2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #50589

Integrating Algorithmic Thinking into Pharmaceutical Education: A Case Study of the "Artificial Intelligence Pharmacy" Master of Engineering Program at Z University

Ziyao Huang, Zhejiang University
Wu Jiayi, Zhejiang University

Jiayi Wu is a Ph.D student in the School of public affairs, Zhejiang University. Her research interests include Engineering Education, Interdisciplinary Research and Innovation Management.

Prof. Tuoyu Li, Zhejiang University

Li Tuo-yu, Associate Professor Institute of China's Science, Technology and Education Policy, Zhejiang University College of Public Affairs, Zhejiang University Research Center on Science and Education Development Strategy, Zhejiang University

Congying Wang, Zhejiang University

Integrating Algorithmic Thinking into Pharmaceutical Education: A Case Study of the "AI Pharmacy" Master of Engineering Program at Z University

1. Introduction

With the development of social economy and the transformation of lifestyles, health threats such as infectious and chronic diseases have become increasingly severe, and society's demand for drug therapy has grown more urgent. As a bridge connecting laboratory research and development with industrial production, pharmaceutical engineering integrates multidisciplinary knowledge including chemistry, biology, pharmacy, and engineering. It is a key engineering technology to ensure drug quality and improve production efficiency. However, this field has long been confronted with challenges such as long R&D cycles, high investment, high risks, and complex production processes. In recent years, the explosive development of artificial intelligence (AI) technology has been reconstructing the R&D and production paradigms of pharmaceutical engineering: ranging from upstream molecular design and target screening to downstream intelligent production monitoring and compliance management, AI has broken through the bottlenecks of traditional technologies with disruptive power, providing a brand-new approach to addressing industry pain points[1].

The high-quality development of the pharmaceutical engineering industry is inseparable from the cultivation of professional talents. Pharmaceutical engineering education originated in the 1990s. In 1995, Rutgers University in the United States took the lead in launching the world's first graduate program in pharmaceutical engineering, followed by universities in the UK, Germany, Japan and other countries[2]. China established its first five-year undergraduate program in Pharmaceutical Engineering in 1997, which has developed rapidly under the guidance of the national "Emerging Engineering Education" strategy. By the end of 2024, the Pharmaceutical Engineering programs at 47 universities in China had passed engineering education accreditation. Among these, the Master's Program in Pharmaceutical Engineering is a key pathway connecting undergraduate education with the high-end industrial demands and nurturing interdisciplinary pharmaceutical engineering technical talents. Open to undergraduates with backgrounds in Pharmacy or Pharmaceutical Engineering, the program adopts the industry-university-research collaborative practice and dual-tutor training model to enhance students' engineering practical capabilities and innovation literacy, thereby supplying the industry with technical engineering talents in the pharmaceutical field.

With the continuous development of intelligent advanced pharmaceutical technologies, the current postgraduate education system for Pharmaceutical Engineering is facing numerous challenges. First, the curriculum design is lagging behind[3]. The teaching content focuses on traditional engineering technologies, with insufficient coverage of cutting-edge technologies and lack of systematic planning for the cultivation of algorithmic thinking. Second, disciplinary knowledge is fragmented. The education tends to emphasize the teaching of fragmented scientific and engineering knowledge, while neglecting the interdisciplinary integration of data science, information engineering and quality control. Third, the connection between industry and academia is weak. It is difficult for students to acquire systematic engineering knowledge from real factory scenarios, resulting in a lack of practicality and innovation in education[4].

To address the abovementioned challenges, educators sought for reforming pharmaceutical engineering education via integrating AI[5]. For example, guiding students to design drug formulations and preparation processes through human-machine collaboration[6], or conducting situational teaching by simulating industry workflows through AI-driven virtual laboratories[7], so as to improve students' algorithmic thinking—that is, the thinking activity of using basic concepts of computer science for problem solving, system design and human behavior understanding[8]—in pharmacy education[9]. However, current literature has yet to establish a clear pathway.

The gap raised a critical question: How can algorithmic thinking be systematically and effectively integrated into pharmaceutical engineering education based on pedagogical design and real-world application. Therefore, in this study, we aim to explore the integration path of the algorithmic thinking in pharmaceutical engineering education, employing the exploratory single-case study method.

The remainder of this paper is structured as follows: literature review discussed previous studies on AI-enabled pharmaceutical engineering education, establishing the foundation for this study. Analytical framework detailed the research design, including the research method, case selection, and data collection procedures. Results section provided details and insights of teaching objectives, teaching design and teaching support mechanisms of the selected degree program, Master of Engineering in "AI Pharmacy". Lastly, the paper discussed three distinctive features of the program designed for cultivating algorithmic thinking, and concluded with implications for curricula reform in pharmaceutical engineering education.

2. Literature Review

2.1 Pharmaceutical Engineering Education

Pharmaceutical engineering is an interdisciplinary engineering discipline that encompasses pharmacy, chemistry, engineering, and biotechnology[10, 11]. It aims to cultivate engineers capable of translating scientific discoveries into industrial-scale production. In recent years, scholars have conducted extensive discussions on topics such as the reform of practical teaching in pharmaceutical engineering[12], curriculum system reform[13], and the construction of first-class programs[14]. In terms of practical teaching, scholars argue that establishing a practical teaching team led by physicians or associate professors with pharmaceutical backgrounds, supplemented by intermediate and senior pharmaceutical engineers, and adopting problem-based learning (PBL) teaching methods can significantly improve teaching effectiveness[15, 16]. Some scholars have proposed a series integrated experimental teaching model, which arranges various experimental courses in a sequence aligned with the pharmaceutical engineering process, and this model can enhance students' learning initiative and creativity[11]. In terms of curriculum construction, it is essential to incorporate cutting-edge scientific advances and innovative engineering practice content into teaching cases and courses to develop core professional courses. In terms of program construction, scholars have proposed the "5M Intelligent Biomanufacturing" talent training model of "Mining-Model-Manipulation-Measurement-Manufacture"[3]. This model takes data science as the overarching framework, integrates upstream basic discipline knowledge and downstream engineering technology knowledge, and emphasizes multidisciplinary integration.

However, most existing studies focus on undergraduate teaching, covering topics such as the factors influencing pharmaceutical engineering undergraduates' pursuit of graduate studies[17], quantitative analysis and evaluation of the achievement of training objectives specified in the graduation requirements for undergraduates[18], and the impact of virtual models such as 3D printing on improving undergraduates' critical thinking and learning interest[19]. In contrast, research on how to cultivate pharmaceutical engineering master's students who can meet industrial demands and integrate scientific and engineering knowledge to conduct engineering research remains scarce.

2.2 AI-Enabled Pharmaceutical Engineering Education

With the advent of the Industry 4.0 era, AI-assisted target discovery and virtual screening technologies have significantly shortened preclinical research cycles, which puts forward new requirements for the development of pharmaceutical engineering students. The industry's talent demand has shifted from a focus on single experimental skills to a focus on interdisciplinary integration capabilities such as Algorithmic Thinking and data-driven decision-making. Algorithmic thinking is a problem-solving mindset centered on algorithm design, which emphasizes decomposing complex problems into smaller, more manageable components and designing clear, executable steps to solve them[20]. In the field of pharmaceutical engineering, the cultivation of algorithmic thinking for AI pharmaceutical engineers runs through the entire process of drug development and pharmaceutical process design. Specifically, engineers can transform the complex, multi-factor, and strongly coupled problems in pharmaceutical engineering into structured problems solvable by algorithms, construct solution paths with clear steps and rigorous logic, and develop and apply AI technologies for drug design, efficacy prediction, process optimization[21], supply chain management and cost control. Meanwhile, through teamwork and cross-functional communication, they ensure the efficient advancement of multi-party collaboration[1].

To adapt to the development needs of the pharmaceutical industry, educational institutions are urgently required to promote in-depth teaching reforms. They should focus on pharmaceutical application scenarios and emphasize cultivating students' algorithmic thinking—specifically the ability to identify problems, establish abstract models, and solve problems through logical steps. Scholars have already explored the application of AI tools in theoretical and practical teaching and learning within the field of pharmaceutical engineering[22-25]. The results indicate that the application of AI technologies can enhance students' algorithmic reflection ability, clinical competence, and collaborative learning skills. However, existing literature on the application of AI in pharmaceutical education remains limited. Most studies focus on the teaching application of single technical tools, lacking the overall construction of an algorithmic thinking training system. In particular, in-depth discussions on the topic of "how to deeply integrate algorithmic thinking cultivation into the pharmaceutical engineering curriculum system and practical training links" are still insufficient. Therefore, constructing a university-based algorithmic thinking training system for pharmaceutical engineering that adapts to the Industry 4.0 era has become a key proposition for the reform of pharmaceutical engineering education.

3. Analytical Framework

3.1 Research Method

This study adopts an exploratory single-case study method, and collects qualitative and quantitative data through literature review, follow-up interviews, classroom observations, and questionnaire surveys, which are used for case description and analysis. There are two reasons for choosing this research method. First, the research question of this study is "how to integrate algorithmic thinking cultivation into pharmaceutical engineering education", which belongs to a "HOW" type question and is suitable for the case study method that focuses on explaining mechanisms or researching processes[26]. Second, research on algorithmic thinking cultivation in the field of pharmaceutical engineering is still in the exploratory stage, so it is of practical significance to adopt an exploratory case study to refine the cultivation system.

3.2 Case Selection

This study selects the "AI Pharmacy" Master of Engineering training program at University Z in China as the research case for the following three reasons. First, the program is targeted at students who already have an undergraduate knowledge base in pharmacy or computer science, and aims to cultivate interdisciplinary "AI+Pharmacy" capabilities and solve cutting-edge engineering problems in the pharmaceutical industry, which is highly consistent with the research question. Second, the university offering this program is a "Double First-Class" university ranked third nationwide, and the program is among the first batch of AI-enabled pharmaceutical engineering master's programs established in China. It is designed to cultivate high-level, application-oriented, interdisciplinary, and innovative outstanding engineers who can use advanced technical methods and tools to solve practical engineering problems in innovative drug R&D, possess the ability to independently engage in AI-driven new drug discovery in terms of engineering design, implementation, research, development, and management, and have good professional literacy and international vision, thus having typical representativeness. Third, reliable internal channels are available to ensure the authenticity and richness of case data.

3.3 Data Collection

This study collected data through the following two approaches:

First, interviews and questionnaire surveys. Semi-structured interviews were conducted with 5 teachers and professors involved in the program, among whom 2 were full-time instructors, while the other 3 not only undertook teaching tasks but also participated directly in the program design process, thus having a comprehensive understanding of the whole process of program design, implementation and operation. Meanwhile, we contacted the person in charge of this program and distributed questionnaires to current and graduated master's students to investigate their participation in and experience of the program. A total of 48 valid questionnaires were collected, including 18 respondents with a Bachelor of Science in Pharmacy, 10 with a Bachelor of Engineering in Pharmaceutical Engineering, and 20 with a Bachelor of Engineering in Computer Science.

Second, literature and document collection. On the one hand, members of the research team are affiliated to the state-funded New Generation AI Science and Education Innovation Platform, and many team members have directly participated in this AI interdisciplinary certification program, thus having access to internal materials such as curriculum structure and faculty list. On the other hand, the team extensively collected public reports on the program released on official websites and mainstream media. Through the above two channels, a total of 5 relevant documents were collected.

Based on the above data sources, a triangulation validation was conducted to ensure the authenticity, richness and completeness of the data.

4. Research Results

This case study focuses on the innovative implementation pathways of the interdisciplinary master's program in "AI+Pharmacy." Drawing upon the classic conceptual framework of "Why-How-What"[27], it constructs a three-dimensional analytical framework comprising "Educational Objectives-Instructional Design-Teaching Support". This framework reveals the program's practical paradigm for cultivating algorithmic thinking within pharmaceutical engineering education.

4.1 Teaching Objectives

The formulation of objectives addresses the question of "why an interdisciplinary program is established"[28]. According to industry data, the global biopharmaceutical market maintains an average annual growth rate of over 10%[10]. Moreover, China has listed the biopharmaceutical industry as a strategic emerging industry, and has continuously increased policy support through initiatives such as the "Healthy China 2030" Plan and the 14th Five-Year Plan for the Development of the Pharmaceutical Industry. Therefore, there is an urgent demand for high-quality interdisciplinary talents who possess solid theoretical knowledge, as well as strong engineering practice capabilities and innovative thinking.

At the strategic level, Z University's Master of Engineering in AI Pharmacy program is guided by national strategic plans and policies such as Healthy China 2030.In recent years, China has placed high priority on advancing AI within the pharmaceutical engineering sector. In April 2025, seven national departments jointly issued the "Implementation Plan for Digital and Intelligent Transformation of the Pharmaceutical Industry (2025–2030)", emphasizing the cultivation of outstanding engineers in pharmaceutical digitalization through platforms such as the National Outstanding Engineer Practice Base. In August of the same year, the State Council released the "Opinions on Deepening the Implementation of the 'AI+' Initiative", which called for strengthening collaborative technological innovation between AI and the field of biomanufacturing. It emphasized promoting the integrated and coordinated development of AI-driven technology R&D, engineering implementation, and product commercialization. The introduction of this series of policies highlights the national emphasis on the digital and intelligent transformation of the pharmaceutical industry and the demand for outstanding engineers in this field. In response to these policy imperatives, Z University established the “AI Pharmacy” Master of Engineering program, capitalizing on the Yangtze River Delta region’s initiative to build a world-class biomedical industry cluster. The program aims to cultivate engineers capable of applying algorithmic thinking and pharmaceutical engineering principles to analyze and solve real-world problems, addressing complex engineering challenges across the entire lifecycle of innovative drug development and translation, clinical application, intelligent regulation, and smart production and distribution.

Since its inception, the master’s program has attracted enthusiastic applications from students, with the quality of applicants steadily improving year by year: the admission ratio for master’s applicants is approximately 10:1, and over 30% of students are admitted through recommendation. Over the past five years, students from Double First-Class universities and those majoring in Class A Pharmacy disciplines have accounted for 50% of the cohort. The program’s discipline has been selected for the Ministry of Education’s Double First-Class initiative. This program aims to cultivate high-caliber pharmaceutical professionals capable of leading the future of smart pharmaceutical manufacturing. These graduates possess an international perspective and practical implementation skills, providing robust intellectual support and talent reserves for China’s ascent among the world’s pharmaceutical powerhouses.

> *“Pharmaceutical engineers of the new era must cultivate core competencies across five dimensions: Value-patriotic sentiment and mission commitment; Cognition-critical thinking and innovation awareness; Collaboration-communication and team leadership; Action-execution capability and resilience under pressure; Tools-operational application and cognitive skills.”* ***(Faculty Member Y)***

4.2 Teaching Design

Teaching translates the guiding vision into practice and addresses the questions of “how to teach” and “what to teach”[28]. It encompasses elements such as learning objectives, teaching methodologies, and assessment methods. Among these components, curriculum design serves as the core of the program and also constitutes a key challenge in its implementation. In contrast to the fixed curriculum system of traditional pharmaceutical engineering master’s programs, the curriculum of the “AI Pharmacy” engineering master’s program at Z University adopts a modular structure of “platform courses + directional courses”. Platform courses are compulsory for all students, aiming to cultivate their core theories and general skills in pharmaceutical engineering. Directional courses feature differentiated modules tailored to students’ undergraduate academic backgrounds, with targeted credit requirements and assessment criteria formulated accordingly, helping them develop professional competencies adapted to the demands of specific industrial subfields.

"Even before AI technology became as prevalent as it is today, the pharmaceutical field had already paid close attention to its precursor technologies, such as machine learning, data science, and other data analysis strategies. In recent years, the continuous iteration of related technologies has brought new ideas and methods to drug research and development. Faced with the new round of technological revolution and industrial transformation, Zhejiang University has emerged as one of the pioneering domestic institutions of higher education to establish a postgraduate program in AI pharmacy. Through cutting-edge teaching design and innovative practices, we have truly kept pace with the forefront of the times." ***(Faculty Member D)***

(1) Engineering Technology Module

As the foundational and core module in the field of pharmaceutical engineering, this segment focuses on all key links throughout the entire pharmaceutical manufacturing process. It systematically imparts core pharmaceutical technologies such as continuous manufacturing technology and miniaturization technology to students, while conducting in-depth analysis of their technical principles, core characteristics, application scopes, as well as modeling and control methods. This helps master's students comprehensively consolidate the theoretical foundation related to pharmaceutical technologies and form a systematic knowledge system before they carry out their research projects. Courses of this module are designated as professional electives. Students without an academic background in Pharmaceutical Engineering are required to complete a minimum of two such courses, whereas those with a Pharmaceutical Engineering academic background are exempted from the professional elective course requirements.

Engineering Technology Module (Core Courses)			
Course Name	Credits	Class Hours/h	Course Type
Advanced Pharmaceutical Formulation Engineering	2	32	Cutting-edge Technology Course
Biotechnology Pharmaceuticals	2	32	Research Methodology Course
Drug Delivery Devices: Innovation and Transformation	2	32	Cutting-edge Technology Course
Advanced Pharmaceutical Technology	2	32	Cutting-edge Technology Course
Pharmaceutical Engineering Examples	2	32	Research Methodology Course

In particular, the course *Pharmaceutical Engineering Examples* adopts a co-teaching model involving both on-campus and off-campus supervisors. Zhejiang University has specially invited senior experts from leading industry enterprises including *Zhejiang Hisun Pharmaceutical Co., Ltd.*, *Chia Tai Qingchunbao Pharmaceutical Co., Ltd.*, *Wanbangde Pharmaceutical Group Co., Ltd.*, and *Huahai Pharmaceutical Co., Ltd.* These experts combine their practical experience to deliver lectures on typical cases covering the entire process of pharmaceutical development. The course content encompasses multiple core themes, such as pharmaceutical research and development, production scale-up, production management, process and equipment modification, quality standard improvement, post-marketing re-evaluation, and pharmaceutical financial investment. Through systematic teaching, the course helps students grasp the integration path of emerging technologies—such as big data, the Internet of Things, and AI—with pharmaceutical development practices. It also enables students to understand and apply advanced concepts including Quality by Design (QbD) and clarify their specific implementation methods in pharmaceutical development. Meanwhile, it cultivates students' ability to apply engineering thinking to solve various practical engineering problems in the process of pharmaceutical development.

> *"For me, the courses in the Engineering Technology Module have helped me systematically consolidate the theoretical foundation of pharmaceutical technologies. Through the study of core technologies such as continuous manufacturing and miniaturization, I have established a complete knowledge system from principles to applications. The practical experience gained from courses like Pharmaceutical Engineering Examples has further enabled me to apply engineering thinking to solve practical problems in pharmaceutical development."* ***(Student W)***

> *"Students with an undergraduate background in Pharmacy have a solid grasp of pharmaceutical knowledge, their in-class interactions mostly involve questions about fundamental principles, and they perform well in the theoretical sections of assignments. Those with a Bachelor's degree in Pharmaceutical Engineering are the most well-adapted—they think clearly in class and produce highly practical assignment work. As for students with a Computer Science background, they exhibit outstanding logical thinking and enjoy exploring methodologies in class, yet they have a relatively weak foundation in pharmaceutical expertise and need to make up for some relevant content."* ***(Teacher Y)***

Among the 48 valid questionnaires, the majority of master's students expressed satisfaction with the courses in the Engineering Technology Module. The satisfaction evaluation results of each course are presented in **Figure 1**. In addition, from the perspective of the practicality of knowledge acquisition, 50.1% of the students indicated that the courses in the Engineering Technology Module were very helpful in consolidating their theoretical foundation in pharmaceutical engineering, while 18.8% considered them moderately helpful.

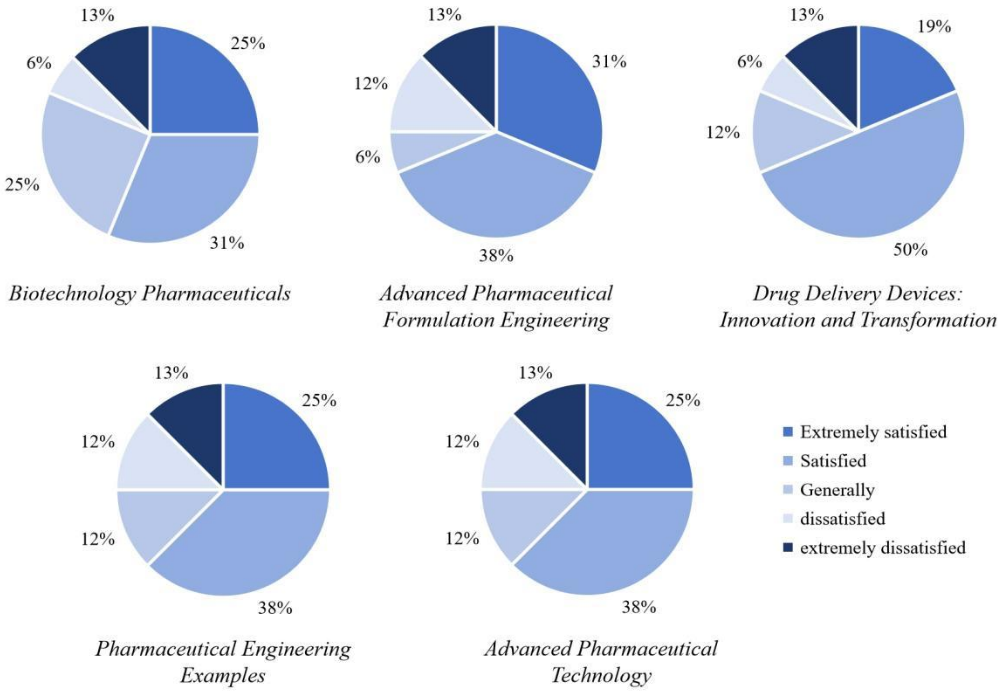

Figure 1 Student Satisfaction Evaluation of Courses in the Engineering Technology Module

(2) Intelligent Technology Module

As the foundational and core module in the field of AI, this segment requires master's students to master AI technologies, gain an in-depth understanding of their application logic in pharmaceutical engineering, and develop professional skills for conducting engineering research using algorithmic thinking. Among the courses, Introduction to Medical AI and AI Algorithms and Systems are compulsory courses; the rest are professional elective courses for which students without a computer science background are required to take at least two courses while those with a computer science background are exempted.

Intelligent Technology Module (Core Courses)			
Course Name	Credits	Class Hours/h	Course Type
Introduction to Medical Artificial Intelligence	2	32	Cutting-edge Technology Course
Artificial Intelligence and Drug Design	2	32	Experimental and Practical Courses
Medical Big Data Technology	2	32	Cutting-edge Technology Course
Pharmaceutical Informatics	2	32	Research Methodology Course
Artificial Intelligence Algorithms and Systems	2	32	Cross-category Interdisciplinary Courses

Taking the course *Pharmaceutical Informatics* as an example, it mainly teaches common algorithms in pharmaceutical informatics and their applications in modern pharmaceutical research. The theoretical teaching section primarily covers the introduction to the basic concepts, development history, and interdisciplinary attributes of pharmaceutical informatics; it explains the application of tools such as Python, R language, and NumPy; it imparts machine learning and pattern recognition algorithms including logistic regression, support vector machines, and principal component analysis; and it also involves cutting-edge technologies such as large language models and generative AI models.

> *"Students with a bachelor's degree in Pharmacy or Pharmaceutical Engineering can accurately combine pharmaceutical problems with algorithm application in their thinking during classes; students with a Computer Science background have a solid foundation in algorithms, respond quickly in class, and deliver excellent performance in model design and code implementation for assignments, yet they struggle relatively more with understanding specific pharmaceutical scenario-based problems. For this reason, I intentionally group students of diverse academic backgrounds together in class to foster a learning atmosphere of complementary strengths within teams."* ***(Teacher F)***

> *"During my undergraduate studies, the Pharmaceutical Informatics course focused on traditional data processing, covering content such as manual database retrieval and basic Excel statistical analysis. In contrast, the AI+Pharmaceutical Informatics course I took at the master's level leverages AI technologies to efficiently process massive volumes of complex data. It uses machine learning to mine data correlations and deep learning to assist in drug design, significantly improving the quality and efficiency of data processing. After completing the course, I have not only mastered AI modeling technologies, but also broadened my research horizons and gained a profound understanding of the significance of interdisciplinary integration for pharmaceutical research."* ***(Student Q)***

Among the 48 valid questionnaires, the majority of master's students expressed satisfaction with the courses in the Intelligent Technology Module. The satisfaction evaluation results of each course are presented in **Figure 2**. From the perspective of the practicality of knowledge acquisition, 50.1% of the students indicated that the courses in the Intelligent Technology Module were very helpful in cultivating algorithmic thinking and mastering AI technologies, while 31.3% considered them moderately helpful. In terms of the integration of courses with practical engineering scenarios, 56.3% of the students reported that the intelligent technology courses were closely combined with pharmaceutical application scenarios, and 25.0% regarded the integration level as moderate.

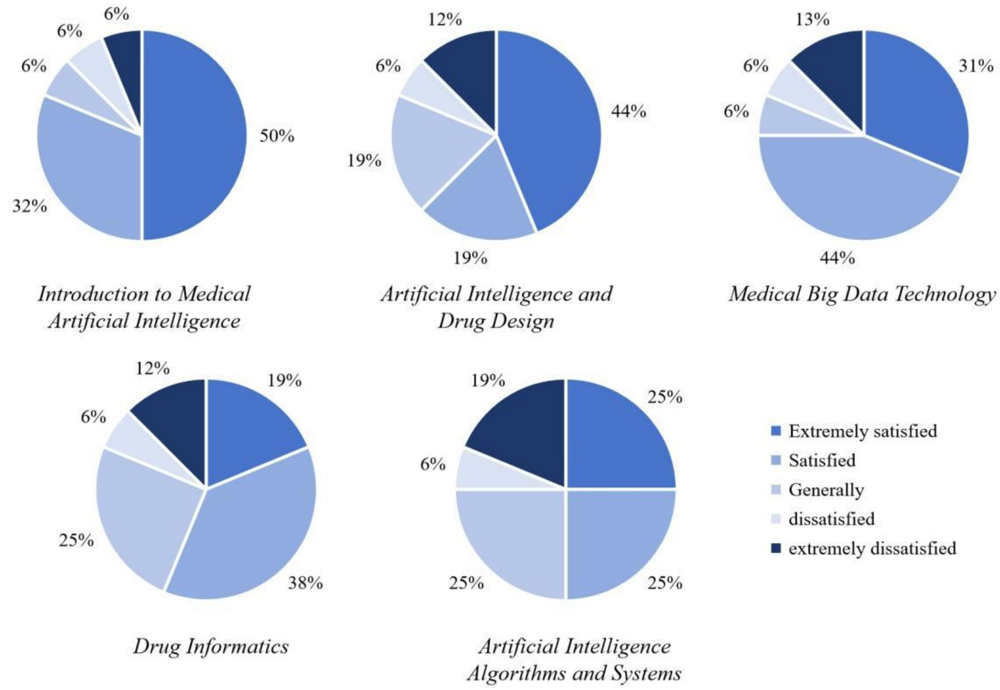

Figure 2 Student Satisfaction Evaluation of Courses in the Intelligent Technology Module

(3) Safety Evaluation Module

Safety evaluation, risk control, and cost forecasting and control constitute an important line of defense for ensuring the safety and efficacy of pharmaceuticals and benefiting public health in the pharmaceutical field, and they are also essential core professional competencies for pharmaceutical engineers. This module includes a total of 2 courses, among which New Drug Evaluation and Registration is a compulsory course. It requires all students to comprehensively master the evaluation processes and relevant policy norms of international authoritative agencies such as the U.S. Food and Drug Administration(FDA), helping to enhance the international competitiveness of Chinese pharmaceuticals and facilitate the entry of domestically produced drugs into the global market.

Safety Evaluation Module **(Core Courses)**			
Course Name	Credits	Class Hours/h	Course Type
New Drug Evaluation and Registration	2	32	Research Methodology Course
Research Methods for Drug Safety Evaluation	2	32	Research Methodology Course

The course *New Drug Evaluation and Registration* combines lectures with discussions, adopting a diverse set of teaching methods that integrate multimedia simulation with heuristic, seminar-style, case-based, and problem-driven approaches. The course content covers new drug registration classifications and application documents, early-stage evaluation of innovative drug research and development, non-clinical pharmacology studies of new drugs, non-clinical safety evaluation of new drugs, as well as laws and regulations related to drug registration. Course assessment consists of three components: course participation (accounting for 20%), case seminar and presentation (30%), and final examination (50%).

> *"Pharmaceutical safety assessment is a completely new area of knowledge for students with a computer science background, so I always start my lectures from the overall framework of the knowledge system. This approach not only helps them learn the new content from scratch, but also allows students with relevant foundational knowledge to review the key points they studied during their undergraduate studies."* ***(Teacher A)***

Among the 48 valid questionnaires, the majority of master's students expressed satisfaction with the courses in the Safety Evaluation Module. The satisfaction evaluation results of each course are presented in **Figure 3**. In addition, questionnaire statistics show that 50.0% of the students indicated that the courses in the Safety Evaluation Module were very helpful for understanding international regulatory standards and enhancing compliance awareness, while 18.8% considered them moderately helpful.

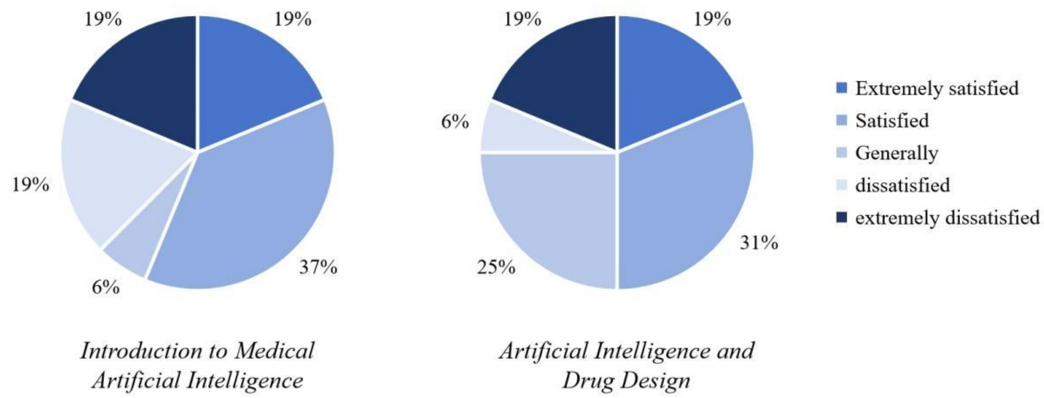

Figure 3 Student Satisfaction Evaluation of Courses in the Safety Evaluation Module

(4) Practical Teaching Module

Practical teaching consists of experimental learning and enterprise internships. Problem-oriented experimental learning is an important approach to enhancing the practical capabilities of pharmaceutical engineering students. It can not only effectively stimulate students' learning enthusiasm, but also help strengthen their abilities in comprehensive knowledge application and critical thinking[29]. Relevant studies have shown that students with work or project practical experience tend to pay greater attention to knowledge application, systems thinking, strategic planning capabilities, as well as innovative technologies such as AI[30].

The "AI Pharmacy" Master of Engineering program at Zhejiang University implements a dual-mentor system, which requires students to select a university professor as their on-campus supervisor and simultaneously appoint an enterprise engineer as their off-campus supervisor. Under the joint guidance of both mentors, students take practical engineering problems as the starting point and gradually complete training components including research direction selection, scientific research implementation, and engineering training practice. Meanwhile, to help students accurately match mentor resources that meet their research needs, Zhejiang University has built a diversified scientific research and practice platform. Relying on *national-local joint engineering laboratories*, *the Belt and Road National Joint Laboratory*, and *university-enterprise joint R&D centers*, more than 20 practice bases have been established. Master's students can conduct engineering research in on-campus and off-campus laboratories, concept verification centers, and pilot-scale platforms. Zhejiang University has also established collaborations with leading internet technology companies such as *Alibaba Cloud, Tencent, and ByteDance*. This collaboration not only provides technical requirements based on real industrial scenarios for research, but also creates opportunities for students to participate in practical algorithm development and coding implementation. Some graduate students can directly join university-enterprise joint projects, realizing the connection between academic theories and engineering practice.

The program requires students to complete professional practice between enrollment and the end of the second academic year. Graduate students without more than 2 years of enterprise work experience shall participate in professional practice for no less than 1 year, among which the practical component carried out in the form of project research shall be no less than 6 months. Meanwhile, the program mandates that students write a practical research report of over 4,000 words within 2 years of enrollment. On-campus and off-campus supervisors will conduct a comprehensive evaluation of students in terms of information acquisition ability, engineering thinking ability, algorithm application ability, and comprehensive analysis ability. Successful completion of the professional practice assessment will earn students 2 academic credits.

> *"Practical teaching helped me break free from the rigid understanding of algorithm theories. In the actual operation of university-enterprise joint projects, I gradually learned to use algorithmic thinking to decompose problems and optimize solutions. The logical sorting and communication in team collaboration further deepened my understanding of the systematic nature of algorithms, helping me transform theories into the ability to solve practical problems and laying a solid foundation for my subsequent work related to AI pharmaceutical science."* ***(Student S)***

Among the 48 valid questionnaires, 31% of the students reported deep participation in the algorithm development of university-enterprise joint projects throughout the entire process, while another 44% indicated involvement in certain core links of the projects **(Figure 4)**. The above data show that relying on university-enterprise joint practice projects, students can acquire relevant knowledge and skills in the hands-on process of algorithm development, and thus gradually cultivate their own algorithmic thinking.

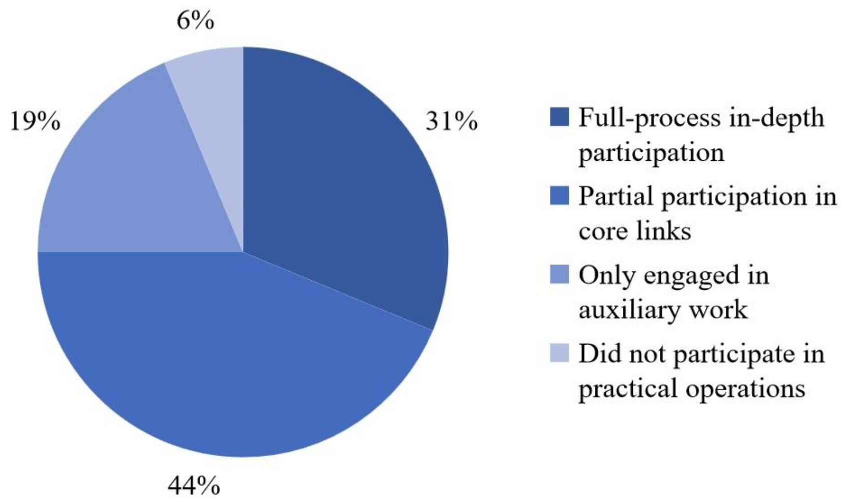

Figure 4 Students' Participation Level in Enterprise Algorithm Development, Engineering Application and Other Practical Training

4.3 Teaching Support

Educational support covers resources such as laboratories, teaching classrooms, learning management systems, information and communication technologies, and infrastructure[31]. For interdisciplinary engineering education programs, educational support is a prerequisite for breaking down disciplinary barriers and integrating interdisciplinary resources. The "AI Pharmacy" engineering education program has built an innovative atmosphere for interdisciplinary research for master's students in terms of infrastructure and collaborative culture.

In terms of infrastructure, the program has built a practical teaching platform integrating virtual simulation laboratories, AI online service platforms, and enterprise internships. It requires master's students to leverage advanced technologies such as AI, and apply algorithmic thinking to explore and solve engineering problems throughout the entire process from R&D and design, experimental verification to pharmaceutical production.

The Reproductive Toxicity Virtual Simulation Experiment allows students to enter a virtual experimental environment, complete virtual operations and online assessments, obtain simulation data for analysis and reporting, and thus improve the simulated new drug R&D chain[32].

In addition, relying on the Zhejiang University Intelligent Drug Innovation Institute co-founded by Zhejiang University and local government, the "AI Pharmacy" program has launched general and professional education courses and practical training platforms themed "AI Pharmacy". Among them, *the Zhejiang University Zhihai Mo Platform* builds a hierarchical curriculum system around the teaching objectives of "popularizing cognition-deepening competence-innovating application". It carries out teaching through medical image-related cases such as Parkinson's disease prediction and diabetic retinopathy grading, and is equipped with a multi-person development environment and an AI teaching assistant Q&A function to facilitate immersive learning for master's students. Meanwhile, the Zhejiang University Intelligent Drug Innovation Institute, in collaboration with provincial hospitals, has built a high-performance domestic thousands-GPU Cluster, 26 professional databases including a drug perturbation group database and a Chinese population database, as well as 4 AI online service platforms. These resources provide master's students with full-chain support for drug translational research from drug design to engineering application, empowering the conduct of research projects.

AI Online Teaching and Training Platforms (Partial)	Scope of Support	Website
Zhejiang University Zhihai Mo Platform	General Education Courses	https://momodel.cn/
Innovative Drug Target Validation	Key Technology Research	https://targetmap.zjuaim.top/home
Artificial Intelligence Molecular Design	Key Technology Research	https://protactm.zetx.tech/

In terms of collaborative culture, the program has established a team of faculty members and industry experts from multiple fields such as pharmaceutical science, computer science, and data science. It regularly organizes interdisciplinary brainstorming sessions to focus on pharmaceutical engineering challenges and spark innovative ideas. Through project promotion meetings, the progress of interdisciplinary research topics is tracked, and difficulties in connecting technology with applications are coordinated and resolved. Meanwhile, relying on the university's innovative competition platforms such as the "China College Students' Challenge Cup Competition" and "China College Students' 'Internet+' Innovation and Entrepreneurship Competition", students are encouraged to form interdisciplinary teams to participate in competitions. Guided by real drug R&D scenarios, the program integrates algorithmic thinking into practical links including drug design and data analysis.

> *"We encourage students to actively participate in innovation and entrepreneurship competitions. In recent years, teachers and students have achieved brilliant results such as national gold medals in competitions like the 'China College Students' Challenge Cup Competition'."* ***(Faculty Member C)***

Among the 48 valid questionnaires, 56% of the students believed that the "AI Pharmacy" Master of Engineering program had improved their Algorithmic Thinking Application Ability, 69% thought it had enhanced their Pharmaceutical Practice Ability, 50% perceived an improvement in their Interdisciplinary Collaboration Ability, and 63% reported that it had boosted their Industry Problem-Solving Ability **(Figure 5)**.

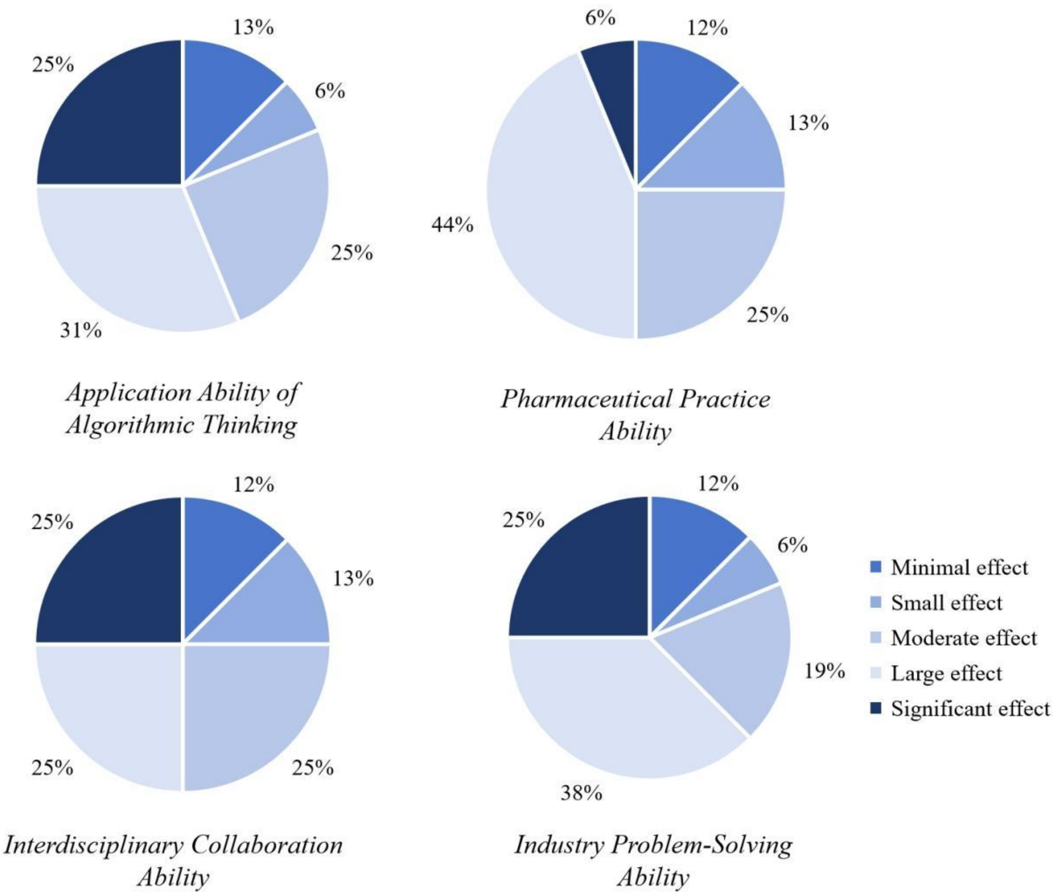

Figure 5 Student Evaluation Results of Ability Improvement in the “AI Pharmacy” Master of Engineering Program

According to statistics, there were 64 graduates in the professional degree program (where this project is located) in the 2021 cohort, with an employment rate of 96.9%, among which the employment rate in key enterprises accounted for 63.9%. Some graduates have founded high-tech enterprises. For example, Alumni Chen established *Hangzhou Xianteng Data Technology Co., Ltd.*, which focuses on pharmaceutical industry big data and provides one-stop software and hardware solutions for pharmaceutical enterprises. The independently developed pharmaceutical industry software has obtained more than 20 software copyrights and been applied in over 10 large-scale pharmaceutical enterprises. Analysis of questionnaire survey results shows that 80% of the graduates of this professional degree program in the past two years are satisfied with their jobs, and most graduates can gain a sense of identity and happiness in their work.

5. Discussion

This study takes the “AI Pharmacy” Master of Engineering program at University Z as a case, and systematically reveals the in-depth integration path of algorithmic thinking and pharmaceutical engineering education through a three-dimensional analytical framework of “teaching objectives-teaching design-teaching support”. It provides practical references for the cultivation of interdisciplinary engineering talents in the context of Pharmaceutical 4.0. Compared with traditional pharmaceutical engineering master’s programs, this program has the following three distinctive characteristics:

5.1 Project Feature 1: Accurately Targeting the Gap in Industrial Talent Demand and Establishing a Strategy-Oriented Goal Positioning

The primary feature of the "AI Pharmacy" Master of Engineering program at University Z is that it closely aligns with the needs of industrial transformation and establishes teaching objectives with clear orientation. Against the backdrop of the accelerated digital and intelligent transformation of the global biopharmaceutical industry and the guidance of national policies such as "AI+" and "Healthy China 2030", the program focuses its training objectives on interdisciplinary talents equipped with "algorithmic thinking+engineering capabilities+interdisciplinary collaboration". This responds to the industry's demand for intelligent pharmaceutical engineers, i.e., professionals capable of using algorithmic tools to solve complex problems across the entire chain of drug R&D, production, and supervision.

5.2 Project Feature 2: Interdisciplinary and Modular Curriculum System Design to Achieve Progressive Cultivation of Algorithmic Thinking

The core innovation of the program lies in constructing a modular curriculum system featuring "engineering technology+intelligent technology+safety evaluation+practical teaching". It realizes the systematic cultivation of algorithmic thinking through a progressive path of "theoretical foundation-laying-technical empowerment-practical transformation". This design effectively addresses the pain points of "fragmented disciplinary knowledge" and "insufficient coverage of cutting-edge technologies" in traditional pharmaceutical engineering education.

In terms of curriculum structure, the engineering technology module provides a pharmaceutical scenario foundation for algorithm application; the intelligent technology module imparts algorithmic tools and thinking methods; the safety evaluation module supplements the compliance perspective. These three modules form a closed loop of "scenario-tool-norm". Meanwhile, the practical teaching module provides a real carrier for the implementation of algorithmic thinking through formats such as the "double supervisor system" and "university-enterprise joint projects". Different from the teaching model of "single technical tool application" in existing research, the curriculum design of this program focuses more on the "internalization" rather than "instrumentalization" of algorithmic thinking. For example, the course Case Studies in *Pharmaceutical Innovation Engineering* invites industry experts to share practical experience in applying algorithms to process optimization and quality control, enabling students to understand the value of algorithmic thinking in solving real-world engineering problems.

5.3 Project Feature 3: Online and Contextualized Teaching Support Platforms to Alleviate the Difficulty of Integrating Interdisciplinary Educational Resources

The key bottleneck of interdisciplinary education lies in breaking disciplinary barriers and integrating diverse resources. By equipping complete digital infrastructure and fostering a dynamic team collaboration culture, this program provides a sound teaching environment for the cultivation of algorithmic thinking.

In terms of infrastructure, the program has built practical platforms including virtual simulation laboratories, AI online platforms, and university-enterprise internship bases: virtual simulation experiments allow students to complete data collection and algorithm verification in a safe and efficient environment; the *Zhihai Mo Platform* enables immersive learning through cases such as medical image analysis; and university-enterprise joint practice bases, in collaboration with internet giants, provide students with real industrial scenarios for algorithm implementation. In addition, the program has partnered with provincial hospitals to build massive clinical datasets, supplying high-quality and large-scale training data for model training. This integration of "virtual+real" and "on-campus+off-campus" resources effectively compensates for the deficiency of traditional laboratories in "simulating complex industrial scenarios", enabling students to temper their algorithmic thinking in the process of solving real-world problems.

In terms of collaborative culture, formats such as interdisciplinary faculty teams, cross-disciplinary brainstorming sessions, and innovation competitions have broken down the disciplinary boundaries between pharmacy, computer science, and data science. They have cultivated students' cross-functional communication capabilities and created an academic atmosphere that encourages algorithm innovation and engineering practice.

6. Conclusion

The "AI Pharmacy" Master of Engineering program at University Z has deeply integrated algorithmic thinking cultivation with pharmaceutical engineering education through precise goal positioning, systematic curriculum design, and a sound support system. Specifically, anchored in national strategies and industrial demands, the program has constructed a modular curriculum system featuring "engineering technology+intelligent technology+safety evaluation+practical teaching". Relying on hardware resources including virtual simulation laboratories, AI online teaching and training platforms, and professional databases, as well as an interdisciplinary collaborative culture, it regards algorithmic thinking as a crucial capability for solving engineering problems across the entire pharmaceutical process. This practice demonstrates that interdisciplinary engineering education must be guided by industrial demands, centered on curriculum integration, and guaranteed by resource coordination to break the bottlenecks of traditional education models and cultivate high-quality interdisciplinary talents for the digital and intelligent transformation of the pharmaceutical industry.

Future research can expand the scope of cases to compare the implementation paths of interdisciplinary programs in different universities; at the same time, conduct longitudinal studies to track the career development trajectories of graduates in the industry, so as to further verify the long-term value of algorithmic thinking cultivation. In addition, in-depth exploration can be conducted on the differences in algorithmic thinking cultivation among students with different academic backgrounds (i.e., pharmacy or computer science), providing a basis for the formulation of personalized teaching plans.

References

[1] Zhang, S., & Chen, Y. (2026). Teaching reform of pharmaceutical engineering design courses via AI-driven CDMO model. *Currents in Pharmacy Teaching and Learning*, 18(3), 17.

[2] Xu, M. L., Zhao, G. R., Bai, P., & Yuan, Y. J. (2004). Pharmaceutical engineering education in foreign universities. *Higher Education in Chemical Engineering*, (1), 12-14. (in Chinese)

[3] Wang, Q. Y., Bai, Y. P., Gao, S. H., et al. (2021). Construction of an intelligent biomanufacturing talent training system based on 5M: Exploration and practice of East China University of Science and Technology. *Research in Higher Education of Engineering*, (2), 111-114. (in Chinese)

[4] Li, Y., Zhang, H., Zhang, T., et al. (2024). Exploration and practice of cultivating innovative talents in pharmaceutical specialty based on deep integration of industry-university-research. *Journal of Chemical Education*, 101(8), 3126-3134.

[5] Ali, M. (2025). Will AI reshape or deform pharmacy education? *Currents in Pharmacy Teaching and Learning*, 17(3), 5.

[6] Yuriev, E., Burton, M. G., Knott, D., et al. (2025). Integrating generative AI in chemistry education: Enhancing career-ready writing skills in pharmaceutical science. *Journal of Chemical Education*, 102(5), 1991-2001.

[7] Wang, T., Xu, N., & Liu, F. (2025). Revolutionizing biotech and pharmaceutical education with adaptive learning. *Frontiers in Education*, 10, 17.

[8] Zhang, W., Wang, L., & Qian, H. Y. (2020). Core competencies of engineering and technology talents in an intelligent society: Element identification and training strategies. *Research in Higher Education of Engineering*, (4), 94-98. (in Chinese)

[9] Aziz, M. H. A., Rowe, C., Southwood, R., et al. (2024). A scoping review of artificial intelligence within pharmacy education. *American Journal of Pharmaceutical Education*, 88(1), 8.

[10] Li, X., Jiang, J., Pan, J., et al. (2023). Training mode of applied talents in pharmaceutical engineering under the background of emerging engineering education and grand health. *Journal of Chemical Education (Chinese & English)*, 44(24), 75-81. (in Chinese)

[11] Zhou, J., Wang, K., Zhang, X., et al. (2018). The comparison between series and parallel: Integrated experimental teaching model for pharmaceutical engineering students based on criteria for accrediting engineering programs in China. *Journal of Cleaner Production*, 172, 4421-4434.

[12] Xiong, P. (2024). Reflections on the reform of practical teaching in pharmaceutical engineering for emerging engineering education. *Research in Higher Education of Engineering*, 43(8), 210-214. (in Chinese)

[13] Chen, J. L. (2023). Exploration on curriculum system reform of pharmaceutical engineering major. *Journal of Pharmaceuticals*, 54(9), 1400. (in Chinese)

[14] Wang, Q. Y., Gao, S. H., Bai, Y. P., et al. (2022). Exploration and practice of constructing a first-class undergraduate program in bioengineering for the emerging engineering direction of biomedical industry. *Journal of Biotechnology*, 38(3), 1227-1236. (in Chinese)

[15] Jiang, J. (2025). Teaching system reform and practice of Industrial Microbiology in pharmaceutical engineering. *Journal of Microbiology & Biology Education*, 26(2), 9.

[16] Strohfeldt, K., & Khutoryanskaya, O. (2015). Using problem-based learning in a chemistry practical class for pharmacy students and engaging them with feedback. *American Journal of Pharmaceutical Education*, 79(9), 11.

[17] Liu, H., & Lin, Y. (2021). Factors influencing pharmaceutical engineering undergraduates to pursue graduate studies. *International Journal of Engineering Education*, 37(2), 351-361.

[18] Yao, S., Li, Z., Huang, W., et al. (2018). Quantitative analysis and evaluation for achievement of training objectives in graduation requirements of pharmaceutical engineering. In Proceedings of the 2nd International Conference on Social Science, *Public Health and Education (SSPHE 2018)* (pp. 89-93).

[19] Lim, T. S., Chia, Z. L., Seah, S. Y., et al. (2022). XANDAR PHARMACEUTICAL: A model plant for process engineering education. *Education for Chemical Engineers*, 40, 56-68.

[20] Yu, Y., & Song, R. Y. (2024). Teaching algorithmic thinking in the digital age: A backward design framework and practical implementation. *Journal of Distance Education*, 42(5), 86-94. (in Chinese)

[21] Gupta, A., Vaidya, K., & Boehnke, N. (2025). AI and machine learning in pharmaceutical formulation and manufacturing of personalized medicines. In [*Artificial Intelligence for Drug Product Lifecycle Applications*] (pp. 121-167). Academic Press.

[22] Douglass, M. A., Casale, J. P., Skirvin, J. A., et al. (2013). A virtual patient software program to improve pharmacy student learning in a comprehensive disease management course. *American Journal of Pharmaceutical Education*, 77(8), 7.

[23] Fernandez-Aleman, J. L., Lopez-Gonzalez, L., Gonzalez-Sequeros, O., et al. (2016). An empirical study of neural network-based audience response technology in a human anatomy course for pharmacy students. *Journal of Medical Systems*, 40(4), 12.

[24] Lucas, C., Gibson, A., & Shum, S. B. (2019). Pharmacy students' utilization of an online tool for immediate formative feedback on reflective writing tasks. *American Journal of Pharmaceutical Education*, 83(6), 1260-1267.

[25] Lucas, C., Shum, S. B., Liu, M., et al. (2021). Implementing a novel software program to support pharmacy students' reflective practice in scientific research. *American Journal of Pharmaceutical Education*, 85(10), 1021-1030.

[26] Eisenhardt, K. M. (1989). Building theories from case study research. US: Academy of Management., 532-550.

[27] Sinek, S. (2009). Start with why: How great leaders inspire everyone to take action. *Portfolio*.

[28] Van den Beemt, A., Macleod, M., Van der Veen, J., et al. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education*, 109(3), 508-555.

[29] Liu, H. N., & Ye, Y. (2019). Implementing the PBL teaching method in comprehensive experimental teaching of pharmaceutical engineering based on the OBE concept. *Experimental Technology and Management*, 36(10), 40-45. (in Chinese)

[30] Chen, J., Zhao, X., Li, J., et al. (2025). Core competencies in pharmaceutical education: a Chinese student perspective. *BMC Medical Education*, 25(1), 22.

[31] Larsen, P., Fernandes, J., Habel, J., et al. (2009). A multidisciplinary engineering summer school in an industrial setting. *European Journal of Engineering Education*, 34, 511-526.

[32] Chen, V., Polley, C., Dunne, B., et al. (2022). Online delivery of surgical skills teaching. *Medical Education*, 56(11), 1130-1131.