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Original Article

Innovative Exploration of the Connotation and Education and Training Practice Path of Outstanding Pharmaceutical Engineers

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ABSTRACT

Objectives: China is on the way to improving the education and training of outstanding pharmaceutical engineers. Still, the training of pharmaceutical engineers cannot meet the needs of innovative drug development and transformation research. So, it is worth sorting out the existing problems to improve the professional identity, enhancing professional confidence and the quality of the training. **Materials and Methods:** First, using questionnaires and interviews to understand the current situation of the education of engineers with excellence; second, collecting information on the current trouble and demands from those students in the learning process; finally, analyzing the problems in the education of engineers with excellence. **Results:** The current training concept is still stuck in the scientific paradigm, so there is a lack of training in scientific thinking, "discipline logic" and the big engineering system. The sense of professional identity still needs to be improved because of the present failure to use diversified educational subjects. Also, the mechanism of integration of industry and education needs to be further strengthened. **Conclusion:** The design of industry-education integration should be optimized to "full-cycle, developed occupation and full openness" to enhance recent graduates' occupational adaptability. Using "new drug research and development" as the guidance to create a four-chain model of industry-education integration which is composed of an "innovation chain", "education chain", "industry chain" and "talent chain". Using "coordination, incentives and evaluation" as the standard to develop a long-term mechanism for the fusion of industry and education.

Keywords: Outstanding pharmaceutical engineer, Connotation, Practical path, China, Occupational competency.

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INTRODUCTION

The education and training of outstanding pharmaceutical engineers is an important area in the education of talents in higher engineering education. China is exploring and contributing to developing an engineering training system with Chinese Characteristics at the world level. The deep integration of industry, academia and research could be achieved by mobilizing the enthusiasm of both universities and enterprises. The final goal is to educate and train a team of engineers who are patriotic, dedicated and selfless, with outstanding technical innovation ability and good at solving complex engineering problems. Outstanding pharmaceutical engineers, as engineers of excellence in the field of biomedicine, the quality of their training is closely related to human well-being. It is necessary to clarify the connotation of excellent pharmaceutical engineers before exploring their career adaptability and the path to improve the quality of education, which assists in making up for the logical gap and ability gap between research in university laboratories and development in industrial research institutes. It assists university students in having the adaptive ability to cross over from college to a career and to become excellent engineers with a strategic perspective and core competitiveness in the industry.

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Connotation Analysis of Outstanding Pharmaceutical Engineer Education and Training

In 2010, the Ministry of Education of the People's Republic of China held a kickoff meeting for the "Outstanding Engineer Education and Training Program", which has been carried out

for 15 years now. The literal meaning of "outstanding" is beyond the ordinary. In this paper, the “outstanding” in outstanding pharmaceutical engineers is a concept corresponding to the "Outstanding Engineer Education and Training Program" proposed by the Ministry of Education. It would be the “ought to” state of outstanding engineering education, which is the direction and vision of engineering education in colleges and universities. Graduates of engineering education in colleges and universities are essentially the “foundation” of outstanding engineers, and they need to take further training via enterprise practice to become engineers at a higher level of outstanding. Both education and training adopt appropriate teaching or training methods to improve students' knowledge and ability, resulting in shaping their values, in a purposeful, organized and systematic way. “Education” is more inclined to the educational process of students at universities; while “training” is aimed at more specialized talents and emphasizes more on the education and training process of students in the stage of enterprise and society. The growth of an outstanding engineer is not enough only by education at universities but also requires continuous professional practice and social training. Therefore, the education and training of outstanding engineers should not be separated from the integration of industry and education, which is the reason for emphasizing the importance of the collaborative education of the government, industry, academia and research.

“Industry-education integration” is defined as a mode of education in which industry and education cooperate deeply to support and promote each other. In other words, the integration of industry and education is not equivalent to the combination of school and enterprise. The personnel training under "integration of industry and education" is oriented to the innovation of novel products and technological innovations with a close combination of teaching simultaneously instead of purely front-line production. Additionally, under "integration of industry and education", students would have the opportunity to be exposed to real projects or real issues, so that they can try to transform the acquired knowledge into “tools” when doing practical work. It would develop students’ comprehensive ability to solve complicated problems in practice to advance the industry.

The education and training of outstanding pharmaceutical engineers for the biopharmaceutical industry is mainly oriented to the pre-clinical stage of drug development, clinical trials, drug production and exploration of clinical applications. The preclinical stage covers the technical research and development of pilot process stabilization and dosage form to determine the quality and stability as well as the bioavailability of Active Pharmaceutical Ingredients (API) and preparations (Figure 1). As a high-level pharmaceutical engineering talent capable of creatively solving key technological problems of innovative drugs, outstanding pharmaceutical engineers are committed to the overall transformation and upgrading of the pharmaceutical industry, thus realizing the enhancement of innovativeness, intelligence and low-carbonization in pharmaceuticals. Additionally, in this case, “innovativeness” refers to promoting the industrialization of innovative drugs and developed medical devices, making up for the short boards of the industrial chain and carrying out research on key technology products; “intelligence” refers to achieving the transformation of pharmaceutical production mode from intermittent production to continuous and intelligent production; and “low-carbonization” refers to advocating the concept of “Green Chemistry”, researching the large-scale production process of new drugs with the objectives of environmental protection, cost and quality and achieving the harmonious development of economic benefits and socio-ecological values of the pharmaceutical industry.

Distinguished by type, the outstanding pharmaceutical engineers include pharmaceutical Research and Development (R and D) engineers, design engineers, data management engineers and production engineers. They are some good ways to understand the connotation of outstanding engineering education and training from the perspective of enhancing students’ career adaptability, harnessing future scientific and technological innovation and leading the development of the future pharmaceutical industry.[1] In other words, they could be shown through five more detailed perspectives.

Firstly, students need to be trained as patriotic people who are mindful of the ideas of the time and situation of the country's prosperity, national revitalization and human well-being. Integrity and honesty are the basic qualities of an outstanding pharmaceutical engineer, while altruism is very important, as it is the basis for dedicating themselves to their country and their field of research. If they can integrate their own “excellence” into society, then they would potentially find their position in the common interests of mankind, which is to create value from the perspective of the human destiny community. While maintaining the ability to think ethically and make ethical judgments about cutting-edge bioscience and technology, it is the responsibility of outstanding pharmaceutical engineers to take the initiative to integrate the ethical awareness of science and technology into the global benefits, human well-being and the destiny of the country.

Secondly, it helps students to build and organize the intersectional knowledge structure. While receiving the outstanding education of “integrating arts and sciences, integrating East and West, broadening horizons and shaping values”, students would follow the logic of educating and training new engineering talents in pharmacy, resulting in acquiring knowledge of pharmacy, engineering, humanities and social sciences through the high-level, diversified and cross-curricular programs. It would help students to develop a global view in the pharmacy area with the ability to combine and balance the global frontiers, national strategies and regional development. In addition, if students are “digitally literate”, they would be better prepared for and can

develop a future-oriented and innovative knowledge system, as the routine application of big data in medicine is becoming one of the mainstream trends currently.

Thirdly, students should possess outstanding abilities and qualities; in other words, they should be capable of deep thinking and learning. Specifically, they can enhance the ability to discover and solve complex problems through experiential learning that combines the teaching of real problems with real work scenarios, and they should also have excellent scientific and technological innovation and practical output capabilities, which would help to highlight their developed technological innovation capabilities, focusing on the core technologies related to containment, to fill the knowledge and technology gaps. In addition, students also need to possess excellent career adaptability. This ability is based on understanding the international frontiers of knowledge in the pharmaceutical industry, being able to plan and accomplish the tasks of the professional role of a pharmaceutical engineer as assigned by the social environment, as well as enhancing professional identity and professional confidence. Excellent career resilience helps students to grow significantly in the comprehensive and frontier program practice of pharmaceutical engineering.

Fourthly, it is to build a training system that integrates undergraduate and postgraduate programs for students. The outstanding pharmaceutical engineers implement this research through the excellent training program, focusing on the new drug research and development field which is about the engineering technical problems or important clinical value-oriented topics related to containment. According to the ability element module, integrating undergraduate and postgraduate knowledge systems provides "organized scientific research" and "organized talent training" for universities and colleges, formulates reasonable entry and diversion mechanisms and mobilizes those outstanding students' teamwork and research initiatives to solve difficult problems.

Lastly, it is also necessary to emphasize the education of international vision, innovation and entrepreneurship. Relying on "The Belt and Road" initiative and the "Go globally" strategy, to provide pharmacy students with some opportunities for global engineering studies, to train them to have a global perspective and the ability to innovate and practice in the pharmaceutical engineering area.[2]

The Necessity of Educating and Training Outstanding Pharmaceutical Engineers

At present, China's pharmaceutical industry is in a major strategic transformation stage from imitation to innovation. Under the great demand for national major strategy and industry development, it is worthwhile to consider the connotation of outstanding pharmaceutical engineers in the new era, how to reform the traditional pharmacy talent training model by training innovative paths and how higher pharmacy education can enhance students' occupational adaptability and meet the new demands for industrial transformation and technological innovation for the education and training of talents for the creation of new drugs in the new stage of the pharmaceutical industry.

Social Level: Promoting the in-depth implementation of the "Healthy China" strategy of strengthening the country's talent in the new era.

The "Outstanding Engineer Education and Training Program" is an important initiative for China's higher engineering education to proactively serve the national development strategy in the

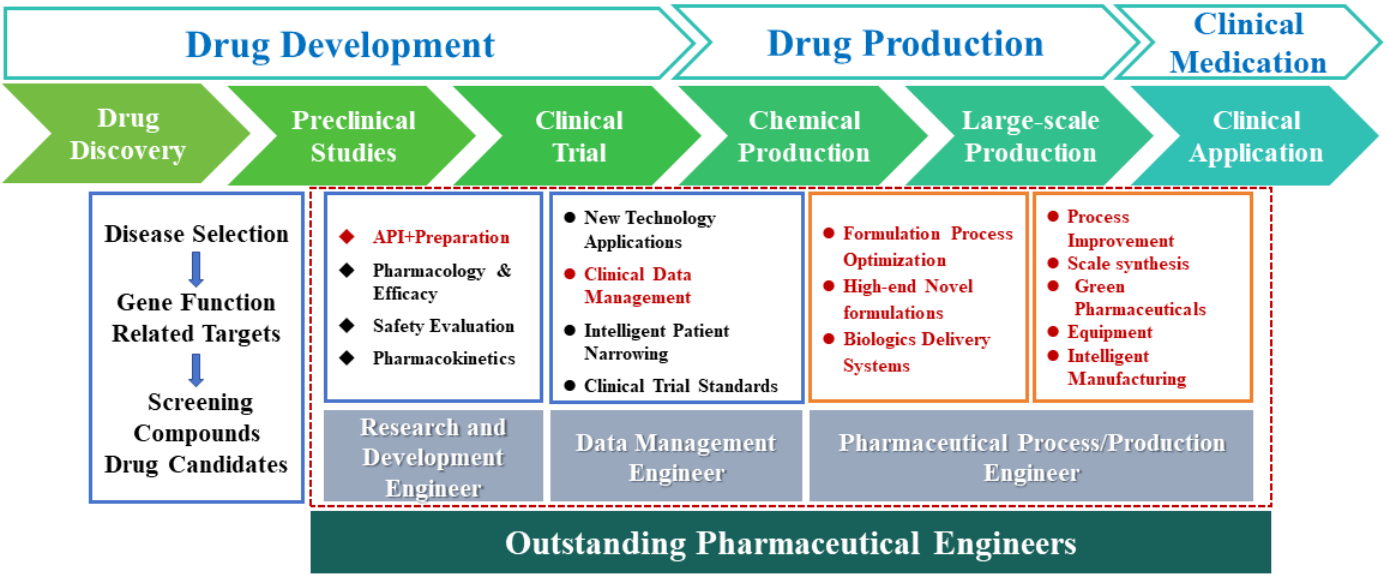

Figure 1: The positioning of outstanding pharmaceutical engineers in the "innovation chain" and "industry chain". It describes the roles of engineers in drug discovery, development and manufacturing stages.

new period and was launched in 2010. In 2018, the Ministry of Education, the Ministry of Industry and Information Technology and the Chinese Academy of Engineering issued the *Opinions on Accelerating the Construction and Development of New Engineering Departments and Implementing the Plan for the Education and Training of Engineers with Excellence 2.0*. In 2022, the Ministry of Education convened the Symposium on Industry-Education Joint Education and Training Actions for Engineers with Excellence, issued the *Beijing Declaration on the Education and Training of Outstanding Engineers* and emphasized the importance of deeply understanding the education and training of engineers with excellence. In particular, it is extremely important to focus on solving the core problems, continuously deepening and strengthening the construction of industry-education-research cooperation system and mode in universities, which helps to implement the fundamental transformation of higher engineering education from the monotonicity and independence of subject specialties to the intersection of major categories of disciplines and the in-depth integration of universities and enterprises.

Under the background of the country's vigorous development of new engineering disciplines, the education and training of outstanding pharmaceutical engineers not only includes the redefinition of education and training objectives and innovation of education and training mode according to the needs of the industry but also focuses on the education and training of the pharmaceutical engineers' sense of service to the country, scientific and technological innovation and engineering practice. The "three-in-one" education concept is composed of value shaping, education and training of abilities and knowledge transfer, which is carried through the whole process of educating and training outstanding pharmaceutical engineers. Such a new model is innovation-driven, providing important talent protection for the development of new drugs in China, thus having a rapid response to the needs of the country's major new drug production and public health and promoting the strategy of strengthening the country with talents.

In the new era, "outstanding" as the core concept and value tendency of modern higher engineering education is not only the realistic demand for the quantity and quality of high-quality applied engineering talents at the national strategic level, but also the intrinsic requirement for the education sector to continue reforming, adjusting and optimizing its system and structural layout and to "enhance excellence" in the education and training of engineering talents to support a strong nation with the value goal.[3]

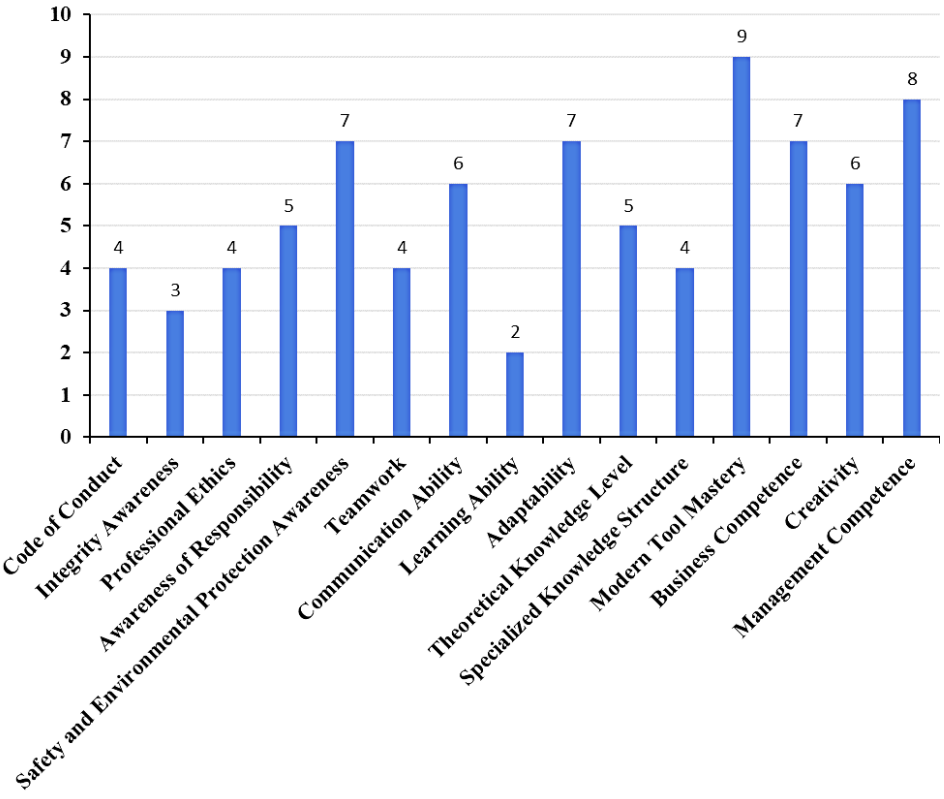

Figure 2: List of competency abilities to be improved for pharmaceutical engineering graduates from University Y.

Industry Level: supporting the high-quality development of the pharmaceutical industry

In 2021, the National Development and Reform Commission and the Ministry of Industry and Information Technology jointly issued the *Implementation Plan on Promoting the High-Quality Development of the API Industry*. In 2022, in the face of the major needs of industrial development, the Ministry of Industry and Information Technology, the Development and Reform Commission, the Health Commission and nine other departments jointly issued the *14th Five-Year Plan for the Development of the Pharmaceutical Industry*, which put forward many construction tasks. Among them, "promote the industrialization of innovative drugs and high-end medical devices", "make up the short boards of the industrial chain and carry out research on key technologies and products", "enhance the advantages of 'API+Preparations', encouraging the industrialization of biopharmaceuticals and technology development" and "promoting the quality and safety level of pharmaceutical manufacturing, digital transformation of the industry and green and low-carbon development", reflect the "14th Five-Year Plan" period.

However, at present the overall level of automation in China's pharmaceutical industry is generally not high and there are relatively more information gaps.[4] In addition, some of the "intelligent pharmaceutical" core common technology also needs to break through. In the national implementation of drug "collection" and the pharmaceutical industry environmental protection requirements have increased dramatically in the context of the API and pharmaceutical intermediates in the production of "high-quality, low-cost, green and low-carbon, intelligent, digital" industrial demand is becoming increasingly evident. Intelligent manufacturing in the pharmaceutical industry should integrate big data and the industrial Internet of Things into all aspects of drug production, which would help the pharmaceutical production process to achieve the economic benefits and socio-ecological value of harmonious development.

To respond to the new requirements and challenges of the development of China's pharmaceutical industry on the education and training of pharmacy personnel, only when the education and training of outstanding pharmaceutical engineers with high innovation and entrepreneurial ability and cross-border integration ability, pharmaceutical can continue to meet the industry's high demand for technological innovation and product upgrading and iteration, as well as the high pursuit of the quality of pharmaceutical personnel ability.

Educational Level: reforming the traditional pharmaceutical engineering technology-oriented personnel training model

Over the past ten years since the reform of higher education, pharmacy colleges and universities have formulated talent education and training objectives and programs according to their schooling orientation and characteristics. They have generally formed three types of pharmacy talent education and training modes, namely, "innovative drug research and development", "pharmaceutical engineering and technology" and "pharmacy service".[5]

Among them, "pharmaceutical engineering and technology" is mainly based on excellent engineering education as a career. There are still some shortcomings in the current talent training model compared with the requirements of China's pharmaceutical industry, which is in a major strategic transition from imitation to innovation. The existing pharmaceutical engineering curriculum design is still based on generic drug research. Specifically, because of the single discipline system as the main setup, it is difficult to connect with the industry's development frontiers and the actual needs of the industry, thus lacking a comprehensive and integrally designed curriculum system, as well as preclinical research and evaluation of the efficacy of the drugs. In addition, the teaching of PROJECT and CASE, for example, is also insufficient to support the student's ability to research or develop new drugs and engineering technology.

In practice teaching, pharmaceutical engineering education has gradually improved the proportion of experimental teaching hours but has not been able to keep up with the actual needs of industrial development. Therefore, there is still a certain gap between new drug research and development and the transformation of industrial demand. Following the requirements of high-level applied talents and independent training about core technologies related to containment, the traditional pharmaceutical personnel training mode needs to implement an open training system. It is very necessary to think about the meaning of opening up the education and training system of this research and study system, carrying out "through pharmaceutical engineering design" and facing the national strategic demand of "Healthy China", to actively explore the "integration of industry and education, innovation-driven" concept of the reform and innovation of outstanding pharmaceutical engineer training mode.

Current Bottlenecks and Problems in Education and Training of Outstanding Pharmaceutical Engineers

Engineering education is cross-border in nature. With the paradigm of engineering education back to "engineering", a single college or university educators have been unable to meet the needs of the new scientific and technological revolution and industrial change, so the integration of industry and education and multi-body collaborative education is the way to educate and train outstanding pharmaceutical engineers. However, many pharmaceutical companies and colleges or universities do not pay enough attention to and invest in the cutting-edge technology fields of pharmacy engineering education, key competencies and qualities of talents and education and training of innovations,

which leads to the disconnection between industry and education, in other words, there is a lack of substantial linkage between the integration of industry and education.

Taking a pharmacy industry characteristic University Y in Jiangsu Province of China as an example, the school initiated a random questionnaire survey on the performance of the school's pharmaceutical engineering graduates to 20 pharmaceutical enterprises in different regions. From the results of the survey (Figure 2), firstly, the enterprises have the lowest satisfaction with the students' ability regarding the mastery of modern tools and management; secondly, the students' adaptability and communication ability need to be improved; and thirdly, the students' work expanding capability in real work practice and essential safety and environmental protection awareness are both also relatively weak. In conclusion, there are still some problems in concept cognition, education and training mode and institutional mechanism of the education and training of outstanding pharmaceutical engineers in colleges and universities.

The Concept of Industry-Education Integration and Education of People Needs to Be Further Improved

The education and training of outstanding pharmaceutical engineers in the new era have inertia thinking and practice and the education and training concept is still stuck in the scientific paradigm. In other words, "scientification" and "disciplinary logic" have led to the poor combination of pharmaceutical engineering personnel training and production practice, thus lacking a real nurturing environment for engineering practice. It is also related to the way of students' academic evaluation, specifically, the way of students' academic evaluation is oriented by examination results and research papers, so the education and training of engineering practice ability and big engineering system thinking are insufficient, in addition, there is a lack of training for pharmaceutical engineers to improve their psychological resilience, so it is worth paying attention to and improving their sense of professional identity.

The formulation of talent education and training objectives also requires full participation and deep integration of enterprise roles. In this 20-enterprise research, University Y found that eight enterprises believe that there is still room for further optimization of the positioning and description of the education and training objectives of pharmaceutical engineering majors of colleges and universities in the current industry in terms of humanistic qualities, scientific qualities, ethical qualities, vocational abilities and vocational fields, to better satisfy the future needs of engineering practice.

In terms of the top-level design of the talent training system, it is necessary to systematically grasp the forward-looking layout of the problem related to containment in the field of key core technologies following the direction of the development of the pharmaceutical industry in the future, to effectively support the development of new technologies and new industries for the future, resulting in achieving the education and training goal of the innovative pharmaceutical leading talents.

Multi-major collaborative education model needs further innovation

At present, big data, cloud computing, the Internet of Things and artificial intelligence have had a variety of impacts on our lives and society. With the rapid updating and iteration of knowledge and information, the traditional single-subject education of colleges can no longer meet the needs of talent education and training and industrial development. In other words, the current "3+1" and "4+2" models of multi-principal collaborative education need to be improved. If it remains only the requirement of students' apprenticeship and practical training in the "1" or "2" stage of the enterprise and fails to make effective innovations from the perspectives of curriculum, practical teaching system and training carriers, it would not be able to give full play to the advantages of government, industry, academia and research in multi-principal education and improve the quality of education.

University Y conducted a return visit to 277 pharmaceutical engineering students who graduated in the past three years. During the interviews, individual students thought that they could not be fully integrated into the production practice and scientific research of enterprises during the "1" or "2" enterprise practice. Therefore, it is necessary to think about how to give full play to the technological advantages of enterprises in new drug research and development and formulation technology. It also needs to think about the way to introduce research results and advanced technologies into the teaching process promptly, to realize a comprehensive and multi-level pharmaceutical practice teaching. Such a perfect model can break through the traditional disciplinary boundaries and school-enterprise boundaries and select real and suitable innovation projects in the development of enterprises as the seed projects for students' entrepreneurial practice, thus helping to improve students' interdisciplinary ability to solve complex problems. In other words, under the careful setup optimization and upgrading of school-enterprise collaboration, problem-oriented high-level pharmaceutical talent training with innovation ability as the core is a way to educate and train more advanced outstanding pharmaceutical engineers.

Mechanisms for the integration of industry and education need to be further strengthened

The core problem facing the existing mechanism for the integration of industry and education is how to improve and innovates the management mechanism of industry-education synergy to stimulate the internal drive of enterprises to educate people in the current situation where enterprises have more advanced pharmaceutical technology and more complete research and development platforms than colleges and universities.

Moreover, there is also a need to dig deeper into the government, industry, academia and research of the main body of the conflict of roles behind the needs and interests of the demand, through the contract and other contractual ways to promote the depth of the integration of industry and education. Although the nation attaches great importance to the integration of industry and education, there is still a need to improve and introduce relevant financial, personnel, land and industrial policies to improve the leading science and technology enterprises in the pharmaceutical industry. These policies help to improve the initiative and continuity of related educational undertakings and motivate enterprises to raise the height of strategic understanding, give full play to their technological advantages, assume social responsibility and form a talented education and training community with colleges and universities.

Innovative Exploration of Education and Training Path for Outstanding Pharmaceutical Engineers

Industry and education need deep cooperation. It is important to insist on the education and training of outstanding pharmaceutical engineers facing the world's scientific and technological frontiers, facing the main battlefield of the economy, facing the major needs of the country and facing the life and health of the people. In the process of educating and training outstanding engineers, multi-dimensional reform strategies such as prioritizing the development of key needs, prioritizing the education of characteristic foundations and seizing directions with prospects are adopted to proactively and continuously push forward the supply-side reform of educating and training outstanding engineers.[6]

Optimize the top-level design of industry-education integration and education with the aim of "full-cycle, vocational strength and full openness".

Enhancing the conformity of the education and training objectives of excellence in pharmaceutical talents with national strategies and drug innovation, the recognition of industries and enterprises and the satisfaction of students themselves would help to promote the top-level design of excellence in education and training of outstanding pharmaceutical engineers.

Firstly, the concept of full-cycle engineering education has been implemented. According to this concept, the engineering problem, engineering consciousness and engineering culture would be throughout the whole process of pharmacy personnel training, to educate and train students' ability to solve complex engineering problems based on practical ability and innovation ability.

We have built a full-cycle and multi-level pharmaceutical practice teaching system, including four modules: basic experiment, engineering practice, comprehensive practice and vocational practice. Through the training of "consistent pharmaceutical engineering design" from typical pharmaceutical unit equipment to pharmaceutical engineering projects, we provide students with diversified practical training modes and sufficient vocational practice resources, to strengthen students' innovative and entrepreneurial thinking and engineering quality and also to enhance students' ability to solve complex engineering problems in a spiral manner. Adopting a full-cycle engineering project case-based teaching design, the program is designed reversely from the industrial needs and competence requirements to help students establish logical thinking for understanding innovative drug R&D from the industry perspective.

In short, it is very important to plan and optimize the cooperation mode between universities and enterprises in scientific research, talents and social services and to carry out comprehensive cooperation among industries, universities and research institutes with talent education and training as the core.[7]

Secondly, it implements the advanced concepts of student-centered, career-oriented and continuous improvement. Optimize all aspects of the entire process of talent education and train students' ability to identify, analyze and solve practical engineering problems. Through occupational psychology training, enhance psychological adaptation, maintain a strong occupational interest in technological innovation and the ability to explore problems in depth and educate and train students' social integration ability using occupation as an interface. Establishing a long-term mechanism of joint training through school-enterprise cooperation can realize the effective connection between talent training and employment by extending school training to enterprises, upgrading the standard of enterprise practice bases and carrying out the customized talent training that enterprises urgently need.[8] The extension of enterprise human resources to the school and the improvement of the design of students' enterprise practice and curriculum learning can help shorten the students' work adaptation cycle in the enterprise after graduation, to enhance the students' professionalism, engineering practice, engineering innovation, engineering research and engineering comprehensive ability.

Thirdly, adhering to the concept of all-open education, expanding the education and training period, integrating internal and external resources, encouraging colleges and universities that have specialization in the pharmacy to extend forward, actively carrying out scientific lectures in secondary schools, inviting secondary school students to enter the college campus to feel the charm of high-end scientific research platforms and stimulating the engineering aspirations of secondary school students and the seeds of pharmacy, to attract more students aspiring to the cause of pharmaceutical engineering. Outward expansion can be realized through the implementation of joint training domestically and abroad. Colleges and universities can enhance students' cross-cultural understanding, establish international competition awareness and improve international competition

ability through various forms of joint degree training and project exchanges. Specific examples include but are not limited to, building a "community of industry-education integration in the smart pharmaceutical industry" and carrying out joint education and training of master's and doctoral degrees in engineering with leading pharmaceutical enterprises, as well as jointly organizing international student classes with enterprises to build a talent education and training base. In addition, serving the regional economy and integrating the mechanism of industry-education integration into the whole system of higher pharmacy education would also help to form a pattern of industry-education integration and collaborative education covering all kinds of talents in pharmacy.

Taking "new drug research and development" as the traction, creating a four-chain ("innovation chain", "education chain", "industry chain", "talent chain") fusion of industry-education integration and education model.

When colleges and universities cooperate with enterprises, they should take new drug research and development projects as the entry point (i.e., enterprises ask questions and universities answer them) and set up a collaborative innovation platform of "medicine, industry, academia and research" for original drug research-oriented by clinical value. This can open up the upstream and downstream barriers in the industry, thus realizing the integration of the independent innovation chain of "Chinese drugs" and the independent training chain of innovative pharmacy talents and accelerating the reform of the training mode of outstanding pharmaceutical engineers.

Firstly, we need to strengthen students' innovation and entrepreneurship education. Focusing on the strategic goal of "Healthy China", "innovation and entrepreneurship education" is used to stimulate "professional creativity" and the result can be used as kinetic energy for further research. In particular, based on the concept of "Internet+Great Health", the training of innovative spirit and entrepreneurial ability is incorporated into the target system of professional education, the training of talents is relative to the development of the regional economy, combined with the transformation and upgrading of the pharmaceutical industry and the process is unified with the effect, to establish the innovation and entrepreneurship education curriculum system which is in line with the characteristics of the specialty of pharmaceutical engineering and to form the innovation and entrepreneurship education ecology of the integration of industry and education to support students. Form the ecology of innovation and entrepreneurship education for college students through the integration of industry and education. In practice, we would explore the education and training rules of pharmaceutical innovation and entrepreneurship talents, which is "industry cognitive education-enterprise entrepreneurship internship-joint training of outstanding pharmaceutical talents-entering enterprise entrepreneurship".

Secondly, the project-based training mode is implemented. In detail, after changing the traditional discipline-based and teacher-centered pharmacy talent cultivation mode, we need to highlight the student center, take the education and training of students' innovation, practice, thinking and other abilities as the main guidance and take the completion of industrial projects and problem-solving as the logic. Adopting the enterprises to issue questions and universities to answer questions, both sides rely on scientific research projects to train talents, through the "fast start, small steps, large space" progressive scientific research and training projects, deconstructing the teaching elements, reconfiguring the form of teaching organization and seamlessly linking the undergraduate and graduate stages of the education and training for outstanding pharmaceutical engineers.[8]

In the implementation of the "3+1+N" system, the "3" means the students need to spend three years on campus through the project-based teaching industry courses to complete the industrial pre-training; the "1" means the students take one year of study in the enterprise; and then, the "N" means the outstanding students from the previous stage would continue to rely on the school-enterprise project to carry out master's degree, or doctoral degree stage of learning. As a result, this system could cultivate excellence in pharmaceutical engineering education undergraduate and postgraduate stage of the seamless convergence.

As a result, students can realize the cross-fertilization of knowledge of different disciplines through the implementation of the project and be able to flexibly combine and migrate the application to solve all kinds of complex pharmacy engineering problems in uncertain engineering practice scenarios in the future, to ensure the quality of education and training. At the same time, through the support of the project, the student's scientific research direction, the academic development of university teachers, the enterprise's technological innovation and the country's major needs are closely integrated to realize the teachers and students to form a long-term stable academic community, to complete the goal of the mutual matching of the supply and demand of talents and the key core technology research and development and talent training in the same frequency resonance.

Thirdly, it is to create an ecological, multi-dimensional industry-education integration pharmacy engineering practice education center. As a comprehensive open platform for engineering quality education and skills training that imparts engineering knowledge, trains engineering awareness and enhances innovation ability, the center covers the education body (i.e., industry-education integration faculty team, on-campus dual-appointed faculty, part-time faculty from enterprises, mentors and professors from industries), the teaching content (i.e., industry-teaching integration curriculum that combines online and offline) and the education platform (i.e., the physical carrier).[9] Physical carriers here include a variety of industrial

education physical carriers such as on-campus GMP simulation training workshops, university-enterprise co-innovation centers, enterprise learning and training centers and university-enterprise postgraduate cooperation and research bases.

Concerning the teacher team for industry-teaching integration, a "one-vote veto" system for teacher ethics and morals has been implemented. We would keep a close eye on the construction of teachers' morality, implement the "five-year full training system for teachers" stipulated by the Ministry of Education, increase the construction of part-time teachers, part-time instructors and industrial professors, realize the diversified development of the teaching team of the Education Center and nurture a "dual-teacher, dual-capable" industry-teaching integration and educator training community led by outstanding scientists, with university teachers, industrial professors, senior engineers of enterprises and management experts as the main body, with specialization and part-time training, a reasonable structure, complementary strengths and focusing on practice.

In terms of teaching content, the plan would focus on the training of talents, creation of major new drugs, transfer of technological achievements and other levels of demand for a balance between curriculum elements and production elements, at the same time, using on-campus practical teaching platforms and off-campus enterprise platforms, organizing the cooperation between schools and enterprises in the development of curricula, textbooks, case studies and innovation and entrepreneurship education courses, building a system of practical courses that emphasizes the practice of engineering, meeting the needs of the industry and promoting the integration of education, industry and innovation in the whole process of training. Finally, to build a practical course system emphasizing engineering practice and meeting the needs of industries to promote the integration of education, industry and innovation in the whole process, chain and link of talent education and training.

In terms of physical carriers, the university-enterprise joint innovation platform for engineers with excellence is built in cooperation with large enterprises and tertiary hospitals. Through "customized talent education and training", we attract enterprises to donate funds for the scholarship system and provide career planning and job selection for students' employment. It is also possible to build national industry-education integration demonstration bases or professional degree graduate training demonstration bases through enterprise investment and school investment, guiding enterprise resources to become teaching resources and realizing symbiosis and win-win situations.

Forming a long-term mechanism for industry-teaching integration and training by taking "coordination, incentives and evaluation" as the foundation and guidance.

When the education and training of outstanding engineers are transformed from being dominated by universities to involving the joint participation of universities, local governments, industrial enterprises and other industry-education-research institutes, it is necessary to follow the rules of engineering education and the rules of scientific and technological innovation and turn the advantages of the system and mechanism into the advantages of governance effectiveness and talent education and training.

Firstly, it is important to improve the management organization mechanism. Continuously enriching and perfecting the connotation of the "Presidential Responsibility System under the Leadership of the Board of Governors - Management Committee" and giving full play to its core functions of top-level design, macro-guidance and strategic deployment, it helps to explore the synergistic management mode of industrialization platforms, professional construction, teacher training, resource sharing and so on, which are participated by the university, government and enterprises.[10]

Secondly, it is necessary to improve the incentive and guarantee mechanism. This can be realized through the introduction of some relevant systems and policies to support the participation of enterprises in the education and training of outstanding pharmaceutical engineers. Specifically, enterprises can be incentivized to raise their strategic awareness, give full play to their technological advantages, assume social responsibility and form a talent training community with colleges and universities in terms of tax incentives, resource allocation and social reputation. In addition, it is important to reform the evaluation mechanism of the engineering teachers' team in the university, focus on the combination of teachers' careers and the development of the university, single out the evaluation series of engineering education and social service titles and list the recognized relevant and important achievements in the related areas of engineering projects (e.g., design, pharmaceutical patents, cooperation between industries, universities and research institutes, technological transformation and social service) as the evaluation requirements and recognition of the teacher's achievements in the reform of engineering education and the education and training of outstanding pharmaceutical engineers' education to enhance the motivation of educating people.[11] Moreover, it is worthwhile to give full play to the main initiative of off-campus industrial teachers, establish a series of personnel incentive policies and management mechanisms for the appointment, management, assessment and rewards of off-campus part-time teachers in industrial colleges and build a hierarchical selection and recruitment system for part-time industrial teachers.

Thirdly, remodeling the evaluation mechanism of engineering education is also important for screening high-potential outstanding pharmaceutical engineers. To emphasize the "three-in-one" process evaluation of applied high-level talent training, evaluation of industrial serviceability and evaluation of representative achievements, it is necessary to establish the

"file package system of training process" and "training quality evaluation mechanism of industrial service contribution and representative achievements". In other words, this is a good way to investigate the engineering ability and innovation potential of students.

CONCLUSION

Outstanding pharmaceutical engineers are excellent engineers in the field of the biomedicine industry and the quality of their training is related to the health of citizens. Because of the problems existing in the current training concept and practice, it is necessary to make further exploration in the aspects of education design, model and mechanism, to promote the further return of pharmaceutical engineering education to engineering practice and improve students' ability to face the future and solve complex problems. This will train high-level pharmaceutical engineering technical talents who can creatively solve key technical problems of innovative drugs for industrial development and social progress.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

API: Active Pharmaceutical Ingredients; **GMP:** Good Manufacturing Practice.

SUMMARY

This study discusses the connotation of education and training of outstanding pharmaceutical engineers under the background of integration of production and education. Through extensive literature reviews, questionnaire surveys and interviews, this paper sorts out the existing problems in the cultivation of pharmaceutical engineers in China and demonstrates the necessity of educational reform for excellent pharmaceutical engineers from the perspectives of talent demand, industrial development and educational reform. Finally, the optimization strategy and suggestions are given, including optimizing the top-level design of education, innovating the training model and establishing a long-term mechanism. The volume of higher engineering education in China ranks among the top in the world. This study will provide an effective reference for improving the training quality of excellent pharmaceutical engineers, enhancing the professional competency of individual students, meeting the new demand for pharmaceutical engineers in the development of the pharmaceutical industry and realizing the harmonious development of economic benefits and social and ecological values of the pharmaceutical industry.

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