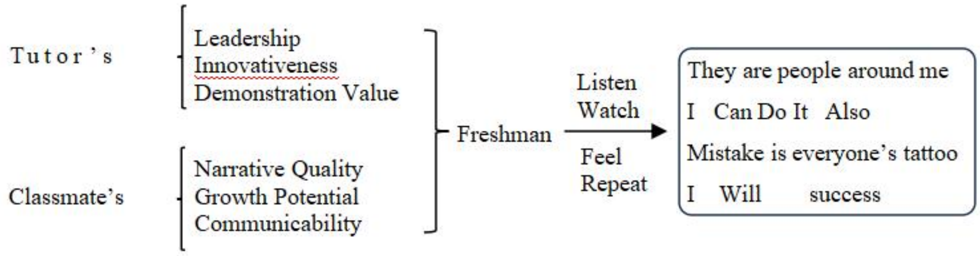

Figure 3 How the People around Students Influence and Stimulate Their Innovative Consciousness

In summary, through the systematic atmosphere-building project on campus and the warm-hearted role model leading work among students, the "PTF" model has successfully created an innovation education environment with a strong innovation awareness, easily perceptible achievements, and an atmosphere where students are encouraged to take risks and learn from mistakes. This provides crucial cultural soil, emotional support, and emotional value for the germination, development, and long-lasting confidence of students' innovation and entrepreneurship awareness [14].

3.1.2 The second driving force of the PTF innovative education model is the comprehensive guidance provided by universities to students during the innovation process and the incentive system for cultivating innovation talents

In the research on the "PTF" education model, this project holds that universities should systematically construct a guidance and management system centered on student development and a scientific assessment and incentive system. This is the core guarantee for standardizing students' innovation and entrepreneurship processes and ensuring the continuous output of innovation and entrepreneurship talents. It can effectively guide students to shift from " Spoon-Feeding " learning to " Intrinsic-Motivation-Driven " active innovation [15].

The "PTF" education model emphasizes that management and guidance covering all aspects of the entire lifecycle of innovation and entrepreneurship projects, including Team Formation, Mentor Guidance, Resource Coordination, Process Supervision, and Research Commercialization, can standardize the responsibilities and work processes of all parties to the greatest extent (see Figure 4). It serves as an important cornerstone for the orderly and efficient progress of innovation activities. The cultivation of innovative talents requires a rigorous and comprehensive management system, reasonable and effective management methods, and a complete guidance process, which play a crucial role in the cultivation and management of innovative talents. Meanwhile, comprehensive management and guidance can also minimize the inefficient management and resource waste that often occur in the early stages of innovation activities, enabling students to focus on creating more scientific and technological achievements in a standardized and stable innovation practice environment.

Student motivation is an essential element of the education administrative system (see Figure 4). It motivates student learning through promoting the transformation of external driving factors for students into their own initiative to achieve personal goals, inner drive and positive conduct, which is conducive to students' study and personality formation [16]. As everyone knows, in the fundamental of education students are the first object and motivate work is especially important in their all-round cultivation. "PDF" new teaching model holds that college needs to formulate special incentive system. In this manner, students' performance of innovation – oriented activities like Science and Technology competition, Project Based Practice, Patent applications can be identified from four dimensions, Innovation Knowledge, Innovation Capability, Innovative Thinking and Innovation Skills, their learning attitude and Team Collaboration, Problem Solving Skill and Moral Resilience should be appropriately identified and must be amply rewarded. This method facilitates a scientific, full process, and complete evaluation of the innovation qualities and development potential of the students. In addition, it also allows those students who have only studied their results to objectively analyze their developmental trajectories and helps these students to effectively take the initiative to engage in innovation practice activities, which is conducive to stimulating a larger number of students with innovative thinking and awareness.

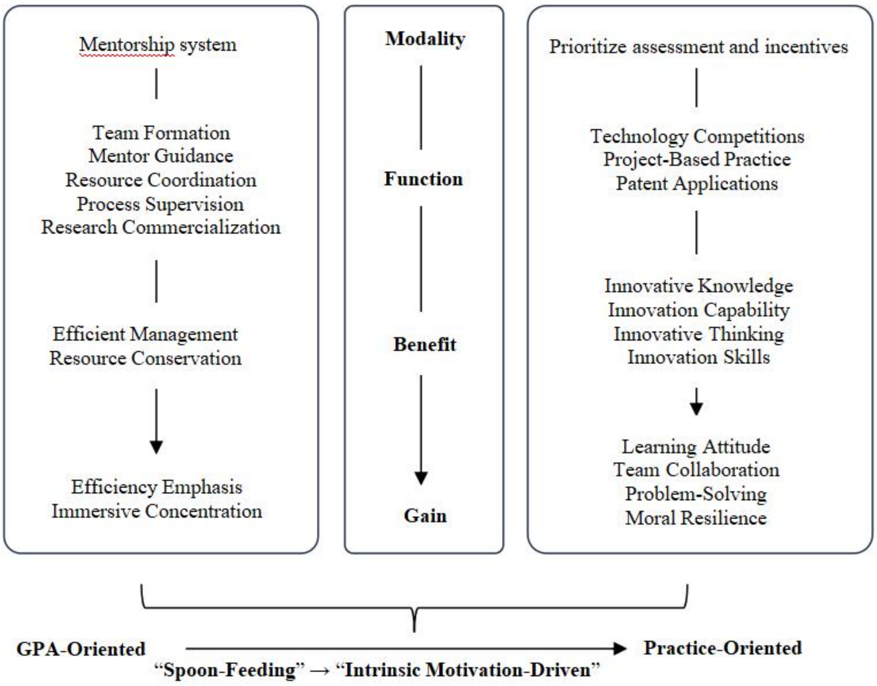

Figure 4 Innovative Guidance and Performance Evaluation Incentive Measures for the PTF

Therefore, this research concludes that providing students with comprehensive innovation guidance and assessment and incentive measures for their participation in innovation activities will not only stimulate the enthusiasm of students with existing innovation intentions but also guide more traditional "GPA-oriented" students to "Practice-Oriente" students who focus on cultivating innovation capabilities and actively engage in innovation practices. The establishment of the PTF education model not only effectively expands the influence and beneficiary groups of innovation and entrepreneurship education but also provides institutional support for the systematic cultivation of compound talents meeting the needs of modern new engineering.

3.2 The Second Axis: Integrated Practice Platform

The practical platform belongs to the physical support entity conditions, placing greater emphasis on physical space, equipment and tools, real-world projects, and human resources. It serves as a "battlefield" where ideas are transformed into reality. In the research on the "PTF" education model, we have found that efficient management and collaboration, along with forward looking interdisciplinary curriculum design, are the key pillars for ensuring the orderly progress of projects and cultivating an environment conducive to the growth of innovative talents. They also provide continuous impetus and resource guarantees for the cultivation of undergraduate students' innovation capabilities.

3.2.1 The third driving force of the PTF model lies in the innovation platforms at various levels established by universities and the diverse types of disciplines set up to cultivate an environment conducive to nurturing innovative talents.

The "PTF" education model posits that the innovation and entrepreneurship practice platform should encompass the entire chain of "innovation-creation-entrepreneurship" in terms of physical space and resource support. It necessitates the integration of all aspects, ranging from basic training (engineering training centers), idea realization (maker spaces), professional R & D (professional laboratories) to business incubation (incubation bases). Relevant work such as institutional standardization, interdisciplinary integration, practical training, and industry education integration should be carried out [17]. The main issues it aims to address are: "Where to carry out the activities, what resources to use, what tasks to undertake, and how well the tasks are accomplished?" (see Figure 5). To this end, this education model contends that universities should formulate detailed regulations for physical spaces (such as the "Management System for Innovation Centers", the "Usage System for Engineering Competence Training Studios", and the "Innovation System for Creative Culture Studios") to provide students with documentation guarantees for using hardware facilities. The practice platform offers students' teams opportunities for real world innovation and entrepreneurship, allowing them to engage in practical exercises as if on a real battlefield. To further enhance students' self-initiated practical abilities, students are allowed to form teams freely to independently complete projects based on the project topics of various innovation laboratories and studios. Through this approach, college students can experience self-learning and independent thinking, gradually become familiar with the inquiry-based learning method centered around problems and topics, and effectively master the methods of thinking about and solving problems [18-19]. Meanwhile, improvements in regulations and innovations in management methods for various innovation laboratories and studios have been made to ensure that students have full autonomy during their free time, without being restricted by venue or time. Students

can put their ideas and creativity into practice in these innovation laboratories and studios and focus on innovation and development.
In addition, innovative talents not only require sufficient professional and cultural knowledge reserves but also possess scientific and rigorous logical thinking abilities. In the entire process of cultivating innovative talents, the discipline setup serves as the foundation, and a teaching team with innovative awareness and scientific research capabilities is the guarantee [20]. Therefore, the "PTF" education model emphasizes that the discipline ne setup should highlight the in-depth integration of "innovation literacy" and "professional competence"[21], promoting the transformation of the curriculum system from basic, professional, and comprehensive types to interdisciplinary, project based, and cutting-edge ones (see Figure 5). Specifically, it is necessary to actively coordinate all teaching staff to focus on cultivating students' innovative awareness in teaching and establish the concepts of personalized development and diversified education. For engineering students, it is particularly important to offer multiple and adequately timed innovation and entrepreneurship courses at an early stage in their lower grade studies, such as the 32hour "Mechanical Innovation Design", the 40hour "Single Chip Microcomputer Application Practice", and the 32hour "Introduction to Python", which provide a solid foundation for teachers and students to engage in innovation and entrepreneurship [22].

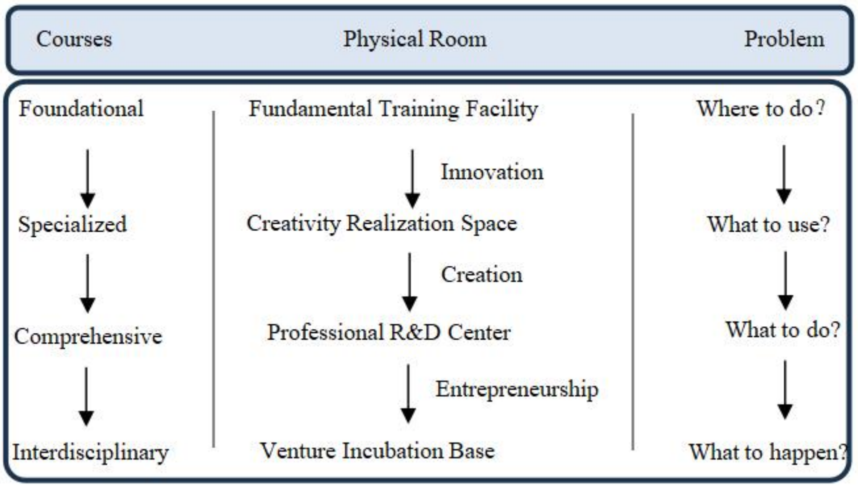

Figure 5 PTF's Various Innovation Platforms and Diagrams of Multiple Types of Disciplines

3.2.2 The fourth driving force of the PTF model is the abundant innovative achievements and high-quality educational outcomes

In the "PTF" education model, practical training and platform construction are regarded as the key links for realizing the transition of innovation talent cultivation from theory to practice and from ability building to value creation. This model effectively connects the "last mile" for the implementation of innovation education by building an open and highly supportive integrated practical platform and implementing the teaching strategy of "real environment, real projects, real practice"[23-24].
The educational philosophy of "PTF" places great emphasis on the collaborative learning effect of the practical platform among industry, academia and research. Taking an innovation training camp of a university in Beijing, China as an example, through the leadership of the university and industry associations, more than twenty enterprises donated high-end equipment worth nearly ten million yuan, jointly building a school enterprise integrated talent cultivation base, achieving a deep integration of industry academic research. In this case, enterprises not only provided advanced equipment, but also transformed actual engineering problems into students' innovation projects, enabling seamless connection between practical teaching and industrial demands, truly forming a "resource sharing, topic core search, and talent coeducation" educational ecosystem integrating industry and education [25-26].
The significant positive change in the distribution of post-graduation destinations of students, with a noticeable rise in further study rate and drop-in direct employment rate, reflects the efficacy of the PTF model in inculcating higher competences and confidence for performing successfully at the post graduate level. Such transformation from focusing on employment to focusing on more academic level goals reflects the essential quality improvement of training and cultivation of engineering talents, which is achieved by organizing "pyramid-shape" competition mechanism and cultivating tutor systems (“The First Axe”) and building a solid project-based practice platform (“The Second Axe”) in an orderly manner. It has successfully promoted a professional development system that focuses on long-term professional growth, innovation potential and coping ability in the face of fluctuations in the labor market. Thus, in this paper we believe that the PTF model is a feasible and efficient model for the current engineering education reform which should change from job-oriented skills training toward the development of various adaptive and innovative talents with depth of thinking to solve future problems.
Data Sources and Sample Description (To protect student privacy and comply with relevant data management regulations, specific major information of the samples has been anonymized. However, it is ensured that there are no significant differences in major backgrounds and admission scores between the experimental group and the control group). This study employs a quasi-experimental research method. To evaluate the effectiveness of the PTF model, the

data are sourced from undergraduate students in a certain engineering major category of a university who participated in the PTF model as The Experimental Group, and students from the same major category in the three adjacent previous cohorts as reference Group 1, Group 2, and Group 3 (see Figure 6).

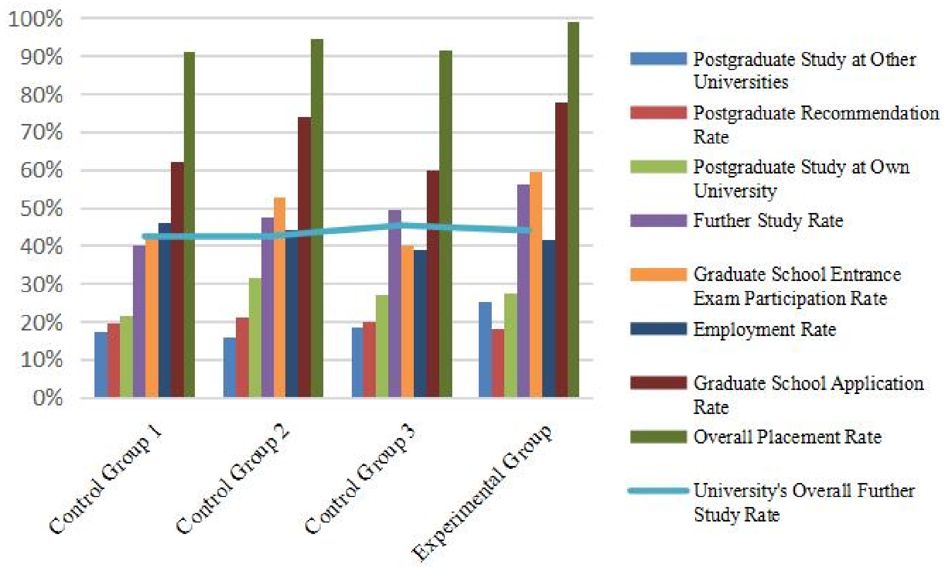

Figure 6 Comparison of Key Indicators of Graduation Destinations between the Experimental Group and the Control Group in the PTF Model

The experimental group (Experimental Group1)'s further study rate, postgraduate application rate, exam participation rate and placement rate are far beyond the control groups, and it has no overlarge unemployment rate, which is the powerful empirical proof for the effectiveness of PTF model. Empirical facts indicate that the PTF model has effect that has been greatly optimized from conventional model: the total placement rate of experiment group reaches 99.12%, far more than control group (highest 94.59%), and the unemployment rate decreases to 0.88%. Its main strength is rebuilding the high-quality further study route. The rate of further studying of experiment group (56.03%) is not only higher than all control groups (the maximum value is 49.57%), but also 12.11 percentage points higher than the school average. This result is the result of the positive mechanism of "Promote Research in Competition" generated by PTF model——Both the rate of application (77.88%) and the rate of postgraduate admission (59.59%).The proportion of the experimental group that has achieved a new level has reached 59%，the expected admission rate for postgraduate entrance examinations is as high as 76.5% and shows that this measures can improve the students' core competitiveness. At the same time, the proportion of students from the experimental group who applied for postgraduate schools outside the university is 25.37%，comparable to the proportion of those of applying for postgraduation of their own university 27.43%，showing that students received recognition from superior universities. Overall, this information indicates that the PTF model by innovative practice realizes students' development mode transformation from "the dependency of getting sure chances to master's degree programs" or "being an unselfconscious employee" into "postgraduate-study-oriented" and "good-employment supplement" type with higher quality, realizing systematic talent training improvement.

In addition, our research group has been actively engaged in innovation education for many years and conducted long term follow up studies. Detailed statistical data show that its effectiveness has been fully verified, demonstrating good scalability and sustainability, and forming the "snowball effect" of innovation and entrepreneurship education [11]. Empirical data shows that this model has achieved remarkable results in enhancing students' participation, project quality, and the level of industry academia integration. The effective realization of the PTF model occurs through iterative and scalable outcomes. Among representative practice and innovation platforms, significant activities have been conducted within a single academic year, comprising more innovation practice instruction hours, greater coverage of student participants, innovation and entrepreneurship guidance events, student engagement, early year innovation entrepreneurship teams incubated, and honors and award recognition. The data presented below are provided for reference. The data presented below demonstrate the effectiveness of innovation education：

More than 400 hours of innovation practice instruction.

More than 3,000 students participated.

18 innovation and entrepreneurship guidance events were organized.

Approximately 7,107 students were engaged, with an average of 3.5 activities per participant.

Incubation of 150 early year innovation entrepreneurship teams, encompassing 169 projects.

Total student participants exceeded 1,600, representing more than 80% coverage.

A total of 385 campus level or higher honors were conferred; 33 groups received provincial or municipal honors; 15 groups attained national level honors.

Notable milestones were achieved in national competitions, including the Challenges Cup and related engineering training events.
Annual patent filings totaled 5, with 6 teams joining campus entrepreneurship bases.
Emergence of representative student innovation exemplars.

4 BREAKTHROUGH AND CONCLUSION

First and foremost are the historical breakthroughs achieved in national competitions such as the Challenges Cup and other related engineering training events; another breakthrough is the annual patent filings totaling five, with six teams joining campus entrepreneurship bases, as well as the emergence of exemplary student innovators. Furthermore, a practical example of such a PTF from Beijing illustrates joint development created by the campus and industry associations. Over one million dollars' worth of high-end equipment was donated by more than 20 enterprises. This example shows how the collaboration can align practical teaching with real industry needs and promote shared resources and joint topic development, coeducating talent. To sum up, the PTF model is a scalable and sustainable model that provides a snowballing effect on the spread and depth of innovation, growth in participation and project quality, and the integration of industry needs at a higher education level. It helps enable broader outreach, systemic reform, and the cultivation of modern, cross disciplinary talents in engineering education.
Science and technology innovation education for students is a key and distinctive aspect of modern education in higher education institutions. When students have in depth knowledge of and passion for their majors and continuously enhance their innovation and entrepreneurship abilities, it will further contribute to the improvement of their comprehensive qualities. A successful innovation and entrepreneurship education model not only needs to provide positive incentives and explore the systems and cultures conducive to the growth of innovative talents, but also needs to focus on addressing institutional and mechanism obstacles as well as the problem of resource misallocation. This can more effectively serve the goal of cultivating new engineering talents and is of great significance for optimizing the existing education model and building a more systematic, open, and supportive innovation education ecosystem.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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