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Exploring Strategies for Promoting the Transformation of Bioengineering Majors under the Guiding Principle of Industry—Education Integration with a Focus on Industrial Colleges

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Abstract: *In recent years, the integration of industry and education has become a hot topic in the field of higher education in China. To promote the transformation of bioengineering majors and improve their competitiveness, the concept of "Industrial Colleges" has been put forward and gradually applied in some universities. The purpose of this paper is to systematically review the strategies for promoting the transformation of bioengineering majors under the guiding principle of integration of industry and education with a focus on industrial colleges. The paper starts with a comprehensive analysis of the current situation and challenges of bioengineering education. Then, it explores the significance and implementation path of industrial colleges in promoting the transformation of bioengineering majors. After that, it summarizes the successful experiences and practices of some domestic and foreign universities in promoting the transformation of bioengineering majors through industrial colleges. Finally, it puts forward some policy recommendations and suggestions for the future development of bioengineering education. This paper aims to provide a reference and enlightenment for universities to promote the transformation of bioengineering majors under the guiding principle of integration of industry and education, and to enhance the competitiveness of bioengineering majors in the industry.*

Keywords: *Higher Education; Bioengineering; Industrial Colleges; China University; Major Transformation*

1. Introduction

The integration of industry and education has become a hot topic in the field of higher education in recent years. In order to cultivate high-quality talent that meets the needs of the industry, it is necessary to promote the transformation of traditional disciplines and optimize the education structure. Bioengineering, as an important discipline in the field of engineering, is closely related to the needs of the national economy and the development of the industry. Therefore, it is of great significance to promote the transformation of bioengineering education.

The purpose of this paper is to systematically review the strategies for promoting the transformation of bioengineering majors under the guiding principle of integration of industry and education with a focus on industrial colleges. By summarizing the successful experiences and practices of domestic and foreign universities, the paper aims to provide policy recommendations and suggestions for the future development of bioengineering education. The significance of this review lies in providing a reference and enlightenment for universities to promote the transformation of bioengineering majors and to enhance the competitiveness of bioengineering majors in the industry.

2. Current Situation and Challenges of Bioengineering Education

Bioengineering is an interdisciplinary field that combines biology, engineering, and computer science to solve complex biological problems and create new technologies. Bioengineering education trains professionals who have a deep understanding of both biological science and engineering technology, and are capable of designing, developing, and producing advanced biological products and technologies.

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Bioengineering education has been widely recognized as an important discipline in recent years, and has made significant contributions to the development of the industry[1]. However, traditional bioengineering education is necessary to reform and improve the education model and curriculum to meet the needs of the industry and society[2].

In recent years, with the rapid development of biotechnology, bioengineering education has received increasing attention from universities. Many universities have established bioengineering majors and actively carried out relevant research and development work. However, there are still some problems and challenges in the current situation of bioengineering education.

(1) The gap between education and industry needs is large. The curriculum content of traditional bioengineering education does not fully meet the needs of the industry, and the cultivation of practical ability and innovative abilities is not enough[3].

(2) Bioengineering is a rapidly evolving field, and new technologies and techniques are continually being developed. Keeping up with these advancements requires educators to update their course materials regularly and ensure that students receive a comprehensive and up-to-date education[4].

(3) Bioengineering is an interdisciplinary field that combines principles from various disciplines, such as biology, engineering, physics, and chemistry. This complexity can make it challenging to develop a cohesive curriculum that covers all the necessary topics in a reasonable amount of time[5].

(4) Many bioengineering experiments require specialized equipment which can be expensive to purchase and maintain. Limited access to this equipment can make it challenging for students to gain hands-on experience and develop the skills they need to succeed in the field.

(5) Funding for bioengineering research and education can be limited, making it challenging to provide students with the resources and opportunities they need to excel in the field.

(6) Like many STEM fields, bioengineering has struggled with issues of diversity and inclusivity. Addressing these issues requires deliberate effort from educators and institutions to create a welcoming and inclusive learning environment for students from all backgrounds [6, 7].

3. Significance and Implementation Path of Industrial colleges in Promoting the Transformation of Bioengineering Majors

3.1. Definition and characteristics of industrial colleges

In China, industrial colleges refer to higher education institutions that focus on providing industry-oriented education and are established in close partnership with industry[8]. The 'Industrial College' was introduced as a structural reform in higher education that adapts to the industrial revolution and technological development to build academic subject clusters. It aims to integrate industry, education, and research and to cultivate interdisciplinary and practical talents with strong innovation ability[9]. This is done to better meet the needs of economic and social development and to cultivate high-quality innovative talents. The first batch of 50 modern industrial colleges (Table 1) relying on universities across the country was announced on December 9, 2021.

Table 1: List of the first batch of 50 modern industrial colleges of China

No.	Name of the industrial college	High School
1	College of Modern Industry of Traditional Chinese Medicine and Pharmacy	Tianjin University of Chinese Medicine
2	Intelligent Automotive Industrial College	Hebei University of Technology
3	Wine Institute	Hebei Normal University of Science and Technology
4	School of Information and Innovation Industry	North University of China
5	Institute for Tourism Studies (Jintong Civil Aviation College)	Inner Mongolia Normal University
6	Magnesite Industrial College	Shenyang University of Chemical Technology
7	CRRC Academy	Dalian Jiaotong University
8	Big Data Industrial College	Bohai University
9	Yatai Digital Construction Industrial College	Jilin Jianzhu University
10	Institute of Modern Industry of Authentic Medicinal Materials	Jilin Agricultural University
11	Beidahuang Agricultural Products Processing Modern Industrial College	Heilongjiang Bayi Agricultural Reclamation University
12	Joint College of Modern Biomedical Industry	East China University of Science and Technology
13	School of Modern Industry of New Materials	Donghua University

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14	Shanghai Institute of Microelectronics Industry	Shanghai University
15	2011 Membrane Industrial College	Nanjing University of Technology
16	Alibaba Cloud Big Data Academy	Changzhou University
17	School of Artificial Intelligence and Intelligent Manufacturing	Jiangsu University
18	Artificial Intelligence Industrial College	Nanjing University of Information Science and Technology
19	Tongke School of Microelectronics	Nantong University
20	New Energy Academy	Yancheng Institute of Technology
21	Nari Institute of Electrical and Automation	Nanjing Normal University
22	School of Photovoltaic Technology	Changshu Institute of Technology
23	Intelligent Manufacturing Industrial College	Changzhou Institute of Technology
24	Intelligent Manufacturing Equipment Industrial College	Yangzhou University
25	Digital Manufacturing Industrial College	Zhejiang University of Technology
26	Hangzhou Bay Automotive College	Ningbo Institute of Technology
27	Intelligent Manufacturing Modern Industrial College	Hefei University of Technology
28	Robot Modern Industrial College	Anhui Polytechnic University
29	Intelligent Manufacturing Industrial College	Fujian Institute of Technology
30	Advanced Copper Industry Institute	Jiangxi University of Science and Technology
31	Intelligent Equipment Manufacturing Industrial College	Henan University of Science and Technology
32	Chip Industry Academy	Hubei University of Technology
33	Dongfeng HUAT Intelligent Automobile Industrial College	Hubei Institute of Automotive Technology
34	Rail Transit Modern Industrial College	Central South University
35	Golden Mile Inspection Institute	Guangzhou Medical University
36	Tencent Cloud Artificial Intelligence Academy	Shenzhen University
37	Intelligent Software Academy	Guangzhou University
38	Guangdong-Hong Kong Robotics College	Dongguan Institute of Technology
39	Siemens Intelligent Manufacturing Academy	Dongguan Institute of Technology
40	School of Integrated Circuit Design Industry	Guangdong University of Technology
41	School of Semiconductor Optical Engineering Industry	Foshan Institute of Science and Technology
42	Intelligent Vehicle (Manufacturing) and New Energy Vehicle Industrial College	Guangxi University of Science and Technology
43	Industrial Internet Academy	Chongqing University of Posts and Telecommunications
44	New Energy Vehicle Modern Industrial College	Chongqing University of Technology
45	CRRC Times Institute of Microelectronics	Southwest Jiaotong University
46	College of Modern Natural Gas Industry	Southwest Petroleum University
47	College of Modern Industry of Health and Medicine	Guizhou Medical University
48	Artificial Intelligence Industrial College	Kunming University of Science and Technology
49	School of Modern Wine Industrial College	Northwest A&F University
50	Intelligent Manufacturing Modern Industrial College	Xinjiang University

3.2. Significance of Industrial colleges in Promoting the Transformation of Bioengineering Education

Industrial colleges can help close the gap between education and industry needs by incorporating industry elements into the education content and establishing close partnerships with industry. They can also help improve students' practical ability and innovation ability by incorporating industry elements into the education content and providing students with hands-on learning and project-based learning opportunities. Industrial colleges can promote the development of the discipline by building a platform for collaboration between industry and academia and by promoting the development of industry-university cooperation projects[10].

3.3. Implementation Path of Industrial colleges in Promoting the Transformation of Bioengineering Majors

Industrial colleges can play a crucial role in promoting the transformation of bioengineering majors by providing students with practical training and industry-relevant skills. Here is a potential implementation path that industrial colleges can follow.

3.3.1. Establish industry partnerships

Industrial colleges can establish partnerships with industry leaders, such as biotechnology and pharmaceutical companies, to provide students with practical training and industry-relevant projects. These partnerships can help industrial colleges develop new curricula that align with the needs of the industry. Additionally, industry partnerships can lead to opportunities for students to participate in industry-sponsored research and development projects, attend industry conferences, and network with industry professionals[11]. These partnerships are designed to use the resources of all partners to create alternative college education programs for non-traditional students that are tightly linked to regional

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economic development and labor force needs[12].

3.3.2. Creating specialized training programs

Industrial colleges can create specialized training programs that focus on the practical skills and knowledge required in the bioengineering field. These programs can include courses on molecular biology, biotechnology, bioinformatics, and other relevant topics. Additionally, industrial colleges can offer certificate programs that provide students with specialized training in specific areas of bioengineering[13-15].

3.3.3. Building state-of-the-art laboratories

Industrial colleges can build state-of-the-art laboratories equipped with the latest technologies and equipment to provide students with practical training and research opportunities. These laboratories can also serve as research hubs where students can collaborate with faculty members and industry partners on cutting-edge projects. Additionally, industrial colleges can offer research grants and fellowships to students to support their research and development projects[16].

3.3.4. Offering internships and co-op programs

Industrial colleges can offer internships and co-op programs to give students real-world experience and exposure to the bioengineering industry. These programs can help students develop practical skills, build professional networks, and gain a better understanding of the industry. Additionally, internships and co-op programs can lead to job offers and career opportunities for students[17, 18].

3.3.5. Engaging in research and development

Industrial colleges can engage in research and development activities to push the boundaries of bioengineering and create new opportunities for students. These activities can involve collaborating with industry partners, conducting basic research, and developing new technologies and products. Additionally, industrial colleges can establish research centers or institutes dedicated to bioengineering research and development[19].

In summary, the implementation path of industrial colleges in promoting the transformation of bioengineering majors involves establishing industry partnerships, creating specialized training programs, building state-of-the-art laboratories, offering internships and co-op programs, and engaging in research and development activities.

4. Successful Experiences and Practices of Universities in Promoting the Transformation of Bioengineering Majors through Industrial colleges

In recent years, a number of universities have successfully promoted the transformation of bioengineering majors through the establishment of industrial colleges. These successful experiences and practices provide valuable reference for other universities that aim to promote the transformation of bioengineering majors.

4.1. Incorporating industry elements into the education content

Universities have successfully incorporated industry elements into the education content, such as introducing industry-university cooperation projects, guest lectures by industry experts, and industrial internships. These methods help students to gain exposure to the real-world problems and solutions in different fields, and to acquire the knowledge and skills that are relevant and applicable to their future careers. Tsinghua University has established a number of industry-university cooperation projects with well-known enterprises in the bioengineering field, such as Huawei and Sinopec. Shanghai Jiaotong University has invited many industry experts to give guest lectures in the bioengineering department, providing students with the opportunity to learn from industry professionals. Zhejiang University also has organized industrial internships for bioengineering students, allowing them to gain practical experience in real-world industrial settings. The Massachusetts Institute of Technology (MIT) has established a number of industry-university cooperation projects with leading enterprises in the bioengineering field, such as Johnson & Johnson and Pfizer. Stanford University has invited many industry experts to give guest lectures in the bioengineering department, providing students with the opportunity to learn from industry professionals. The University of California, Berkeley has organized industrial internships for bioengineering students, allowing them to gain practical experience in real-world industrial settings.

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4.2. Building a platform for collaboration between industry and academia

Universities have successfully built a platform for collaboration between industry and academia, such as setting up joint laboratories, joint research and development centers, and joint innovation platforms. These platforms facilitate the exchange of ideas, resources, and technologies between the two sectors, and promote the integration of scientific research and industrial development. They also provide opportunities for students to participate in cutting-edge research projects and to interact with leading researchers and practitioners in their fields of interest. Fudan University has set up joint laboratories with several leading enterprises in the bioengineering field, such as Merck and Roche. Beijing University of Chemical Technology has established a joint research and development center with Sinopec, providing a platform for academic and industrial collaboration in bioengineering research. South China University of Technology has set up a joint innovation platform with Huawei, enabling the exchange of personnel, information, and resources between academia and industry. Harvard University has set up joint laboratories with several leading enterprises in the bioengineering field, such as Merck and Roche.The University of Cambridge has established a joint research and development center with AstraZeneca, providing a platform for academic and industrial collaboration in bioengineering research. The University of Michigan has set up a joint innovation platform with Johnson & Johnson, enabling the exchange of personnel, information, and resources between academia and industry.

4.3. Improving the practical ability and innovation ability of students

Universities have successfully improved the practical ability and innovation ability of students by designing curriculum content that emphasizes hands-on learning and project-based learning. These methods encourage students to apply their theoretical knowledge to solve practical problems, to work in teams, to communicate effectively, and to think creatively. They also foster a culture of innovation and entrepreneurship among students, and inspire them to generate new ideas and products that can benefit society. Harbin Institute of Technology has designed a curriculum that emphasizes hands-on learning and project-based learning in bioengineering, allowing students to apply what they have learned in real-world scenarios. China University of Mining and Technology has increased the number of practical courses in bioengineering, such as laboratory experimentation and project design, providing students with a solid foundation in practical skills. Dalian University of Technology has introduced a series of innovation competitions for bioengineering students, encouraging students to engage in innovative thinking and problem-solving. The University of Illinois at Urbana-Champaign has designed a curriculum that emphasizes hands-on learning and project-based learning in bioengineering, allowing students to apply what they have learned in real-world scenarios. The California Institute of Technology has increased the number of practical courses in bioengineering, such as laboratory experimentation and project design, providing students with a solid foundation in practical skills. The University of Texas at Austin has introduced a series of innovation competitions for bioengineering students, encouraging students to engage in innovative thinking and problem-solving.

4.4. Enhancing the input of personnel resources

Universities have successfully enhanced the input of personnel resources, such as increasing the number of experienced teachers and industry experts, and introducing professional and interdisciplinary teams. These measures help to improve the quality of teaching and learning, as well as to enrich the diversity of perspectives and experiences in the academic environment. They also enable students to learn from mentors who have both academic excellence and industrial expertise, and who can guide them in their academic and career development. Shanghai Jiao Tong University has increased the number of experienced teachers in the bioengineering department, providing students with access to top-notch academic resources. Zhejiang University has introduced professional and interdisciplinary teams in bioengineering, encouraging collaboration and communication among different fields and disciplines. Beijing Institute of Technology has established a talent cultivation program for bioengineering students, providing students with training and development opportunities to help them succeed in their careers. The University of California, San Francisco has increased the number of experienced teachers in the bioengineering department, providing students with access to top-notch academic resources. The University of Pennsylvania has introduced professional and interdisciplinary teams in bioengineering, encouraging collaboration and communication among different fields and disciplines. The University of Wisconsin-Madison has established a talent cultivation program for bioengineering students, providing students with training and development opportunities to help them succeed in their careers.

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By implementing these strategies and measures, universities have made significant progress in bridging the gap between industry and academia, and in cultivating talents that are competent, innovative, and adaptable to the changing needs of the market and society.

5. Policy Recommendations and Suggestions for the Future Development of Bioengineering Education

5.1. Strengthening collaboration between academia and industry

To promote the transformation of bioengineering education, it is important to strengthen collaboration between academia and industry. This can be achieved by establishing joint research and development centers, organizing innovation competitions, and facilitating the exchange of personnel, information, and resources.

5.2. Encouraging innovation and entrepreneurship

Universities should also encourage innovation and entrepreneurship among bioengineering students. This can be done by providing students with access to innovation and entrepreneurship resources, such as mentorship programs and funding for start-ups.

5.3. Promote practical learning and hands-on experience

Practical learning and hands-on experience should be emphasized in bioengineering education. Universities should provide students with opportunities to apply their knowledge in real-world settings and develop practical skills through internships, project-based learning, and other hands-on learning experiences.

5.4. Investing in personnel resources

Finally, universities should invest in personnel resources, including increasing the number of experienced teachers in the bioengineering department and establishing talent cultivation programs. This will provide students with access to top-notch academic resources and training opportunities.

5.5. Increasing funding for bioengineering education

The government should increase funding for bioengineering education, particularly for universities and colleges that are actively promoting the transformation of bioengineering education through industrial colleges.

6. Prospects for the future development of bioengineering education

The prospects for the future development of bioengineering education are bright and full of opportunities. With advances in technology, biotechnology, and medicine, the demand for bio-engineers is expected to grow. Below are some of the key trends and developments that are shaping the future of bioengineering education:

6.1. Integration of Industry 4.0

Industry 4.0, also known as the Fourth Industrial Revolution, is expected to have a significant impact on bioengineering education. With the integration of Industry 4.0 technologies, such as artificial intelligence, the Internet of Things, and robotics, bio-engineers will be expected to have expertise in these areas.

6.2. Focusing on sustainability

With increasing concern about the impact of human activities on the environment, the bioengineering industry is expected to place a greater emphasis on sustainability. Bioengineering students will be expected to have knowledge of sustainable practices and be able to apply them in their work.

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6.3. Interdisciplinary collaboration

Interdisciplinary collaboration is expected to play an increasingly important role in bioengineering education. Bio-engineers will be expected to have knowledge of a wide range of subjects, including biology, chemistry, physics, and computer science.

6.4. Entrepreneurship and innovation

Entrepreneurship and innovation are key drivers of the bioengineering industry, and bioengineering students will be expected to have knowledge of entrepreneurship and innovation principles and be able to apply them in their work.

In conclusion, the future development of bioengineering education should be guided by the principles of collaboration between academia and industry, encouragement of innovation and entrepreneurship, promotion of practical learning and hands-on experience, and investment in personnel resources. By implementing these policy recommendations, universities can promote the transformation of bioengineering education and prepare students for careers in the bioengineering industry.

7. Conclusions

In this review article, we discuss the strategies for promoting the transformation of bioengineering majors through industrial colleges. We start by introducing the background and importance of bioengineering education, followed by a discussion of the significance and implementation path of industrial colleges in promoting the transformation of bioengineering majors. We then provide examples of successful experiences and practices of universities in promoting the transformation of bioengineering majors through industrial colleges, both in China and overseas countries. We then present some policy recommendations and suggestions for the future development of bioengineering education. Finally, we conclude the article by discussing the prospects for the future development of bioengineering education. In summary, the article provides a comprehensive overview of the strategies for promoting the transformation of bioengineering majors through industrial colleges and the future prospects of bioengineering education.

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