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Research on the Integrated Synergy Mechanism of Industry-University-Research Cooperation in Continuing Engineering Education

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ABSTRACT

Industry-university-research cooperation in continuing engineering education is an effective educational mode to enhance the competitiveness of the national manufacturing industry. The integrated synergy mechanism of industry-university-research cooperation in continuing engineering education is introduced from the theoretical level in this paper. Then we conduct a pentagon model containing both elements and process throughout the mechanism. Finally, it is proposed that the implementation of the mechanism relies on the integrated synergy of policy, technology, systems, risk and learning.

Keywords: continuing engineering education, industry-university-research, integrated synergy mechanism

INTRODUCTION

Industry-university-research cooperation in continuing engineering education is an effective educational mode to enhance the competitiveness of the national manufacturing industry at a time of drastic changes in the world's industrial development and the major adjustment of national industrial development strategies. Industry-university-research cooperation has been mentioned many times in the National Middle and Long-Term Education Reform and Development Plan Outline (2010-2020) and the National Middle and Long-Term Talent Development Plan Outline (2010-2020) in China. In the last 20 years or so, industry-university-research collaborations have improved, but they are still weak. In the future, industry-university-research collaborations should be further reinforced, and more universities and research institutes should be encouraged to become involved to help enterprises enhance their innovative capabilities (Gao, Guo & Guan, 2014). Many scholars have built various models to enhance industry-university-research cooperation, such as the Network Model made by Sense (2014) and the Symbiosis Model made by Xu and Song (2017). Yet it is still important for us to improve the mechanism of industry-university-research cooperation in continuing engineering education. This is what we aimed at in this paper.

The structure of the paper is as follows: We put across the integrated synergy mechanism of industry-university-research cooperation in continuing engineering education in Part 3 CONCEPTION, which is based on a flood of literature reviewed in Part 2. Further discussion of the mechanism is shown in Part 4. Finally, we proposed five ways to implement this mechanism in China in Part 5.

LITERATURE REVIEW

Foreign researchers have studied industry-university-research cooperation in continuing engineering education from different perspectives, such as Mansour, Albalawi and Macleod (2014) and Qablan, Mansour, Alshamrani, Aldahmash and Sabbah (2015) This research on the theory of the industry-university-research cooperation in continuing engineering education is derived from the development of research on innovation theory and industry-university-research cooperation. Innovation tends to have more than one behavioural undertaker with different roles, which means that the innovation subject is not a single identity but a complex of identities with an internal

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Contribution of this paper to the literature

- The integrated synergy mechanism of industry-university- research cooperation in continuing engineering education is put across from the theoretical level.
- A pentagon model containing both elements and process throughout the mechanism is conducted.
- Five ways are proposed to implement the mechanism in China from the practical level.

structure, including both enterprises and other associated social groups (such as research institutions, individuals, etc.). According to Cyert and Goodman (1997), cooperation provides good learning opportunities for enterprises, and enterprises should focus not only on specific technologies, processes or products bringing short-term benefits but also on continuing to learn through cooperation with universities. Decter (2009) found that universities in Britain and American were closely linked to industries. The cooperation has been strengthened by legislation in America and industry links had been simplified through cooperation in Britain.

On the cooperation mechanism of continuing engineering education, some foreign scholars have studied the reasons for the endogenous nature of new product development and commercialized development by enterprises. Karmarkar (1996) analysed how enterprises (as the innovation subject) could successfully carry out Research and Development (R&D) activities to obtain higher profits. Fyvie and Ager (1999), from another perspective, studied the collaborative innovation project launched by non-governmental organizations and the United Nations Industrial Development Organization. They found that it was still difficult to obtain the corresponding output, even if they had considerable organizational capacity to complete project innovation without profitable business-led participation. Lakpetch and Lorsuwannarat (2012) believed that partner attributes and cooperative relationships were direct influencing factors in cooperation after studying the efficiency of knowledge transfer in cooperation. Rawlinson and Dewhurst (2013) drew on Michael Eraut's work (1997) on the transfer of knowledge between education and the workplace.

Some foreign scholars have studied how governments develop scientific and technological policies to enhance cooperation. Lubatkin, Srinivasan and Merchant (1997) analyzed the importance of the government's establishment of a market-oriented economic relationship between industry, university and research. Mowery (1998) explored the changes in science and technology policies of the US federal government with an analysis on its practice to promote collaborative research between US universities, industries and federal laboratories. Archibugi and Coco (2004) discussed cooperation between EU academic institutions and enterprises at home and abroad and studied the policy reasons affecting their cooperation.

In addition, some foreign scholars have studied the effective roles of universities in the cooperation. Lind, Styhre and Aaboen (2013) explored university-industry collaboration in research centres, taking the different institutional logics of the parties involved in the collaboration into account. Striukova and Rayna (2015) provide a better understanding of what Open Innovation means within the university context.

CONCEPTION

In this part, we put across the concept of integrated synergy mechanism of industry –university-research cooperation in continuing engineering education.

The concept of "synergy" was proposed by the physicist Haken for the first time during the study of physical lasers, which was later described by the strategic manager Igor Ansoff (1965) from the perspective of economics, who indicated that the company's overall value was greater than the simple sum of the independent parts using the formula "2 + 2 = 5". Integrated collaboration refers to a process of coordinating two or more different individuals to complete a task. The integration mechanism is interdependent with the system and characterized by automatic adjustment, internality and objectivity.

Based on these theories, we propose a synergy mechanism of industry-university- research cooperation in continuing engineering education integrated throughout the whole process of industry-university-research cooperation in continuing engineering education. This is the integrated synergy of power-driven, benefit-sharing, cooperation-selection, organizational coordination and learning innovation. We believe that industry-university-research cooperation in continuing engineering education is operating towards integrated synergy mechanism.

Continuing engineering education is divided into three important stages (as shown in **Figure 1**): the establishment of cooperation relationship, the cooperation process and the end of the cooperation project. The establishment of a cooperation relationship is aimed at seeking partners and cooperation opportunities, establishing the benefit-sharing mechanism in accordance with the parties' power-driven mechanism, clearing different partner's rights and obligations as well as to ensure the smooth progress of cooperation. In the cooperation process, cooperation selection and organizational coordination are conducted for parties based on the existing benefit-sharing mechanism. After the end of a cooperation project, partners learn from each other, realizing

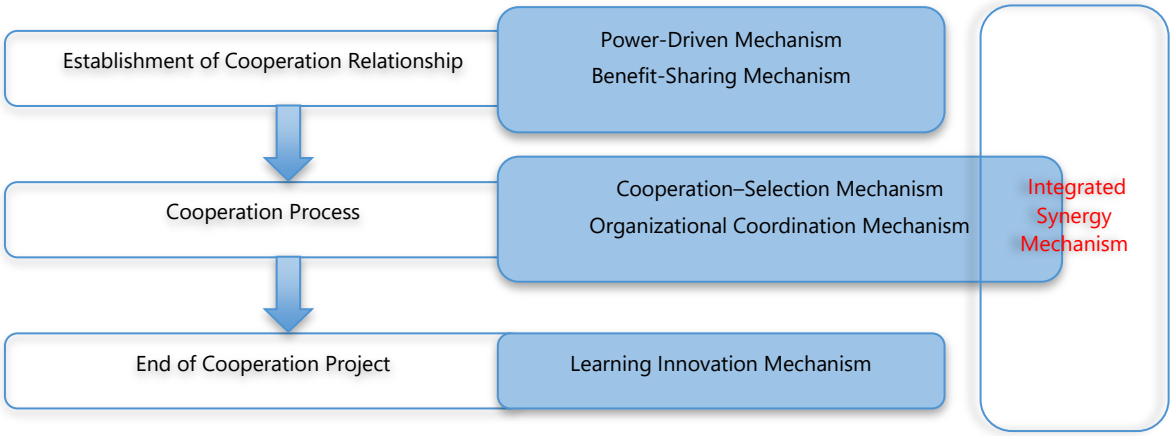

Figure 1. The Integrated Synergy Mechanism of Industry-University-Research Cooperation in Continuing Engineering Education

advantageous complementarities and summarizing lessons to instruct the next cooperation. In the process of cooperation, the government and the market respectively act as a tangible and intangible regulatory mechanism, forming an integrated and synergistic operating mechanism.

FURTHER DISCUSSION

The integrated synergy mechanism of industry-university-research cooperation in continuing engineering education means that the subject achieves efficient allocation through coordination and cooperation around a common goal combined with its own functions and resource advantages. Jauhari and Thomas (2013) concluded that it is important to understand the expectations of the various stakeholders: universities, industry, students, government and civil society among others. So we will further explain the integrated synergy of elements and integrated synergy of processes within industry-university-research cooperation in continuing engineering education.

First, is the integrated synergy of elements of industry-university-research cooperation in continuing engineering education. In the process of industry-university-research cooperation in continuing engineering education, the integrated synergy of elements aimed at improving each subject's ability for technological innovation. The effective integrated synergy of cooperation subjects is conductive to the exchange and integration of different knowledge sources allowing users to generate new explicit and implicit knowledge. In this manner, cooperating subjects are able to explore new management methods or arrange new systems with an increased innovation capacity. The stronger the integrated synergy among cooperation subjects, the better the results of cooperation and innovation will be.

Second, is the integrated synergy of processes of industry-university-research cooperation in continuing engineering education. As one of the driving forces for industry-university-research cooperation in continuing engineering education, technological innovation includes many links. For example, the preparatory stage covers discovering problems, generating innovation demands, preparing information and selecting the appropriate partners. The formal stage mainly includes the consultation and determination of the cooperation mode, internal coordination, technological innovation and achievement acceptance. The latter stage is divided into result transformation, benefit distribution, appraisal of cooperation performance and new demand for innovation, during which cooperative performance will be affected by many factors, such as the market, finance, the relevant policies and regulations of the country, the system, the study of cooperation subjects, etc.

From the above, we conducted a pentagon model (**Figure 2**) that contains both elements and processes throughout this mechanism. In the process of industry-university-research cooperation in continuing engineering education, the synergic relationship between these elements and innovation is as follows:

Reasonable policies play a role in supporting and guiding technological innovation activities, protecting intellectual property rights as well as improving the enthusiasm of enterprises and the technological innovation cooperation of colleges. The market is the starting point of technological innovation aimed to meet the market needs, with the final results requiring the market's acceptance. Only technological innovation recognized by the market can achieve the enterprise's objectives, so that the market is the destination of technological innovation. There are market risks in the process of technological innovation; thus, the effectiveness of the technical innovation in industry-university-research cooperation in continuing engineering education can be best achieved by fully

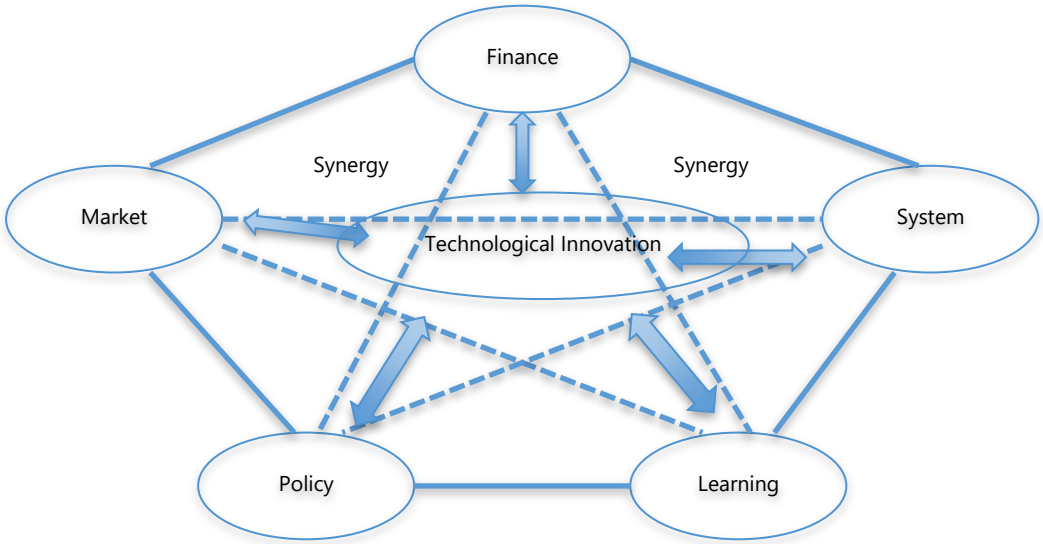

Figure 2. The Integrated Synergy of Processes and Components in the Industry-University-Research Cooperation in Continuing Engineering Education

understanding the importance of the market and obeying market rules. In addition to this, broadening the funding sources by financial institutions as innovation managers for industry-university-research cooperation in continuing engineering education is crucial. In addition, institutional arrangements have an important influence on the trading costs and cooperation modes of industry-university-research cooperation in continuing engineering education. The performance of technical innovation will be affected by the learning performance among cooperation subjects, and the relevant technical innovation is caused by exchange among different kinds of knowledge.

As shown in **Figure 2**, the establishment of an integrated synergy mechanism for cooperation and technological innovation should comply with the strategic requirements of industry-university-research cooperation. It should be achieved through the synergy of elements related with finance and market, and by the coordination of each link. The integrated synergy of elements related to technological innovation extends through each stage of the industry-university-research cooperation in the continuing engineering education process. It creates good conditions and provides background support for the integrated synergy of the overall process. Each element in this process works together, influencing each other and finally achieving good cooperative results. Therefore, the integrated synergy of elements and that of processes support and influence each other. During the cooperative process, the relevant parties should evaluate the cooperative results to form the organized structure of the system innovation. If the expectations of the cooperative parties are not achieved, some adaptive adjustments should be made by negotiation. In conclusion, the integrated synergy of processes and that of elements influence each other and work together to meet the requirements of the relevant parties and to further improve the performance of technological innovation in industry-university-research cooperation in continuing engineering education.

REALIZATION APPROACHES

A survey which we conducted online shows the major problems of industry-university-research cooperation in continuing engineering education (**Figure 3**), based on the views of 341 respondents. Therefore, we put forward five ways to achieve the integrated synergy mechanism below.

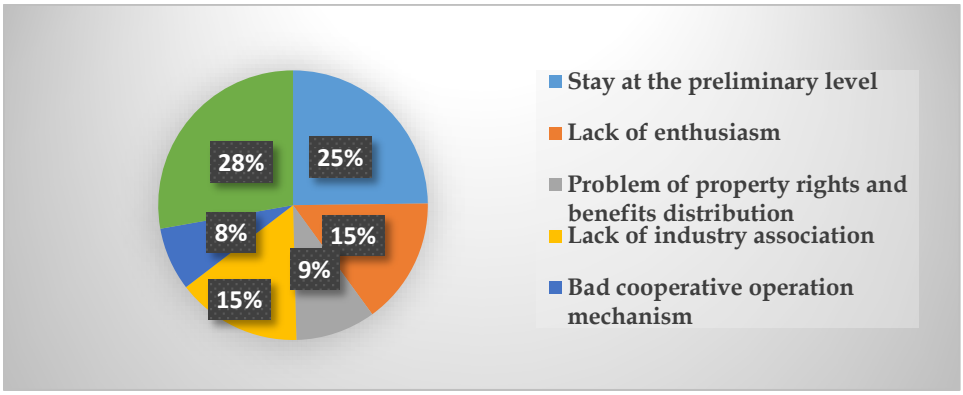

Figure 3. The major problems of industry-university-research cooperation in continuing engineering education

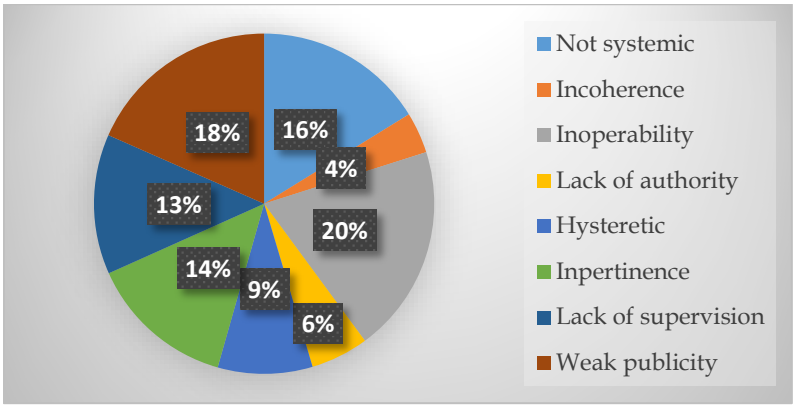

Figure 4. The major problems of industry-university-research cooperation in continuing engineering education in policies

Integrated Synergy of Policies

To achieve effective industry-university-research cooperation in continuing engineering education, relevant policies should be integrated and synergized. The same online survey revealed certain problems of policies (**Figure 4**). No policy can exist alone. Each will be influenced by other policies to different degrees. The integration and synergy of policies related to industry, technology and education will work to hasten the industry-university-research cooperation and help the relevant parties share their research results, which is beneficial in advancing their application. The integrated synergy of policies is different from the simple combination of various policies. The proper policy system, capable of promoting industry-university-research cooperation, should be established.

Integrated Synergy of Technologies

According to the different innovation targets, technological innovation includes product innovation and process innovation. Product innovation means improvement or production of new products. According to the volume of technological changes, product innovation can also be classified as a major product of innovation and incremental product innovation. Process innovation means the innovation of technologies used for producing products, which includes the application of new technologies, new devices and new methods for organizational management. Enterprises, universities and R&D institutions share their technologies and knowledge with each other to promote the transfer of R&D results. Enterprises focus on technological innovation, while the universities and R&D institutions work on knowledge innovation. In industry-university-research cooperation in continuing engineering education, each party's own advantages in resources and risk factors should be considered as they work together, solve relevant problems and finally achieve the effective cooperation.

Integrated Synergy of System

System constraint is an obstacle for industry-university-research cooperation in continuing engineering education. An unclear ownership-management relationship and the lack of proper incentive systems and financial systems undoubtedly will influence the smooth implementation of cooperative programmes. Therefore, the

corresponding systems and mechanisms should be adjusted, and the management methods should be improved to create a good environment for cooperation. The institutional innovation also includes the improvement of existing financial systems and methods, rational distribution of financial resources, and expansion of the financing channels. All these measures will bring large profits and benefits for industry-university-research cooperation in continuing engineering education.

Integrated Synergy of Risks

Industry-university-research cooperation in continuing engineering education brings the innovations of technology, techniques or products. However, two distinct features of technological innovation are high risk and high yield. Great risks (e.g., technological risks and market risks) exist in the process of researching and developing a new technology and launching it into the market. Therefore, a good risk-bearing mechanism is needed; otherwise, the cooperation might become a lost cause. Therefore, the risk and yield of different parties at certain stages should be determined. Generally, universities and R&D institutions bear the risks occurring at the R&D stage. The risks in the achievement-transformation process should be borne by each party involved in industry-university-research cooperation in continuing engineering education. The market-related risks should be borne by the enterprises.

Integrated Synergy of Learning

Enterprises, universities and R&D institutions have their own different knowledge backgrounds. Industry-university-research cooperation in continuing engineering education can promote the communication and integration of different kinds of knowledge, increase the knowledge supply for technological innovation, produce new implicit and explicit knowledge, and shorten the time required for research and development. The learning of different kinds of knowledge is influenced by elements in or out of the cooperative institutions. The government should provide a good environment for this kind of learning. For example, a series of legal protections should be established to defend the intellectual property of relevant parties, protecting the benefits of all cooperative partners. Reliable financing channels should be offered for industry-university-research cooperation. The risks of R&D should be reduced. Furthermore, policy supports and financial supports should be provided to promote cooperation and innovation, and proper motivators should be adopted to promote learning synergy and knowledge integration.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, an integrated synergy mechanism for industry-university-research cooperation in continuing engineering education was researched. The integrated synergy of each process and component was specifically analysed and described. Finally, methods of achieving the integrated synergy mechanism for industry-university-research cooperation in continuing engineering education were proposed.

In conclusion, industry-university-research cooperation in continuing engineering education is an integrated synergy mechanism, which goes through the process of power driving, benefit sharing, cooperation selection, organizational coordination, learning and innovation. However, strictly speaking, this kind of division has a different emphasis at each stage. In regard to each mechanism and stage, the boundary is not clear. Therefore, the integrated synergy mechanism is needed.

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