Optimization of Talent Cultivation Strategies for Bioengineering Majors under Employment Orientation

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Abstract The rapid advancement of the bioeconomy imposes increasingly stringent demands on bioengineering education. Drawing on data from the *2025 Chinese Undergraduate Employment Report* and related sources, this study revealed that while employment placement rates for bioengineering graduates remain stable, starting salaries exhibit limited growth and career trajectories lack clarity. These challenges originate from a curriculum lagging behind technological progress, inadequate practical training, and a mismatch between student competencies and industry expectations. To address these issues, this paper proposed a strategic framework grounded in "demand-driven design, industry-education integration, and competence-centered development". Key strategies include dynamic curriculum renewal, collaborative university-industry training, holistic competency development, and personalized student support, which collectively aim at enhancing graduates' employment competitiveness and long-term professional sustainability.

Key words Bioengineering; Biology major; Employment orientation; Employment quality; Talent cultivation; Training strategy

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Entering the third decade of the 21st century, the global life sciences and biotechnology fields are undergoing profound transformations. The rapid advancement of cutting-edge technologies such as gene editing, synthetic biology, cell and gene therapies, and biomanufacturing is reshaping numerous industries including pharmaceuticals, agriculture, energy, and environmental protection. To seize this crucial strategic opportunity, China has elevated the development of the bioeconomy to a national strategy. According to the "Plan for Bioeconomic Development during the 14th Five-Year Plan", the country aims to accelerate the widespread application of biotechnology in health, agriculture, energy, environmental protection, and other fields. It is projected that by 2035, bioeconomy will become a pivotal pillar of the national economy. These policy measures underscore the significant role of the bioeconomy in China's overall development strategy and simultaneously indicate a strong demand for high-quality bioengineering talents.

In this context, bioengineering, as an interdisciplinary and application-oriented engineering discipline, integrates knowledge from biology, engineering, chemistry, information science, and other fields. It bears the critical mission of cultivating high-quality engineering and technical talents for the biotechnology industry. The quality of talent development not only impacts students' individual career growth but also directly influences the innovation capacity and industrial competitiveness of China's biotechnology field. However, a gap still exists between current undergraduate bioengineering education and the actual needs of the industry. Companies generally seek to hire graduates capable of solving complex engineering problems with substantial practical experience, while many graduates face challenges such as slow salary growth and unclear career development paths. Therefore, establishing a demand-oriented talent cultivation system that is closely aligned with industrial needs has become one of the key tasks for universities in deepening educational reform. Based on analysis of the latest employment data, this paper explored the employment status and major challenges faced by bioengineering graduates, delved into the bottlenecks in the talent development process, and proposed forward-looking and actionable improvement measures.

Analysis of Employment Status and Trends for Bioengineering Graduates

Stable employment placement rate provides important enlightenment for the trend of pursuing further education

The employment placement rate for undergraduate students in bioengineering-related majors has remained relatively stable over the past three years, but it has declined slightly, reaching 89.2% in 2022, 87.4% in 2023 and 87.2% in 2024[1]. Although specialized data for this particular major is unavailable, the overall trend of undergraduate graduates' enrollment for further education nationwide (increasing from 18.0% in 2020 to 21.5% in 2024), with the postgraduate enrollment rate in "Double First - Class" universities approaching 50% (rising from 35.6% in 2020 to 45.4% in 2024)[1], indicates a significantly growing demand for advanced degrees. This trend provides essential context for understanding the inclination of graduates in science and engineering fields such as bioengineering to enhance their competitiveness through pursuing further studies.

Moderate starting salaries with slow growth: Weighing the pros and cons of further education

The starting salaries for bioengineering graduates rank in the

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medium range among undergraduate majors and exhibit relatively slow growth. Data from the classes of 2022 to 2024 indicate that the annual growth rate of monthly income for bioengineering graduates within six months after graduation is less than 1% [1], significantly lower than that of popular engineering fields such as electronic information and computer science, as well as the overall average for engineering disciplines[1]. According to the report from eRoad, the starting salary for fresh graduates in the biomedical industry typically ranges from 6 000 to 8 000 yuan for bachelor's degree holders, 8 000 to 10 000 yuan for master's degree holders, and is even higher for doctoral graduates[2]. It demonstrates a clear positive correlation between academic qualifications and starting salary.

Further research indicates that pursuing higher education serves as an effective pathway to break through salary stagnation. According to the *2025 Chinese Undergraduate Employment Report*, among the 2019 undergraduate cohort, those who advanced to postgraduate studies demonstrated significantly higher monthly income and employment satisfaction five years after graduation compared to the graduates who did not pursue further education[1], highlighting the long-term advantages. However, the decision to pursue advanced degrees requires careful consideration of potential costs and risks. Pursuing a postgraduate degree entails delaying entry into the workforce, facing several years of opportunity costs, and direct educational expenses. Furthermore, against the backdrop of postgraduate program expansion, the phenomenon of academic "inflation" is gradually becoming apparent. Master's degrees have now become the norm for certain positions, potentially diminishing the marginal returns of higher academic qualifications. Additionally, the extended duration of study and potentially narrower career paths are factors graduates must carefully consider when deciding whether to pursue further education.

Industry and regional distribution and specialty-job match

Graduates in bioengineering primarily enter related industries such as biomedicine, biotechnology, food science, environmental protection, and agriculture. The specialty-job match rate for graduates in this field has remained stable at approximately 70% for several consecutive years[3], indicating a solid alignment between educational training and industry demands. Employment is concentrated in economically developed regions with robust biomedical industry clusters, such as the Yangtze River Delta, Pearl River Delta, and Beijing – Tianjin – Hebei area[3]. Macro-level data show that pharmaceutical manufacturing, scientific research and technical services serve as the primary fields absorbing these professionals[1].

Despite the high specialty-job match rate, there remains room for improvement in precisely aligning talent cultivation with specific job requirements. Some graduates report needing a relatively long adaptation period to acclimatize to the work environment after employment. It reflects a certain lag between the pace of curriculum updates in higher education and the actual skill demands of enterprises, underscoring the need to further enhance the alignment between talent development and workplace requirements[3].

Main Problems in the Cultivation of Bioengineering Professionals at Present

The curriculum system lags behind industrial technological development

The bioengineering curriculum in some universities fails to keep pace with rapidly evolving industry trends, exhibiting a noticeable lag phenomenon. The current curriculum structure remains predominantly focused on traditional biological theories, with insufficient depth and breadth in covering cutting-edge fields such as synthetic biology, bioinformatics, bioprocess engineering, and intelligent manufacturing. The curriculum fails to adequately incorporate the latest scientific and technological advancements, such as CRISPR gene editing, mRNA vaccine development, antibody production, and cell and gene therapies, resulting in a gap between students' knowledge structure and the forefront of corporate research and development. Furthermore, there is a need to strengthen the proportion and practical components of courses that reflect the distinctive features of engineering disciplines such as *Bioreactor Design*, *Separation and Purification Engineering*, and *GMP and Quality Management Systems* in the teaching plan, in order to enhance the cultivation system for students' engineering practical ability[4].

The depth and breadth of practical teaching need enhancement

As a highly practical discipline, bioengineering education should place greater emphasis on the quality of experiments and internships. However, current laboratory instruction in many universities still predominantly focuses on verification-based experiments, lacking comprehensive and design-oriented projects. Furthermore, laboratory equipments often fail to fully simulate real-world production environments, which restricts the development of students' ability to solve complex engineering problems. In terms of off-campus internships, while most universities have established internship bases, students have limited opportunities to participate in actual corporate research and development projects or production processes, resulting in internship outcomes that need improvement. Wu Jianrong pointed out that higher education reform should closely align with industrial development and the employment needs of university students to ensure effective integration between talent cultivation and market demands[5].

The comprehensive competency structure of students needs optimization

Although graduates generally possess a solid theoretical foundation, there remains room for improvement in their comprehensive ability to meet industry demands. In terms of hard skills, some students demonstrate deficiencies in translating biological principles into engineering technology solutions, designing and optimizing process flows, as well as applying data analysis and information technology. Particularly, students' lack of experience in utilizing AI tools for literature mining, experimental design assistance, and image recognition has become a significant obstacle in adapting to the trend of intelligent research and development. In terms of soft skills, students' communication ability, teamwork, and project management ability also require strengthening. Meanwhile, weak entrepreneurial awareness and limited knowledge of intellectual property protection constrain their potential for development within the innovation ecosystem[6].

The teachers' industrial practice experience is relatively insufficient

University faculty often possess strong academic backgrounds but relatively lack hands-on experience in industrial engineering standards, quality control, cost management, and project management. This situation, to some extent, affects their ability to integrate real-world industry needs into teaching, thereby impacting students' understanding and adaptation to the industrial environment[5].

Employment-oriented Optimization Strategies for Training of Bioengineering Talents

Promoting dynamic curriculum updates based on market demand

Given the rapid development of the biotechnology industry, updating the curriculum system should not rely solely on periodic evaluations or expert discussions but should establish a more flexible mechanism. A feasible approach is to collect and analyze the recruitment information on mainstream recruitment platforms regularly, extract specific skill requirements that employers seek in graduates and use this as a basis for curriculum adjustments.

According to the latest recruitment data, companies generally emphasize various core competencies. The first competency requires proficiency in experimental techniques and instrument operation, including mastery of both conventional and cutting-edge technologies such as PCR, qPCR, Western blot, vector construction, gene editing (*e. g.*, CRISPR-Cas9), cell culture, HPLC, and mass spectrometry. The second involves the understanding of quality management systems, requiring familiarity with standards such as GMP, GLP, and ISO, as well as foundational competence in QC/QA. The third is data analysis capability, encompassing omics data processing, sequence alignment, and the use of bioinformatics tools (such as BLAST, Primer-BLAST, R, and Python). The fourth is process and R&D experience, involving engineering practices such as fermentation process optimization, purification process design, and pilot-scale amplification. The fifth is knowledge of regulations and registration, particularly the registration and application processes for pharmaceuticals and medical devices. The sixth involves production management capability, including bioreactor operation and the integration of upstream and downstream processes. The seventh desires the application of interdisciplinary tools, such as utilizing AI for literature mining, image recognition, or experimental design assistance. The eighth is project management and communication skills, demonstrated through cross-team collaboration and technical documentation writing.

Based on the aforementioned demands, curriculum development should strengthen the practical components of core courses such as *Molecular Biology*, *Microbiology*, and *Fermentation Engineering*, while enhancing the cutting-edge relevance and application-oriented nature of courses such as *Bioinformatics*, *Synthetic Biology*, and *Bio-manufacturing Engineering*. Meanwhile, exploring the establishment of micro-majors or interdisciplinary modules such as "Biology + AI" and "Biology + Data Science", while encouraging students to minor in related fields, can enhance their interdisciplinary competencies[4]. By continuously integrating genuine industry demands into teaching content, the curriculum system can truly develop dynamic adaptability, effectively improving the relevance and competitiveness of talent cultivation[5].

Deepening university-enterprise collaborative education through pragmatic pathways

To overcome challenges such as enterprise confidentiality requirements and limited willingness to collaborate, more practical cooperation models can be explored. For instance, establishing "simulated GMP workshops" or "pilot-scale simulation platforms" that use non-confidential parameters and publicly available data to replicate production and quality control processes can help students master key skills such as SOP execution, batch record management, and deviation handling. Enterprises could publish non-core tasks such as literature review, data cleaning, preliminary screening of solutions, and compilation of registration materials in the form of projects to be completed by students under faculty guidance, achieving "lightweight" collaboration. The curriculum teaching can introduce enterprise engineers to teach real cases, and the teaching materials and cases are developed based on CDE public documents, patents, product manuals and other public materials to avoid confidentiality risks.

Graduation practice could adopt a "3 + 1" model, where students engage in foundational roles such as production rotation, testing operations, and technical documentation management within enterprises. Under the guidance of "dual tutors", they would conduct their graduation projects addressing actual processes or common industry challenges, achieving "real-world environments, non-confidential tasks, and hands-on operations". Such pathways, not reliant on deep integration, can be promoted more easily and can effectively enhance students' engineering proficiency and career adaptability while safeguarding corporate interests[6].

Cultivation paths of comprehensive competencies oriented to individual development

To meet evolving industry demands, students should proactively build their personal competency frameworks. Beyond classroom learning, they should begin planning their career paths early and supplement their professional knowledge through online resources such as MOOCs, covering bioinformatics, programming, and the application of AI tools. Universities should provide corresponding support by offering courses such as *Scientific Writing and Communication and Team Collaboration and Project Management* to enhance students' communication, collaboration, and professional awareness. Additionally, establishing a "Biotechnology Innovation Incubation Center" and supporting student participation in competitions such as the "Internet Plus" and "Challenge Cup" can facilitate the transformation of outstanding projects into practical applications. Elective courses such as *Fundamentals of Biotechnology Entrepreneurship*, *Intellectual Property Management*, and *Pharmaceutical Markets and Regulations* should be offered to broaden students' perspectives. Establishing alumni and corporate mentorship programs and inviting professionals from pharmaceutical companies, CROs/CDMOs and investment institutions to conduct lectures, seminars, or one-on-one mentoring sessions, will help students build industry awareness and clarify their career development paths[7].

Meanwhile, active engagement in research training, academic competitions and in-depth internships is crucial for gaining experience. Graduation projects should address real-world problems, and tasks such as process optimization, data analysis or technical documentation preparation that align closely with job requirements should be completed under the joint guidance of internal and external supervisors[6]. Only by transforming external resources into individual action can students genuinely enhance their employment competitiveness and long-term development ability[8].

Specialty construction paths aligned with regional industrial needs

The development of bioengineering professionals should be closely integrated with the characteristics of regional leading industries to establish a collaborative education mechanism linking "specialty-industry-employment". Given significant variations in industrial structures across different regions, talent cultivation plans should be tailored to local conditions to avoid homogenization. For instance, in Wuxi City, Jiangsu Province, the "training + employment" model has effectively enhanced the employment suitability and stability of university graduates, providing replicable experience for regional talent development[9].

Universities should establish modular practical training course systems tailored to the industrial characteristics of their respective regions. In biomedical industry clusters, priority should be given to developing courses such as *Biopharmaceutical Technology*, *Biotechnology Pharmaceuticals*, *Bioseparation Engineering*, *GMP Implementation and Management*, and *Medical Device Regulations*, to strengthen students' understanding of the entire drug lifecycle management. In regions with food and health industry clusters, emphasis should be placed on areas such as *Food Fermentation Engineering*, *Functional Food Development*, *Food Safety Testing Technologies* and *HACCP System Practice* to cultivate students' practical ability in process stability control and quality management systems. In the key areas of modern agriculture and biological breeding, it is essential to strengthen the development of courses such as *Molecular Breeding Technology*, *Plant Genetic Engineering*, and *Genetically Modified Organism Safety Assessment* to enhance students' core competencies in genetic manipulation, phenotypic identification, and biosafety compliance. In the key areas of ecological environment governance or resource recycling, practical training components such as *Environmental Microbial Engineering*, *Biological Conversion of Organic Waste*, and *Water Treatment Biotechnology* can be added. In the areas with a high concentration of third-party testing institutions, applied courses such as *Standardized Operations in Biological Testing*, *Laboratory Quality Management Systems and Statistical Analysis of Test Results* should be offered to enhance students' mastery of standardized procedures and data compliance.

To further enhance the effectiveness of industry-education integration, it is recommended to establish a "Regional Skill Demand Response Mechanism". Local governments or industrial parks should regularly release *Key Industry Skills Demand List*, based on which universities can dynamically adjust their teaching content and collaborate with enterprises to conduct short-cycle and small-class skill micro-training programs. Through the approach of "enterprises posing challenges, universities accepting assignments, and students solving problems", non-confidential technical improvement tasks such as testing method validation, SOP development, and process parameter organization can be transformed into graduation projects or comprehensive training topics. Such approaches enable low-cost and highly-adaptable collaborative talent development while safeguarding enterprise information security.

Conclusion and Outlook

The cultivation of bioengineering professionals should closely align with the national bioeconomy development strategy, focusing on enhancing graduates' employment competitiveness and sustainable development capability. Based on the analysis of challenges related to salary growth, competency alignment and career development, this study proposed several optimization recommendations. Looking ahead, universities should actively align with regional bioindustry clusters by establishing an optimized system that incorporates dynamic curriculum adjustments, in-depth university-industry collaboration, comprehensive competency cultivation, personalized growth support, and continuous feedback mechanisms to innovate talent development models. Through the joint efforts of universities, enterprises, and students, a cohort of high-quality bioengineering professionals proficient in technology, well-versed in engineering, adept at innovation and effective in collaboration will be cultivated, laying a solid talent foundation for the high-quality development of China's bioindustry.

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(Continued on page 85)

Fig. 1 Creation of short Videos in agricultural production

Fig. 2 Agricultural technicians seek agricultural information and knowledge

Fig. 3 Marketing and monetization of agricultural products

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