Construction and Continuous Improvement of Talent Training System for Pharmaceutical Engineering Professionals in China: Exploration and Practice of Sichuan University

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Abstract: In this paper, the experience and mode for the construction of training system for pharmaceutical engineering professionals in Sichuan University were introduced and discussed. Training objectives of students in this major were formulated and provided firstly, and then "student-centered" educational idea was practiced in various aspects and ways. The design, formulation and revision of the teaching plan for pharmaceutical engineering specialty of Sichuan University was explored through joint effort of relevant leaders, teachers and professionals of the faculty. The training objectives, teaching programs, courses settings and curriculum outlines of the specialty were also studied. Finally, current problems in the existing system were analyzed and related continuous improvement mechanism has been developed. Above research is expected to provide useful reference for relevant educators.

Key Concepts:
Pharmaceutical engineering, Sichuan University, Talent training, Exploration & practice

1.1 Introduction

As a sunrise industry with fast development, drug manufacturing is technology-intensive and has the characteristics of high investment, high risk and high return. Its industrial chain structure is mainly composed of the development of new drugs, the production of bulk drugs, the production of preparations, quality management and marketing, etc. China is the world's most populous country with a large demand for medicines. With the rapid improvement of the social economy, people's demands for health and quality of life are increasing day by day. Drugs have become the most basic guarantee of population health and social well-being. The development of China's pharmaceutical industry urgently needs a strong guarantee for the training of pharmaceutical engineering talents. Pharmaceutical engineering is the most highly chemical-related specialty. It organically combines the disciplines of pharmacy and chemical engineering, and has grown to be one of the most potential growth disciplines (Cheng, 2006).

Sichuan University (SCU) began to enroll the students of pharmaceutical engineering in 1999, which is one of the earliest universities to set up this major in China and constructs it continuously as one of the newly emerging key specialties. With the long-term strong support of the university, the major has striven to cultivate professionals with high vocational literacy, strong engineering practice and innovative ability together with international vision, and has become an important national base for talent training, scientific research and social services in the field of pharmaceutical engineering. After 20 years of development, supported by the three national first-level disciplines of chemical engineering and technology, biological science and pharmacy of Sichuan University, as well as the solid foundation of the National Bioscience and Technology Talent Base and the National Engineering Chemistry Teaching Base of Sichuan University, pharmaceutical engineering in SCU has gradually developed into the top major among China colleges and universities, which is full of interdiscipline characteristics. And the teaching idea together with distinguishing feature of "integration of science and engineering, practice-oriented, innovative training" have been established and implemented for many years. In 2013, the construction of national-level characteristic specialty was completed; in 2015 and 2018, the major has passed the International Engineering Education Certification twice in succession. At present, Pharmaceutical Engineering specialty in SCU mainly covers the following discipline directions: the synthetic technologies and equipments of drugs and pharmaceutical intermediates, preparation technologies and engineering of natural medicines, pharmaceutical preparation engineering, pharmaceutical analysis and production process testing, computer-aided drug design and process simulation, research and development of new pharmaceutical materials and preparations, and biopharmaceuticals, etc.

1.2 Professional training goals and expected ability of students

The goal of this major is to train undergraduates to meet the needs of the production and development of modern pharmaceutical industry in the 21st century (Yang, 2008). Students should systematically master the basic theories, knowledge and skills of modern pharmaceutical engineering and related science and technologies, have good humanistic accomplishment and innovative consciousness, and be able to engage in pharmaceutical and related fields such as process and engineering design, technology and production management, quality management and control, technology and product research and development, business management, etc; and finally become backbone power of technology and management in the field they are engaged in (McIver, 2012). After four-year study, the graduates of this major can serve enterprises and government departments, research institutes, colleges and universities, in medicine, healthcare and related fields,

and engage in the works about scientific research, engineering design, new drug development, production management, quality control and pharmaceutical marketing and management. In the past six years, the employment rate of graduates has been stable at more than 90%.

The goal of training is the concretization of educational purposes in various universities and educational institutions at all levels, which is determined by the needs of specific fields and social levels. The goal of professional training is relatively stable in a certain period of time. At the same time, it should be constantly adjusted with the change of social and economic development level to meet the current needs (Yao, 2015). In recent years, whether the training goal has been achieved or not is being evaluated based on the analysis of the information and data obtained from the follow-up survey of graduates, the alumni follow-up survey and the employer evaluation of graduates' quality; meanwhile the investigation results are combined with the new requirements of the society for talents in order to strengthen the cultivation of students' innovative spirit and comprehensive quality. In the teaching plan, teaching content, teaching and testing methods of the specialty, the specialty has strengthened the cultivation to meet the needs of the society for pharmaceutical engineering professionals. The organizational implementation process of evaluation and revision of professional training objectives is shown in **Figure 1**.

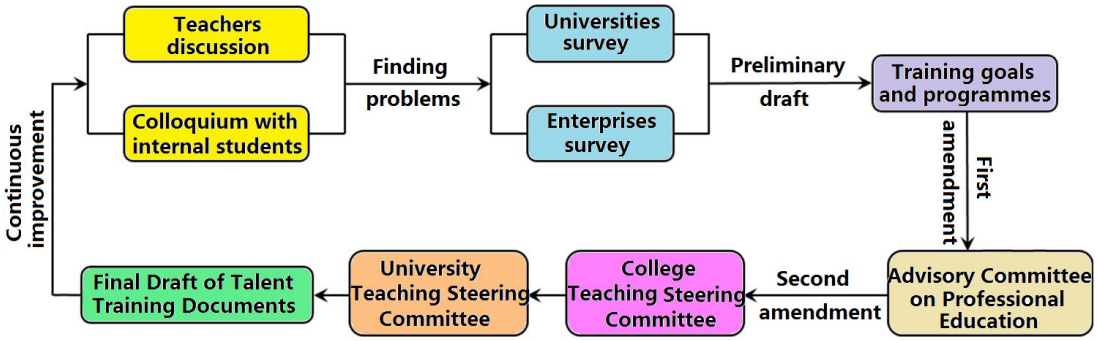

Figure 1: Organization and Implementation Process for Evaluating and Revising Talent Training Programs

Through the above training objectives, students can quickly adapt to the relevant jobs in the industry after graduation, apply innovative thinking, basic knowledge, practical ability, international vision and engineering literacy in their daily work, and combine the characteristics and advantages of the professional personnel training with the needs of enterprises. About five years after graduation, they are expected to have:

(1) Good professional ethics, strong patriotism and professionalism, high sense of social responsibility and profound humanities literacy;

(2) Good awareness of quality management, environmental protection, occupational safety and social services;

(3) Solid knowledge of basic theory and technology of pharmaceutical manufacturing, basic principles and methods of Engineering design, quality management and control of production, economic management, etc.

(4) Ability to comprehensively apply the scientific theory of pharmaceutical engineering, analyze and propose solutions to pharmaceutical engineering problems, and have the ability to solve practical problems of pharmaceutical engineering.

(5) Ability to research, develop and design new drug resources, new products and new processes, have good pioneering spirit and innovative consciousness, and acquire new professional knowledge;

(6) Comprehension for technical standards in the field of pharmaceutical engineering, and be familiar with the national policies and regulations on drug production, drug safety, environmental protection and social responsibility.
(7) Good organizational management, communication, environmental adaptation and teamwork capabilities;
(8) Ability to deal with emergencies in drug production, use and public health;
(9) Ability to communicate, compete and cooperate in an international perspective and cross-cultural environment.

2.1 Practice of "student-centered" educational idea

"Student-centered" is the core idea of talent cultivation in Sichuan University (see **Figure 2**). On the basis of a full understanding of the nature and responsibility of education, the university sets a new talent training goal of "national pillar and social elite with profound humanistic connotation, solid professional knowledge, strong sense of innovation, broad international vision", and puts forward the principles of "classified guidance, personality training, innovation-focused and facing the world". Pharmaceutical engineering is one of the national characteristic specialties of Sichuan University, which deeply implements the core idea of "educating students as the center" in all stages of enrollment, discipline construction, personnel training and employment, as well as the concepts, goals, methods and means of personnel training, so as to ensure that education and training achieve the developed objectives. It attaches great importance to the enrollment of excellent students and carries out multi-channel network propaganda (portal websites of college entrance examination, university website, college website) to ensure the quality of student resources. It is also encouraged to study across disciplines in their lower grades. Nearly 10% of the students in this major have studied and obtained double degree, second major or minor certificate every year, which has become one of the important factors to attract excellent students. In addition, the major can enroll some excellent students through joint examination and recruitment mode of self enrolment universities, and determine the final candidate list according to the comprehensive evaluation and test results. Besides that, the major has a wide range of grants and scholarships system, and a powerful support system for those students with financial difficulties has been developed to ensure that their study can be completed smoothly. Moreover, the university, college and department encourage and support students to participate in all kinds of scientific and technological innovation activities. Their practice abilities can be greatly improved meanwhile their good performance shows the characteristics and strength of pharmaceutical engineering in SCU, which will attract more excellent students to choose it as their major. In the past three years, more than 460 students of this major have participated in the pharmaceutical engineering design competition, the pharmaceutical engineering research essay competition and pharmacy forum for national university students, the University Students' scientific exploration and research training plan, the innovative experiment plan and other extracurricular activities; among them several dozens of people won various awards at different levels. Especially, an innovation and entrepreneurship street was built in the campus to provide various support and services and help students realize their dreams.

According to the four stages of "cognitive education in freshman year, standard education in sophomore year, stimulating education in junior year and talent education in senior year", this major has jointly carried out a series of works including study guidance, career planning, employment direction, psychological counseling and quality education with the participation of the principals, deans, counselors, head teachers, professional teachers and retired teachers. Through designing all-round and multi-level guidance programs, giving targeted guidance to students regularly, constantly

cultivating an excellent discipline of study, and carrying out various colorful campus cultural and social practice activities, their professional foundation is consolidated; a good atmosphere for scientific and technological innovation is actively created, and the comprehensive quality and professional competitiveness of students are enhanced continuously. In order to focus on talent cultivation and make all the graduates meet the training goals, teachers have put forward specific requirements for all the students, and then track and evaluate dynamically their whole learning process in the daily teaching activities of pharmaceutical engineering. In all teaching links, the learning performance of every student is assessed through the combination of their usual achievements and final examination results, and the former is based on process detection including discussion on engineering case, classroom questioning, scientific research and invention related with curriculum. Depending on small-class inquiry teaching and diversified examinations, the evaluation for training performance is ensured to be more scientific. At the same time, teachers are required to collect feedback from students in various forms. After the careful analysis of homework and test papers, potential problems in teaching are founded and continuously improvement for teaching quality is carried out. At last, the goals of education and training are finally achieved through the "all-round development, all-round education, all-round service" personnel training mechanism and "four in one" student growth care service system.

Training mode is also very important (Wang, 2010), which is also student-oriented. In addition to classroom learning, the students majoring in pharmaceutical engineering can complete good training of basic skills on public experimental platforms such as Chemical and Physical Basic Experiment Center, Chemical Engineering Basic Experiment Center and the Outstanding Engineer Training Center of SCU, where they will complete comprehensive training about professional skills and engineering practice ability. The major teaching laboratories and related equipments are completely open to all relevant students for free after the rapid application and authorization through the internet. To a certain extent, it improves the utilization rate of equipments and stimulates their passion for exploration and creation. As the result, the average daily utilization rate of laboratories and equipments reaches more than 90%. Besides above centers, there are professional laboratories with total building area of 640 square meters and a large number of instruments, and experimental conditions are being continuously upgraded. In the past three years, the renewal rate of teaching equipments has exceeded 30%. Since 2010, these teaching laboratories have been gradually renovated according to the international standards of Health, Safety & Environment (HSE), and the relevant management system has been constantly revised and improved with the guidance of "intrinsic safety" idea. Moreover, the laboratories of pharmaceutical engineering have begun to work hard on the greenization of experimental reagents and operations from 2013 to now. In addition, the infrastructure project of undergraduate classrooms (including network interactive classroom, multi-window interactive classroom, remote interactive classroom, multi-screen interactive classroom, mobile interactive classroom and special seminar classroom) has reached the best level in history together with the construction of network infrastructure, book resources and living facilities. All the environment and external conditions of students' study in this major have been in line with the international level. Intellectualization, interaction, individualization and humanization have been realized comprehensively.

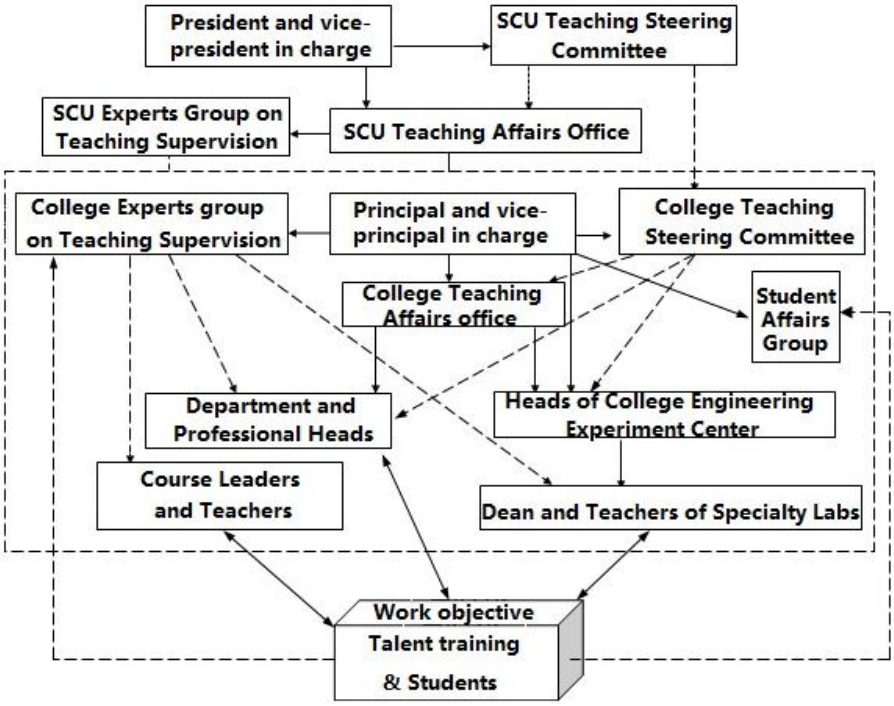

Figure 2: "Student-Oriented" Teaching Operation Mode snd Participants

2.2 Curriculum system of pharmaceutical engineering

In order to achieve the above professional training objectives and expected abilities of undergraduates, the curriculum system of this major covers six main categories: general humanities and social sciences, mathematics and natural sciences, engineering basic, professional basic, professional, engineering practice and graduation design (thesis). Their arrangement and relationship are shown in **Figure 3**.

(1) General courses of Humanities and social sciences (25% of the total credit) include ideological and moral cultivation and legal basis, outline of modern Chinese history, situation and policy, Chinese culture, mental health of College students, College English, physical education and so on. Emphasis is laid on the cultivation of student humanities and sciences literacy, social responsibility, team spirit, communication skills, environmental protection and sustainable development awareness, so that students can take all of the factors involving economy, environment, law and ethics into account for their future engineering work.

(2) Mathematics and natural science courses (14% of the total credit) include calculus, linear algebra, probability and statistics, University physics, modern chemistry (including inorganic, analytical, physical and organic chemistry) and so on. It will lay a solid foundation for students to study, analyze, solve engineering problems and carry on the engineering design.

(3) Engineering basic courses (8% of the total credit) include computer foundation, engineering drawing, electrotechnics foundation, information retrieval and utilization courses to cultivate basic engineering application ability and quality of students.

(4) Professional basic courses (15% of the total credit) include chemical engineering principles, biochemistry, microbiology, drugs and fine chemicals synthesis, etc. They focus on training students to apply basic principles of professional knowledge and engineering science for analyzing

and resolving complex engineering problems, and lay a foundation for them to engage in drug research and development, production and quality control.

(5) Professional courses (16% of the total credit) include pharmaceutical chemistry, industrial pharmacy, pharmaceutical analysis and process monitoring, pharmaceutical separation engineering, chemical pharmaceutical technology, pharmaceutical engineering design, etc. They can help students engage in pharmaceutical production, quality control, workshop and workshop design. The basic skills are emphasized to find and analyze solutions for complex engineering problems.

(6) Practical links (22% of the total credit) include experiments, internships, engineering design, innovation and frontier disciplines. The experimental courses include basic experiments, professional basic experiments and professional experiments to deepen students' understanding of the knowledge learned in the classroom. Internships include visiting and production practice. The purpose is to enable students to have an intuitive understanding of the pharmaceutical industry and understand the industrialization process of pharmaceutical production. Engineering design includes pharmaceutical process design and simulation training and graduation design. The latter is an important link in transforming book knowledge into practical application ability, so as to prepare for future work and further study. Innovation and scientific research training activities include pharmaceutical engineering design competition, scientific research training and innovation experiments at different levels, etc. Above practical links cultivate students to use engineering and professional knowledge comprehensively to solve complex engineering problems. Meanwhile they can evaluate the impact of related solution ways on society, health, safety, law, culture, environment and sustainable development.

The design, formulation and revision of the teaching plan for pharmaceutical engineering specialty of Sichuan University are jointly participated by the relevant leaders, teachers and professionals of the faculty. The training objectives, teaching programs, courses settings and curriculum outlines of the specialty are also studied, consulted and approved by these people.

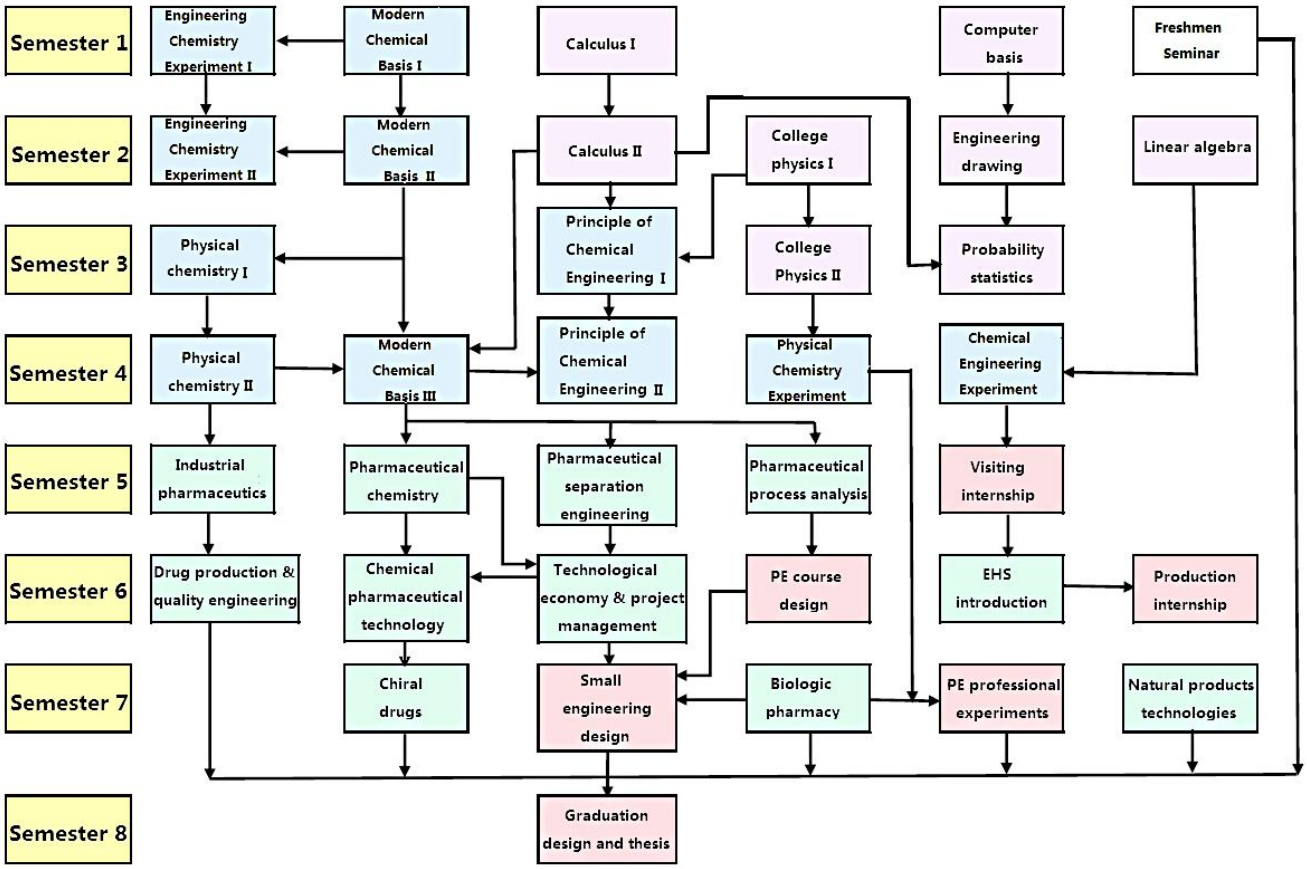

Figure 3: Relationship Among Major Courses in Various Semesters

2.3 Teaching team

Excellent teaching staff and reasonable teacher structure are the source and foundation of the sustainable and healthy development of specialty, and the support and guarantee of training outstanding students one after another. After nearly 20 years of construction and improvement, pharmaceutical engineering specialty has formed a team composed of old, middle-aged and young teachers, and the latter two are the main body. There are 33 full-time teachers, including 9 professors (2 over 60 years old, accounting for 27.3%); 15 associate professors (13 middle-aged teachers and 2 young teachers, accounting for 45.4%); 9 lecturers (4 middle-aged teachers and 5 young teachers, accounting for 27.3%). Those with doctoral or master degrees account for 93.9% of the total number of full-time teachers. More than 80% of the teachers have engineering practice experience, and 53% of the teachers have overseas learning experience. Their education background was diversified and multinational, and had a broader international vision. More importantly, the school has built up a vocational development center (now its name is SCU center of teaching advancement, http://cta.scu.edu.cn/) through the corporation with Michigan University (USA) , which often organizes various activities for teachers in different positions, involving informal discussion, professional training, psychological release, experience exchange and so on. This major attaches great importance to the sustainable development of teachers and actively help them integrate into the two-level training system of university and college, focusing on training young

and middle-aged backbone teachers, experimental technology backbone and management backbone talents.

Teachers play a decisive role in improving the quality of teaching as they are the dominators of the whole teaching process. In the process of teaching, it is one of the most important responsibilities of teachers to train students to lay a solid professional foundation, complete professional knowledge system, good practical ability and ability to analyze and solve problems. Whether in classroom links, teaching seminars, teacher training, production practice, graduation design, curriculum design, supervision and inspection or student evaluation, this major has established an internal teaching quality evaluation and monitoring system, and formed complete management rules to enable teachers to perform their duties, obtain teaching feedback through various channels and fulfill their responsibility in the teaching process. In order to strengthen the management of teachers, schools and colleges will compulsorily assess each teacher's teaching workload every year, including classroom teaching, experimental guidance, credit tutor, internship and practice guidance and so on. Professors are asked to take on at least one undergraduate course and must meet the requirement of basic teaching workload; moreover, they should take charge of the organization of teaching work and the task of curriculum construction, as well as to communicate with undergraduates in flexible ways, such as conducting discussions and salon on new developments in professional fields or guiding their life choices. In order to adapt to the new trend of the internationalization of higher education, promote the internationalization of undergraduate education and promote the international cooperation and exchange of undergraduate teaching, teachers are encouraged to carry out bilingual teaching and there are corresponding incentives in workload calculation. Furthermore, the specialty always promotes teachers to compile characteristic textbooks with the development of pharmaceutical engineering. In the past four years, professional teachers have published 15 textbooks, including 3 national-level and 5 award-winning textbooks. In addition, teaching reform research is also one of the important daily works of teachers in this specialty, which make it more efficient and scientific to improve the teaching quality and level.

2.4 Continuous improvement

Pharmaceutical engineering specialty carries out corresponding teaching management, quality control, training plan formulation, evaluation and improvement according to the relevant system and norms of university and college, which effectively guarantees the realization and continuous improvement of training objectives and graduation requirements. At the same time, the quality control on the two levels of university and college starts at the same time. It mainly checks the existing problems in the mentioned teaching cycles, and continues to supervise the solution of these problems so as to achieve continuous improvement and closed-loop (Zhao, 2014).

According to the needs of social development, the opinions of experts, the employment and development of graduates, the training objectives of this major is regularly discussed and adjusted, the curriculum system is also further improved for training students' ability to solve complex engineering problems with their basic knowledge and practical skills. For example, the latest amendment is mainly reflected in the adjustment and refinement of related achievement indexes for graduation requirements, and more emphasis is paid on the cultivation of actual abilities, the skilled application of relevant knowledge in engineering design and the cultivation of humanistic literacy, social responsibility and innovative consciousness. It is hoped to tap the cultivation of students'

potential to become the backbone of professional technology and management in the field they are engaged in.

The results of social evaluation have also played an important role in promoting the continuous improvement of this major (see **Table 1**). University and college have formed institutional regulations for a very long time. The establishment and adjustment of training programs require the opinions and suggestions of colleagues and employers of enterprises, which is also necessary for the approval and acceptance of important teaching and research projects. For example, according to the feedback of the society and pharmaceutical industry (especially the employers) on the quality and requirements of personnel training, some courses related to professional basic courses and professional courses have been significantly adjusted to make them more in line with the new requirements of personnel training in 2011 and 2012. Some courses have been added or deleted, or their compulsory/elective nature and credits were changed. In 2013, a partial adjustment of professional courses was made. Further adjustments were followed in 2016 and 2017. In this way dynamic progress of the whole curriculum system is developed.

Table 1: Main ways to evaluate the rationality of training objectives

Mode	Evaluation subject	Evaluation content	Cycle time
Grade evaluation	Teachers	Whether the students' learning meets the curriculum requirements	Every year
Teaching evaluation	Students, peers, supervisory groups, and college leaders	Whether teachers' teaching meets the course requirements	Every semester
Course self-evaluation	Teachers	Whether the main course meets the corresponding training goals	Every year
Graduation evaluation	Academic Degree Committee Teaching Steering Committee	Whether the students meet the training objectives	Every session
Enterprise evaluation	Employers Enterprise experts	Whether graduates meet the needs of talents	1~2 years
Alumni evaluation	Graduates	Whether the course meets the requirements of career development	1~2 years

This major pays great attention to employer survey and investigates typical pharmaceutical enterprises by asking questions in writing, and then summarizes and analyzes the evaluation of graduates by enterprises. At the same time, based on the results of the questionnaire, it evaluates whether the graduates achieve the expected training goals. Through the survey of employers, the enterprises are generally satisfied with professional accomplishment and performance of the graduates of this major. They think that the overall result of training quality is good, and the graduates have solid theoretical foundation, can quickly enter the role in the work position, have strong engineering practice ability and practical ability, and achieve the training objectives of this major. In addition, there are graduate questionnaires and alumni feedback; the former mainly aims to obtain the opinions and suggestions from professional graduates in the professional curriculum system, curriculum teaching, curriculum arrangements, practical teaching and other aspects after four years of university life and form a record of documents, thereby forming the evaluation of training objectives. As for the forms of alumni feedback, such as regular seminars between in-service teachers and representative graduates who have graduated for about five years, constructive

opinions can be grasped and dealt with on the curriculum of pharmaceutical engineering and the time arrangement of engineering practice. Through above activities a platform has been built for communication between enterprises and students. Outstanding alumni are invited to carry out lectures or share their precious experience through the network. Related facts have proved that these means have strongly promoted the self-perfection and continuous improvement of the major.

3.1 Conclusions

After twenty years of development, the major of Pharmaceutical Engineering in Sichuan University has emerged from scratch. At present, nearly 1000 undergraduate talents have been trained for the pharmaceutical industry in China. Training objectives, discipline construction, curriculum system and teachers are still improving. Current problems in the existing talent training system will be properly solved with the joint efforts of schools, colleges, teachers, alumni and industry. It can be predicted that the cultivation of pharmaceutical engineering professionals in China will continue to grow under a more scientific and effective model and then keep up with the times.

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