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Improving Education for Innovation and Entrepreneurship in Chinese Technical Universities: A Quest for Building a Sustainable Framework

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Abstract: The global economic trends and the winds of technological change have elevated the status of integration between industry and education for innovation and entrepreneurship to that of being a national strategic priority of China. However, for a long time prior to that, the many differences between the industrial and educational systems have caused a rift between education for innovation and entrepreneurship and professional education, a profound disconnection between professional education and the local industries, and the subsequent disinterest of entrepreneurial mentors. In this paper, we analyze the status of education for innovation and entrepreneurship in Chinese technical universities. It is pointed out that technical universities should deepen the integration between the industry and education for innovation and entrepreneurship in order to mitigate the imbalance between the supply side of the higher education talent training and the demand side of industrial development. It is also argued that technical universities should change their talent training paradigm, which includes a makeover of the organizational structure and of the curricular system, as well as make amends in the innovation ecosystem with respect to the organization of incubation platforms and of teacher–student teams, in order to promote national and regional economic development, as well as social progress. A method to evaluate the performance of the education for innovation and entrepreneurship in Chinese technical universities, based on specific performance indicators including patents filled, publications, awards in competitions, and acquired funding and on certain non-specific ones including organizational arrangements and satisfaction rates, is presented and then applied to the specific case of the Changzhou Institute of Technology.

Keywords: education for innovation and entrepreneurship; talent training; organizational structure; curriculum system; teacher team; incubation platform

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1. Introduction

A significant part of the strategic competition between countries is the competition for finding and developing innovation and entrepreneurship talents, leading to the establishment of comprehensive policies and regulations aimed at specific target groups at local, regional and national levels.

On 3 September 2014, the German Federal Cabinet adopted a high-tech development strategy called "Innovation for Germany", aiming at ensuring coherence within the country's approach towards nurturing innovation and at defining five areas of particular relevance for prosperity and economic growth. The strategy thereby put forth had a strong focus on easing and speeding the transfer of scientific advancements into marketable products and services, fostering cooperation between industry and academia and improving the overall environment for innovation [1]. After just eight months, the French Ministry for Economy and Finance launched the program "Industry of the Future", based on the premise that the digital revolution and the new manufacturing technologies will provide golden opportunities for the French companies to modernize, innovate, and manufacture and that the digital changeover, once properly assimilated and implemented, would transform their business and organizational models, as well as their product markets. Within this program, 47 key technologies were emphasized as possible medium-term avenues for the development of New Industrial France [2].

Similarly, the Japanese government has envisioned measures to promote core manufacturing technologies, as evidenced by the 2019 White Paper on Manufacturing Industries (Monodzukuri). This report, which was jointly compiled pursuant to Article 8 of the Basic Act on the Promotion of Core Manufacturing Technology (Act no. 2 of 1999) by the Ministry of Economy, Trade and Industry (METI), the Ministry of Health, Labour and Welfare (MHLW), and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), was approved by the Japan Cabinet on 11 June 2019 [3]. The report was mainly focused on the status and problems of Japanese manufacturing at the time of writing and was looking at the progress of Industry 4.0, the development of globalization and the rise of protectionism, the acceleration of Society 5.0, and the strategic deployment of measures meant to improve the competitiveness of Japanese manufacturing.

The international strategic competition represented by these countries' research and assessment on future technological, economic and social development trends and by the subsequent measures taken prompted a quest for finding innovative Chinese talents with appropriate entrepreneurial spirit, that is, a spirit of dedication, hard work, innovation and development, focus on quality, pursuit of excellence, compliance with laws and regulations, patriotism, and service to society. This undoubtedly poses a significant challenge of the utmost importance to higher education in China.

It is now widely believed that entrepreneurship, or at least certain aspects of being an entrepreneur, can be taught and learned, although in a different manner from general management [4,5]. In Chinese colleges and universities, education for innovation and entrepreneurship has started with introducing innovation and entrepreneurship courses and setting up student subject contests. After decades of continuous development, most universities moved to an intermediate stage, characterized by the firm establishment of appropriate organizational structures and the integration between the education for innovation and entrepreneurship and professional education. A further stage of in-depth advancement is now emerging, characterized by the cultivation of innovative and entrepreneurial talents and by the cooperation and integration between industry and higher education [6]. In addition, four different approaches towards education for innovation and entrepreneurship have emerged in Chinese universities, as typified by Tsinghua University, Renmin University, Heilongjiang University and Wenzhou University. Additionally, promoting the integration between industry and higher education and the transformation of the talent training paradigm are highly valued by many circles of the Chinese society, being seen as laying the groundwork for high-quality economic growth and inspiring China to move from the "demographic dividend" to the "talent dividend" in the new era.

In line with the international trend and in order to improve the performance of the national framework for innovation-nurturing, China, as the world's second largest economy, has put forward the strategic ideas of "Made in China 2025" and "Innovation-driven Development". Currently, the Chinese economy is moving from a stage of high-speed growth to a stage of high-quality development, entering a critical period of transforming its model of development, shifting its growth momentum and optimizing its economic structure. In this regard, China's Cabinet recently promulgated "Opinions of the State Council on Several Policies and Measures for Vigorously Promoting Mass Entrepreneurship and Innovation" (issued by the General Office of the State Council in 2015 with no. 32), "Implementation Opinions of the General Office of the State Council on Deepening the Reform of Innovation and Entrepreneurship Education in Colleges and Universities" (issued by the General Office of the State Council in 2015 with no. 36), "Opinions of the General Office of the State Council on Deepening the Integration of Industry and Education" (issued by the General Office of the State Council in 2017 with no. 95), "Opinions of the State

Council on Promoting the High-quality Development of Innovation and Entrepreneurship and Creating the Upgraded Version of Innovation and Entrepreneurship" (issued by the General Office of the State Council in 2018 with no. 32).

The common trait of these documents is the strategic idea that higher education institutions must actively pursue the supply-side reform of talent training to meet the diversified needs of society for a large number of high-quality innovative talents and high-quality technical skills and talents and accelerate the development and expansion of a modern industrial system with coordinated development of the real economy, technological innovation, modern finance, and human resources for enhancing the core competitiveness of the industry and gathering new momentum for development. This undoubtedly puts forward higher requirements for technical universities.

Provincial governments have subsequently implemented the strategies of the central government in a thorough manner, and consequently issued many specific implementation plans to account for specific regional features and advantages. For example, Jiangsu Province has promulgated the "Implementation Plan for Deepening the Reform of Innovation and Entrepreneurship Education in Higher Education Institutions in Jiangsu Province" (issued by the General Office of the People's Government of Jiangsu Province in 2015 with no. 137) and "Implementation Plans of the Jiangsu Provincial Government on Deepening the Integration between Industry and Education" (issued by the General Office of the People's Government of Jiangsu Province in 2018 with no. 48). Zhejiang Province has promulgated " Implementation Opinions of the General Office of the People's Government of Zhejiang Province on Promoting Innovation and Entrepreneurship Education in Colleges and Universities" (issued by the General Office of the People's Government of Zhejiang Province in 2016 with no. 9).

All these documents emphasize that higher education institutions should contribute to the integration between industry and education and should promote education for innovation and entrepreneurship as a starting point for the reform and reconstruction of the talent training paradigm. Additionally, higher education institutions should set up educative programs around the various links of the industrial chains, encourage their economic partners to participate in education for innovation and entrepreneurship, and promote the tight interconnection between the educational chain, the talent chain, the industrial chain and the innovation chain. They should also comprehensively improve the quality of education and promote economic transformations in various regions of China.

Objectively speaking, a technical university and its industrial partners are often nothing alike in terms of mission, personnel, operating mechanisms, strategies for development and approaches towards reform. Consequently, this type of collaboration is so heterogeneous that its success depends heavily upon the efforts of all parties involved, while also requiring public policy support from the government [7]. As China enacted new policies aimed at supporting the transition from a low-cost and resource-intensive growth path to a path in which a key role is assigned to innovation [8], all issues below are worth discussing, since they must be faced directly.

- How to clarify the logical connections among the integration between industry and education [9], innovation and entrepreneurship [10], and the cultivation of innovative talents [11] to meet the needs of local industry development.
- How to achieve a mutually beneficial relationship and build a community of interests, development, and destiny; how to use the specific features of technical universities to connect with industrial partners while focusing on applications in higher education, and to seize the opportunity of the transformation and development of technical universities.
- How to combine the particularities of the regional environment, the regional integrated development strategy and the national innovation-driven development strategy, and precisely address the necessities of the provincial and municipal industries in terms of talent training.

Consequently, our paper analyzes how technical universities can establish a high-level supply-side mechanism for cultivating innovative talents, a goal that is achievable by setting up an appropriate framework to sustain education for innovation and entrepreneurship, in order to solve the challenges coming from industry and ultimately enhance the quality of life for ordinary people [12], serve the regional economy, and promote its transformation and upgrade [13]. We point out certain shortcomings of the current framework put in place in order to further education for innovation and entrepreneurship in Chinese technical universities and measures to be taken for enabling systemic and conceptual improvements pertaining to adjusting organizational structures, modifying curricular systems and furthering the integration between the educational chain, the talent chain, the industrial chain and the innovation chain. Further, we propose a method to evaluate the performance of the education for innovation and entrepreneurship and illustrate its application to the concrete situation of the Changzhou Institute of Technology, China.

The remaining part of this paper is organized as follows. In Section 2, a brief background regarding the status of education for innovation and entrepreneurship in Chinese technical universities is indicated and certain shortcomings are pointed out. Section 3 proposes a set of measures for improving education for innovation and entrepreneurship, systemically and conceptually. Section 4 presents the design of the MPEIE (Measuring the Performance of Education for Innovation and Entrepreneurship) method and demonstrates its usage. The final conclusions are given in Section 5.

2. Status of Education for Innovation and Entrepreneurship in Chinese Technical Universities

In Chinese technical universities, education for innovation and entrepreneurship faces specific challenges, as outlined below.

2.1. The Educational Concepts and Goals Are Relatively Lagging, Which Causes a Split in the Logical Relationship among Innovation, Entrepreneurship, University Major and Industry

In China, colleges and universities adhere to a national paradigm on nurturing students with innovative abilities [14]. As per national requirements, technical universities are strongly urged to consider closely combining innovation and entrepreneurship and adjusting talent training to assist industry needs. However, certain university staff believe that colleges and universities have neither the ability nor the experience to guide their students through education for innovation and entrepreneurship, and, first and foremost, it is not the responsibility of colleges and universities to carry out this type of education. A few others are content to believe that education for innovation and entrepreneurship has reached its goals as long as they have secured the necessary funding to have the respective lectures delivered, the students have built a few small companies, and have won a few prizes in student competitions.

In addition, the cooperation between universities and their industrial partners is not nearly close enough to promote industrial and economic development. This is specifically reflected in inadequate policies issued by universities, and a lack of motivation for cooperation that materialized in a failure to find common interests. These sharp and sensitive issues have caused more than a few colleges and universities to either wait and see, or just deal with these matters unwillingly, and to be unable to take education for innovation and entrepreneurship seriously.

2.2. The Educational Organization System Lacks Coherence, Which Weakens the Mechanisms Put in Place for Collaborative Education

In accordance with the national, provincial and municipal requirements regarding education for innovation and entrepreneurship, a large number of colleges and universities have established Schools of Innovation and Entrepreneurship (SIE). However, in most cases, SIEs are set up as department-level units affiliated to the Office of Academic Affairs. In such a setting, the academic courses on innovation and entrepreneurship are under the responsibility of the Office of Academic Affairs, and so is organizing most related academic competitions. In the meantime, entrepreneurship training is arranged by the Office of Student Affairs, while the top innovation and entrepreneurship competition is organized by the Student Union. Further, the incubation platforms are managed by the university's Asset Management Company. This arrangement causes non-optimal resource use and management conflicts, sometimes resulting in excessively complicated procedures to handle even ordinary events.

2.3. The Curriculum Is Dull and Does Not Involve Practical or Personalized Guidance

There is now considerable evidence that innovation and entrepreneurship can be taught and the teaching process can be designed to involve the active participation of students [15–18]. However, in many Chinese universities, courses on innovation and entrepreneurship are offered as general elective courses and delivered as traditional lectures or via large-scale MOOC online platforms. At a glance, the courses seem then to reach a wide range of students, but the reality is that some of these courses are neither very pertinent nor very practical. In particular, support for personalized practical guidance and the encouragement of students towards developing personal projects is often found lacking.

Unfortunately, on the one hand, technical universities have no unified standards for curriculum development and have not fully tapped the innovative and entrepreneurial culture of the industrial partners involved by the local governments. On the other hand, in many cases, students still deal with theoretical matters and examinations only and have no opportunity to apply what they have learned, as they either do not have to develop any practical project or are involved only in the theoretical and laboratory stages of the project, failing therefore to develop real-world experience.

2.4. The Incubation Platforms Are Relatively Lacking, Restricting Project Cultivation and Docking Resources

Incubation platforms allow businesses to develop and deliver higher quality, more personalized products and services [19]. Additionally, a large number of active, thriving incubation platforms embodies and illustrates the academic and research strength of an university [20]. In this regard, the central governmental structures and industry associations have responded to the necessities of the Chinese economy and provided applicants with multi-level incubation platforms, such as those below.

- The Ministry of Education's entrepreneurial talent training innovation pilot zone, innovation and entrepreneurship education reform demonstration school, and innovation and entrepreneurship practice education center.
- The entrepreneurship platform and entrepreneurship demonstration base of the Ministry of Human Resources and Social Security.
- The makerspace and university science park of the Ministry of Science and Technology.
- The demonstration base of mass innovation and entrepreneurship of the National Development and Reform Commission.
- The modern industry college of the Ministry of Education and the Ministry of Industry and Information Technology.

It should be noted that many incubation platforms are to be applied for stage by stage, which means that applicants must first apply for the municipal platform, then may apply for the provincial platform if they pass the assessment of the municipal platform and are finally eligible to apply for the national platform provided that they pass the assessment of the provincial platform as well. If the preliminary steps are missed, it is difficult to apply for them again, and the applicants for these platforms are not only colleges and universities, but also all eligible institutions in the society. Additionally, a few platforms only have provincial and national levels.

Technical universities should then take advantage of their own assets, avoid pressure from competitors, and proactively connect with suitable incubation platforms. If funding is insufficient for properly establishing schools for innovation and entrepreneurship, they should strive to obtain social support and actively connect to the industry development and market demand, which can provide the necessary feedback for the refinement of the research results of teachers and students.

2.5. The Cooperation between Professional Teachers and Entrepreneurial Mentors Is Often Not Substantive

The teacher–mentor team is the cornerstone of education for innovation and entrepreneurship in colleges and universities [21]. However, at present, due to the significant differences in organization and priorities between the industrial system and the educational system, university teachers complete most of their teaching tasks concerning education for innovation and entrepreneurship, while off-campus mentors are busy with their own businesses and have little to no time to take care of students, or just give lectures and leave it at that, which indicates that no substantive cooperation really takes place. Further, teachers in colleges and universities understand education but rarely understand entrepreneurship, and are sometimes out of touch with industrial development, while off-campus mentors understand entrepreneurship but may not necessarily understand education, which makes the the talent training goal of colleges and universities significantly more difficult to achieve.

3. Necessary Measures for Improving Education for Innovation and Entrepreneurship, Systemically and Conceptually

The goal of education for innovation and entrepreneurship is not only to train students to successfully set up companies and to be ready to create commercial value, but also to educate them in an entrepreneurial spirit and to nurture their pioneering, innovative and enterprising nature. In some sense, the ultimate goal is to make entrepreneurship a way of thinking and acting. In fact, entrepreneurship itself has an element of innovation. Innovation, as opposed to the mere licensing of patented technology, may rely in addition to technological invention and process improvement, upon cultural creativity, innovative exterior design or management and business model innovation [22,23].

The main purpose of education for innovation and entrepreneurship in universities is to cultivate suitable talents. Technical universities, like other universities, undertake the basic functions of student training, scientific research, social service, cultural inheritance and innovation, and international exchanges and cooperation. The focus of these functions is, for technical universities, closely linked with the integration between industry and education. This is because technical universities have a well-defined, valuable role in assisting the development of local economy, which in turn shapes the future development of the university, alongside the orientation provided via local government resource allocation and subsidies. This aligns with the triple helix model (government, academia and industries) of Etzkowitz and Leydesdorff [24–27], introduced as one of the important patterns of the nonlinear model of the multidisciplinary and transdisciplinary knowledge-based innovation. Those altogether underline the fact that integration between industry and education should be the basis for training of professional talents on campus.

3.1. "5+1" Talent Training Model

The "5" in the "5+1" talent training model represents the integration of the following five pillars of education and industry, as shown in Figure 1.

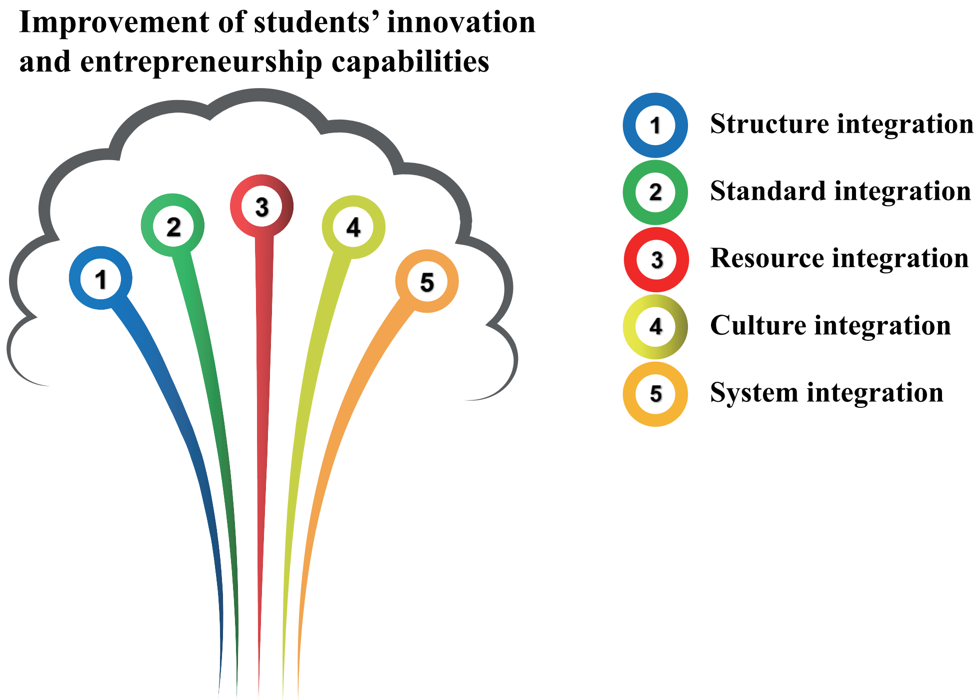

Figure 1. The "5+1" talent training model.

1. Integration between industrial structures and the catalogue of university specialisations
The catalogue of specialisations in technical universities should be highly consistent and highly coupled with the orientation of regional industrial development, ideally in such a way that they would cross-promote each other. In agreement with their development goals and talent training specifications and also with the needs of the local and regional industries with regard to applications-oriented talents, technical universities need to improve the dynamic adjustment mechanism of their catalogue of specialisations in such a way as to promote the connection between enrollment, training and employment and to account for the emergence of new technological trends around the world. Finally, study plans oriented towards precise specializations and close connection with the industrial and innovation chains must be established in technical universities.
2. Integration between specialisation standards and professional requirements
Technical universities must follow future directions of industrial development, corresponding to different specialisations and subdivisions of industries. During the period of reconstruction and reestablishment of majors and specialisations, referring to the Ministry of Education's first-class undergraduate specialisation construction standards and engineering education professional certifications, technical universities should identify the characteristics of specialisations and then form a pattern of professional standardization and specialisation, which takes root in local industries and deepens the integration between industry and education.
3. Integration between educational resources and industrial resources
It is necessary to establish a steering committee consisting of senior enterprise managers, industry experts and university teachers in order to formulate the blueprints of a talent training program with a multi-level curricular system and teaching materials that integrate production and education. By making use of all pooled resources, experience and know-how, technical universities can then explore the establishment of industrial colleges or research institutes that can integrate talent training, innovation and entrepreneurship, high-tech research and development, and social services.

4. Integration between educational culture and enterprise culture
Technical universities should organize lectures and various social activities to strengthen the promotion of the best practices in enterprise culture, so that the enterprise culture could find its way into the daily lives of college students. At the same time, through internship training programs, college students could adapt to the corporate culture, in order to develop professional habits and professional ethics in advance of the actual employment.
5. Integration between the educational system and industrial research and development mechanisms
Enterprises should formulate actual problems encountered in production and R&D as study cases for students to discuss and/or solve. As a result, on the one hand, students can learn by doing and can refine their critical thinking and problem-solving capabilities in a realistic environment, on actual real-world problems. On the other hand, this may lead to specific problems in enterprises, such as technical bottlenecks, usability issues, technological upgrades, being solved or mitigated.

The "1" represents the improvement of students' innovation and entrepreneurship capabilities. Technical universities must strive to increase students' real-world productive experience and enhance their mastery of professional knowledge and industrial technology, cultivate their sense of innovation, inspire their innovative thinking, and promote their creativity. This is an effective way to alleviate the inherent contradictions between the educational system and the industrial system, and promote the full integration of basic elements on the supply side of talent training and on the demand side of the industry.

3.2. Organizational Structures for Talent Training

Technical universities can try to separate the School of Innovation and Entrepreneurship from the Office of Academic Affairs and re-establish it as an independent academic entity overseeing, managing and integrating all university work pertaining to innovation and entrepreneurship. This entity, organized in several departments and having its own dean and deputy dean, is projected to group relevant staff from the Office of Academic Affairs (overseeing talent training programs), Office of Student Affairs (supervising entrepreneurship training) and the Student Union (organizing top student competitions), the Asset Management Company (in charge of incubation platforms) and the Technology Transfer Office (in charge of industry docking) to participate part-time or full-time in the management and operation of the school (see Figure 2). This way, the SIE would be able to contact in a more efficient manner relevant national and provincial authorities, social organizations, industry associations, incubation platforms, and twinning universities, and would also better coordinate with relevant colleges and departments within the same university.

In addition, giving full credence to the autonomy and initiative of university students, the university should recruit demanding, creative and energetic students from the entire campus to establish a school-level student organization, a College Student Innovation and Entrepreneurship Alliance. With funding and help from the school, the Alliance could guide students with innovative thinking and entrepreneurial ideas to set up innovation groups, entrepreneurial groups or even small companies, create a culture of innovation and entrepreneurship on campus and become a valuable assistant of the school.

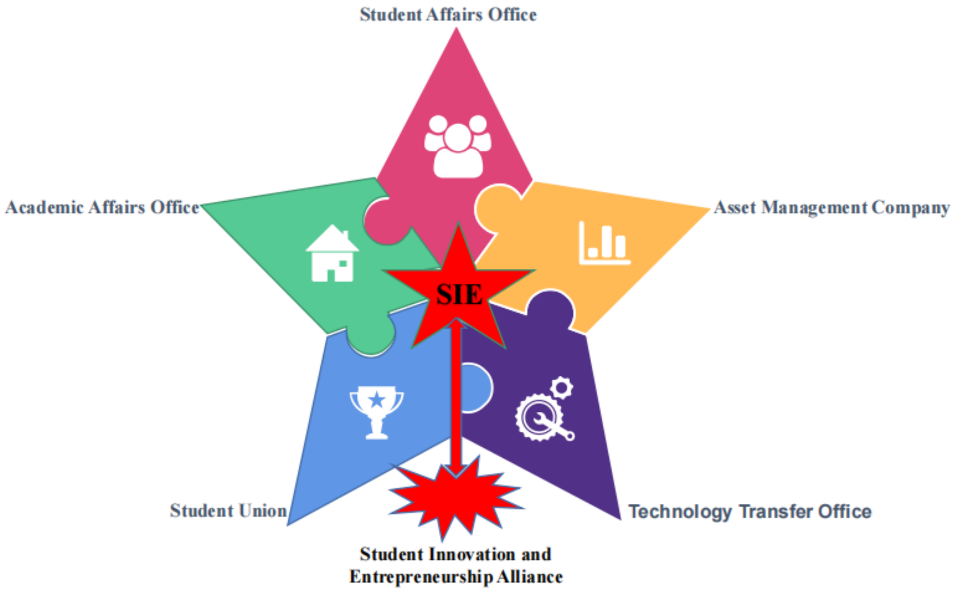

Figure 2. The organization chart.

3.3. Curriculum Systems for Talent Training

The curriculum system for education for innovation and entrepreneurship, aiming at close cooperation between industry and education, is not a supplement to the traditional curriculum system, but rather a reconstruction. One has to integrate general education, professional education, education for innovation and education for entrepreneurship by setting up courses at different levels, as shown in Figure 3.

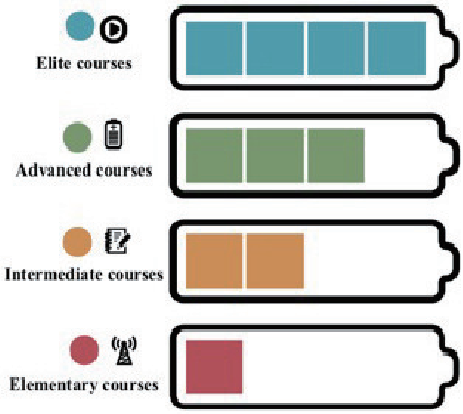

Figure 3. Courses by levels of difficulty.

Level 1 Elementary courses. These include basic courses in innovation and entrepreneurship. Combining with the unearthing and learning of local regional innovation culture and entrepreneurship history cases, the courses cultivate all students' deep understanding of local innovation culture and entrepreneurial spirit.

Level 2 Intermediate courses. Teachers unearth relevant professional curriculum resources in teaching, and include subject competitions, scientific research practice, social surveys and elements of entrepreneurship in their courses to cultivate the innovative and entrepreneurial potential of interested students.

Level 3 Advanced courses. These courses are taught in order to set up a training program for a small number of students, and set up an experimental class to develop their innovative and entrepreneurial knowledge.

Level 4 Elite courses. Students are trained in college student entrepreneurship parks through projects and practical problems provided by enterprises, meant to enhance students' innovation and entrepreneurship capabilities as well as serve the development of local economic industries.

3.4. Teacher Team Building for Talent Training

A team of well-trained teachers is indispensable to adequate talent training. The training of teachers will then have to shift from a single subject to a plurality of subjects. Besides receiving professional training in their institutions, teachers can also take temporary positions in enterprises, government organizations and research institutes to grasp the front-line situation. In 2020, Jamieson and Shaw [28] described the use of a mixed teaching team of academics, engineers and entrepreneurs to teach engineering innovation, design and leadership. Accordingly, colleges and universities can hire or invite well-known entrepreneurs, management elites, technical experts, and master craftsmen from the industry as off-campus mentors or industry professors, as shown in Figure 4, and let them share the latest management concepts, business models, industry hot spots, and their own entrepreneurial growth experience with undergraduate students. The latter would then mold the spirit of entrepreneurs and makers into the university's cultural characteristics of innovation and entrepreneurship education. The bidirectional cooperation between school teachers and off-campus mentors can greatly improve the efficiency of student learning and enterprise production. In fact, teachers, students, and off-campus mentors can cooperate to solve the problems arising in the day-to-day operation of the enterprise, which provides an opportunity for teachers and students to develop, test and transfer their laboratory research results through real projects.

Figure 4. The well-trained teacher team.

3.5. Creating Incubation Platforms for Talent Training

In order to evolve into real products, the innovative work done by students by themselves or within a teacher–student team must undergo a gradual accumulation and incubation process, following a progressive "pyramid-shaped" platform mechanism as shown in Figure 5.

1. Pyramid base
   Department and schools in the university are the main units of talent training, relying on college laboratories to complete the experimental projects assigned in the curriculum of the training program in order to meet the needs of all students. The colleges should also open up a certain area of dedicated space to establish a makerspace with a distinct environment that allows students to engage in research projects that go beyond basic courses.
2. Pyramid body
   The universities rely on the establishment of entrepreneurship parks or science parks open to college students and on well-funded industrial colleges to form inter-academic

and inter-disciplinary makerspaces and then dynamically select distinguishing teams and projects from different schools to enter this makerspace. In the context of the integration between industry and education, the university provides venues, facilities and supporting policies, through the collaborative assistance of professional teachers on campus and entrepreneurship mentors off-campus, for resident teams and projects that accept re-cultivation, re-polishing and re-incubation. The teams that are able to master innovation and entrepreneurship abilities become seed teams for the university and are intended to be active on the stage of various innovation and entrepreneurship university activities.

3. Pyramid top
   The successful teams trained on campus are recommended to enter the off-campus incubation platform, connect with local industries, and continue to acquire experience and grow in the market environment. These successful teams will not, hopefully, break up when they graduate, getting rid of the greenhouse effect in the post-campus era, and continue to have strong vitality. A few years later, their growth and achievements will have a demonstrative, positive impact on the student teams on campus. A similar phenomenon occurred for Stanford University, known as the "Heart of Silicon Valley", since nearly 80% of well-known companies in Silicon Valley such as Apple, Google, Hewlett-Packard, Yahoo, Cisco, and so forth are the results of collaborative entrepreneurship between Stanford University's teachers and students.

Figure 5. A "pyramid-shaped" platform mechanism for technical universities.

The layered incubation mechanism described above has the potential to foster a better relationship between university innovation, specialization, entrepreneurship and industry, and set up the carrier group of laboratories, training areas, cultivation spaces, incubator and industrial areas.

3.6. Building an Innovation Ecosystem for Talent Training

After decades of development, the education for innovation and entrepreneurship of today has departed from the traditional concept of "doing business and building companies" and is moving towards a comprehensive development path that relies on the trend of closely connecting industry and education. In the process of talent training, technical universities combine courses, projects and competitions on innovation and entrepreneurship and employ innovation and entrepreneurship incubation platforms, pursuing a close connection between industry and education in order to construct an interconnected and mutually beneficial innovation and entrepreneurship community of interests. This community of interests interacts with local governments, industries, research institutes, financial institutions, and so forth to further form a higher-level multi-dimensional symbiotic innovation ecosystem consisting of local governments, new product users, universities and research institutes, industrial partners, financial institutions and venture capital institutions, intermediaries, commerces and media. This ecosystem is pictured in Figure 6, in which the basic elements are specified as follows.

- Local governments: Adopt subsidy strategies to promote innovation and ensure the participation of interested parties by providing incentives to cooperate [29].
- New product users: Discovering and then meeting the needs of new product users promotes scientific and technological innovation, keeping the product up with the times.
- Universities and research institutes: Cultivate talents with innovative ability and pioneering spirit and ensure their cooperation with industrial partners to the best of their abilities by utilizing the support of off-campus organizations and trade associations.
- Industrial partners: One of the main parties in the collaboration, enjoying the support of the local government. Ensure the transfer of teachers' and students' knowledge and research to the assembly lines by preparing the basis for implementing the scientific knowledge gained in the academic stage.
- Financial institutions and venture capital institutions: As these institutions are well aware of the regional financial policies and economic development trends, they can play an effective role in selecting and financing the industrialization of worthy scientific and technological achievements.
- Intermediaries: Give full play to the role of bridges and ties, so that the elements of innovation can be effectively connected and gathered.
- Commerces: Build channels for the purchase of raw materials and for product sales.
- Media: The national and local innovation policies cannot be fully accepted by people without vigorous media propaganda. The promotion of new technologies and new products cannot be done without mediatic cooperation. The media is like a window that allows us to peek into the world of innovation.

In such a way, we can realize the four-level linkage of talent training, scientific research, experimental development and application promotion and the four-chain connection of education chain, talent chain, industrial chain and innovation chain in technical universities.

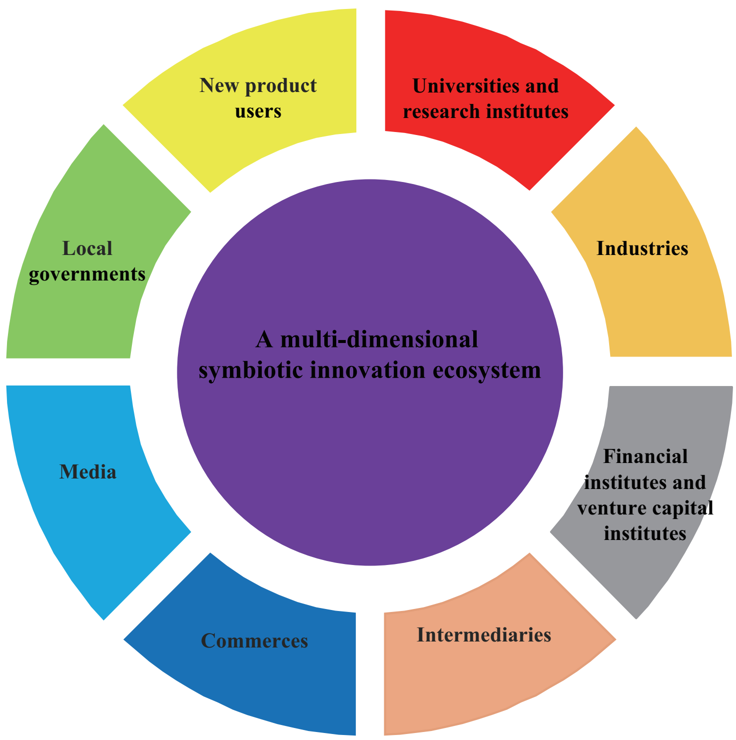

Figure 6. A multi-dimensional symbiotic innovation ecosystem.

4. The Design of the MPEIE Method and Its Usage

First, a detailed review of the existing literature on the subject of performance measurement for the integration between industry, education, innovation and entrepreneurship has been conducted. Subsequently, the MPEIE method was devised in order to assess the efficiency and sustainability of the existing framework enabling education for innovation and entrepreneurship in Chinese technical universities, and to allow for adjustments and improvements. This method is based on the core of the Design Science Research Methodology first proposed by Peffers et al. [30], applied to the five phases of the program and project management life cycle (Program Preparation, Program Initiation, Program Benefits Delivery, Program Closure and Post-Program) suggested by Fernandes et al. [31], and uses D'Este and Patel [32], Perkmann et al. [33], Seppo and Lilles [34] and Tijssen et al. [35] as partial sources of performance indicators. See also Fernandes et al. [36] and Fernandes et al. [37] for a related approach towards measuring the success of of collaborative university-industry R&D funded contracts.

The MPEIE method uses specific, objective outcomes, such as patents filled, publications, awards in competitions and acquired funding, as indicators, as well as non-specific, subjective indicators such as organizational arrangements and satisfaction rates. The necessary data has been collected through interviews, questionnaires and the analysis of university documents and analyzed using SPSS, Microsoft Office tools and related software in order to attribute a score to each performance indicator.

Data Sources and Motivations for the Choices of Performance Indicators

During our research activity, we chiefly used the following sources of qualitative and quantitative data.

- Document review: All official documents related to the education for innovation and entrepreneurship in China have been reviewed.
- Interviews: It has been attempted to engage teachers, students and off-campus mentors in one-on-one conversations. A total of 115 teachers and mentors outside the university and 853 students from 13 schools accepted to be subjects of our interviews.
- Focus groups: Discussions has been started in a group of people involved in the symbiotic innovation ecosystems, questions relevant to the subject of our research being asked and answered.
- Surveys: A total of 2693 questionnaires with open-ended questions have been distributed on-line, of which 2586 were effectively recovered.
- Secondary research: Related books and scholarly articles have been surveyed, existing data being collected as text or images.

The MPEIE method considers two phases, namely a preparation phase with a weight of 30% and a benefits delivery phase with a weight of 70%, the specific percentages being an outcome of authors' experience in teaching and practice of innovation and entrepreneurship and of the answers to the questionnaires. Here, our preparation phase encompasses both the preparation and initiation phases of Fernandes et al. [31], while our benefits delivery phase includes the benefit delivery and closure phases, as well as the post phase of Fernandes et al. [31].

In order to set up a valid approach towards quantitative evaluation, a legitimate concern during the development of the MPEIE method was how to make it as objective and verifiable as possible. Apart from identifying suitable weights for each phase, the questionnaires aimed at selecting suitable PIs and appropriate weights for each of them and for each process component. The resulting percentages were converted on a 5-point Likert scale, where 5 means "very high" and 1 means "very low". The same scale was used when interviewing the respondents, wherever appropriate. A set of tentative weights for both phase components and PIs is proposed in Tables 1 and 2 for illustrative purposes, while being understood that in concrete situations the actual weights should be chosen in accordance to the specifics of the university where the MPEIE method is to be applied.

Table 1. PIs adopted by the proposed method for measuring the performance of the sustainable framework (preparation phase).

Phase	Phase Weight	Process Component	Component Weight	Performace Indicator	PI Weight	Source
Preparation phase	30%	Organizational structure	20%	1. Percentage of administrative offices guaranteeing education for innovation and entrepreneurship	30%	
				2. Percentage of student organizations involved in education for innovation and entrepreneurship	30%	
				3. Rate of off-campus collaborators with their participation in education for innovation and entrepreneurship (performed/planned)	40%	
		Curriculum system	30%	4. Rate of elementary courses (performed/planned)	25%	
				5. Rate of intermediate courses (performed/planned)	25%	
				6. Rate of advanced courses (performed/planned)	25%	
				7. Rate of elite courses (performed/planned)	25%	
		Teacher team	20%	8. Average h-index of the academic staff	25%	[34]
				9. Percentage of off-campus mentors with a higher education qualification	25%	[34]
				10. Percentage of school teachers with past experience	10%	
				11. Percentage of school teachers satisfied with the contribution of their participation	20%	
				12. Percentage of off-campus mentors satisfied with the contribution of their participation	20%	
		Incubation platform	30%	13. Average number of laboratories provided by each college	50%	
				14. Number of makerspaces provided by the university	50%	

Table 2. PIs adopted by the proposed method for measuring the performance of the sustainable framework (benefits delivery phase).

Phase	Phase Weight	Process Component	Component Weight	Performace Indicator	PI Weight	Source
Benefits delivery phase	70%	Collaboration intensity	10%	15. Rate of steering committee meetings (performed/planned)	25%	[32]
				16. Rate of workplace meetings (performed/planned)	25%	[32]
				17. Rate of progress meetings (performed/planned)	25%	[32]
				18. Rate of result-sharing events (performed/planned)	25%	[32]
		Human capital	15%	19. Rate of students win awards in subject competitions	30%	
				20. Rate of students win awards in top innovation and entrepreneurship competitions	30%	
				21. Rate of university graduates serving local industries	40%	[34]
		New knowledge	10%	22. Rate of publications (performed/planned)	50%	[33]
				23. Rate of joint publications (performed/planned)	50%	[35]
		Technology achievements	10%	24. Rate of patent application (performed/planned)	100%	[33]
		Education achievements	20%	25. Rate of teaching achievement award (performed/planned)	20%	
				26. Rate of publishing innovation and entrepreneurship textbooks (performed/planned)	20%	
				27. Rate of innovation and entrepreneurship research project application (performed/planned)	20%	
				28. Rate of innovation and entrepreneurship lectures (performed/planned)	20%	
				29. Rate of innovation and entrepreneurship social activities (performed/planned)	20%	
		Incubation achievements	20%	30. Rate of projects incubated by the industry collaborators (performed/planned)	30%	
				31. Rate of university graduates starting their own businesses	30%	
				32. Rate of provincial and national incubation platforms (performed/planned)	40%	
		Financing achievements	15%	33. Rate of government funding (performed/planned)	20%	
				34. Rate of university funding (performed/planned)	20%	
				35. Rate of enterprise funding (performed/planned)	20%	
				36. Rate of bank and other financial institution funding (performed/planned)	20%	
				37. Rate of Angel investor funding (performed/planned)	20%	

Although most PIs are of a quantitative, assessable nature, a minority of them are eminently subjective. In this regard, quantitative PIs may be evaluated by the appropriate administrative personnel of the university through the use of searchable research databases, while the subjective PIs can be evaluated by interviewing project members off-campus mentors.

As shown in Table 3, an application of the MPEIE method to the particular situation of Changzhou Institute of Technology led to an overall score 4.0415 on a scale from 1 to 5 at the time of application, being also concluded that the scores for 26 of the PIs are at least 4, while the scores for 11 of the PIs are at most 3. The quantitative data leading to this evaluation was collected with the help of colleagues from several academic units, administrative offices involving education for innovation and entrepreneurship, and off-campus collaborators.

Table 3. Current MPEIE scores for Changzhou Institute of Technology.

PI	Result	Score	Weighted Score
1	83%	5	0.09
2	75%	4	0.072
3	5/7 = 71%	4	0.096
4	1/1 = 100%	5	0.1123
5	7/13 = 54%	3	0.0675
6	5/13 = 39%	2	0.045
7	4/2 = 200%	5	0.1125
8	82%	5	0.075
9	73%	4	0.06
10	76%	4	0.024
11	65.8%	4	0.048
12	68%	4	0.048
13	100%	5	0.225
14	69%	4	0.18
15	7/10 = 70%	4	0.07
16	7/10 = 70%	4	0.07
17	6/8 = 75%	4	0.07
18	6/10 = 60%	4	0.07
19	110%	5	0.1575
20	50%	3	0.0945
21	85%	5	0.21
22	35/50 = 70%	4	0.14
23	8/15 = 54%	3	0.105
24	16/20 = 80%	5	0.35
25	1/2 = 50%	3	0.084
26	2/1 = 200%	5	0.14
27	345/200 = 173%	5	0.14
28	15/20 = 75%	4	0.112
29	10/12 = 83%	5	0.14
30	15/13 = 115%	5	0.21
31	56%	3	0.126
32	2/3 = 67%	4	0.224
33	35/50 = 70%	4	0.084
34	50/200 = 25%	2	0.042
35	20/30 = 67%	3	0.063
36	5/20 = 25%	2	0.042
37	5/20 = 25%	2	0.042
		Overall score	4.0415

5. Discussion and Conclusions

As the times and the social, economic and industrial environments change, so should the talent training model of Chinese universities. This is because in an increasingly knowledge-based society, universities can and should play a more prominent role in innovation and entrepreneurship.

In the context of globalization, education for innovation and entrepreneurship has become an important part of talent training in China's top universities. About a quarter of the more than 2700 higher education institutions of China are technical universities. As seen from the in-depth implementation of China's 14th Five-Year Plan, the distinctive characteristics of technical universities stem from the development orientation shaped by the local industries, the resource orientation guided by the local government resource allocation and subsidy policy, and the value orientation established by serving the local people. This means that technical universities cannot simply copy the experience and practices of other types of universities in regards to innovation and entrepreneurship, but should rather continue to deepen the reform of the innovation and entrepreneurship education, based on a redesign of the whole educational system concerned and on overall considerations, and continue to explore new ways of talent training that are suitable for their own development.

Facing the opportunity of development, high-level technical universities should take the initiative to undertake the historical mission of building an innovative country, solve the problem of the imbalance between the supply side of higher education talent training and the demand side of industrial development, and finally contribute to the high-quality development of regional economy, society, science and technology, and education. As shown in Figure 7, driven by the national innovation and entrepreneurship policies, one needs to integrate the talent training model, organizational structures, curriculum systems, teacher teams, incubation platforms, and the innovation ecosystem to form a multi-faceted system of education for innovation and entrepreneurship that creates a new pattern of integration between industry and education.

Further research regarding possible improvements should be carried out based on the feedback from the existing partnership between Changzhou Institute of Technology, Changzhou government and regional mainstay industries, which deals with the management of this collaboration on a semestrial basis. In order to further refine the MPEIE method, perhaps by finding more suitable PIs or weights, a larger, more representative sample of members of the academic community should be engaged.

This paper specifically addressed the challenges of improving education for innovation and entrepreneurship in China and, as such, it is tailored to the particulars of the educational system and to the organizational mechanisms and structures present in the Chinese society. Although we do expect most of our ideas to be valid and to retain their comparative value in other specific contexts as well, we also expect the general structure and concepts of MPEIE to be valid when evaluating the performance of education for innovation and entrepreneurship in higher-education institutions from other countries also, and our findings have a very specific (and perhaps narrow) focus.

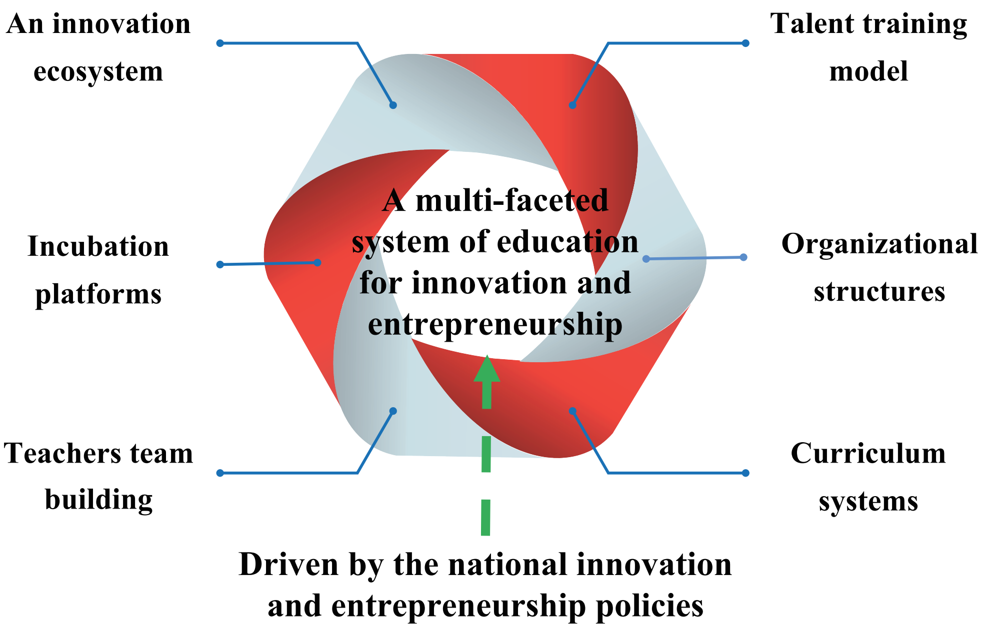

Figure 7. A multi-faceted system of education for innovation and entrepreneurship.

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