Scientific Research Publishing

Open Journal of Social Sciences, 2023, 11, 74-84
https://www.scirp.org/journal/jss
ISSN Online: 2327-5960
ISSN Print: 2327-5952

Curriculum Setting and Practice of Biological Engineering in the Context of Engineering Education: A Case Study of Qilu University of Technology

Tongjun Liu, Hongxing Li*, Liping Tan*

Department of Bioengineering, Qilu University of Technology, Shandong Academy of Sciences, Jinan, China
Email: *lihongxing1111@163.com, *tanliping163@163.com

How to cite this paper: Liu, T. J., Li, H. X., & Tan, L. P. (2023). Curriculum Setting and Practice of Biological Engineering in the Context of Engineering Education: A Case Study of Qilu University of Technology. *Open Journal of Social Sciences, 11,* 74-84.
https://doi.org/10.4236/jss.2023.114006

Received: February 17, 2023
Accepted: April 9, 2023
Published: April 12, 2023

Abstract

China has become a full member of the Washington Accord, an international agreement on mutual recognition of undergraduate engineering degrees. Under this background, the cultivation of undergraduate bioengineering talents in engineering majors has to fully meet the requirements of engineering education accreditation. Based on the practice of Qilu University of Technology for many years, the theoretical courses and experimental and practical courses have formed a curriculum system with three orientations and three main sections. This paper summarizes this to provide a reference for similar majors.

Keywords

Biological Engineering, Engineering Education, Accreditation, Teaching Reform

1. Introduction

Bioengineering is an emerging technical engineering discipline developed by the intersection, penetration and integration of biochemistry, molecular biology, genetic engineering, cell engineering, enzyme engineering, microbial engineering and biochemical engineering. Bioengineering is the basis for the industrialisation of biotechnology, and is the link between laboratory research and large-scale industrial production.

According to the Biological Engineering Professional Specification, the General Standard for Professional Accreditation of Engineering Education, the National Standard for Quality of Education in Biological Engineering and the Sup-

plementary Standard for Professional Accreditation of Biological Engineering, and the China Professional Accreditation Standard for Engineering Education (2015 version) issued by the Teaching Committee of Biological Sciences and Engineering of Higher Education Institutions of the Ministry of Education, combined with the teaching practice and professional characteristics of the bioengineering majors of Qilu University of Technology, it has gradually three orientations of curriculum setting have been formed: OBE, academic frontier and production practice. Based on the three orientations, three major sections of the curriculum have been set up: basic subjects, OBE practical subjects, and frontier cross-cutting subjects. Through teaching practice and students' employment feedback, the curriculum has been continuously optimised and improved, and the Biological Engineering major has gradually developed into a highly distinctive and reputable major of the University.

2. Positioning and Features of the Biological Engineering Major

2.1. Features of Biological Engineering

Bioengineering is a new engineering discipline that designs and modifies the structure and function of organisms according to human needs, and transforms and produces substances on an industrial scale in order to provide human beings with the products they need economically and effectively, and is a bridge from laboratory research to industrial production of life sciences. Modern bioengineering involves objects and scopes covering medical, energy, health care, agriculture, environmental protection, chemical, light industry, food and many other fields, the problems to be solved and the scope of impact often cross disciplinary areas. With the in-depth development of artificial intelligence, big data, biomics, synthetic biology and gene editing, bioengineering is entering the era of intelligent manufacturing. 21st-century bioengineering profession and industry are advancing at an unprecedented speed driven by the rapid development of multiple disciplines, which inevitably puts forward higher requirements for professional talents.

2.2. Background of Bioengineering

Qilu University of Technology was established by the former Qilu University of Technology and Shandong Academy of Sciences. It is one of the first universities in China to be built under the "integration of industry and education" project, the first batch of famous universities in Shandong Province for the cultivation of applied talents, and the first batch of universities in Shandong Province to be built as collaborative innovation centres.

The major of bioengineering of Qilu University of Technology originated from the brewing process in the period of Jiaodong Industrial School established in 1948, and the undergraduate major of industrial fermentation was set up in 1978, which was renamed as fermentation engineering and bioengineering in 1984 and 1998 respectively according to the national requirements.

After more than 40 years of development, the major of biological engineering

has become a key discipline at provincial level in Shandong Province, a key construction major in the project of famous schools with characteristics in Shandong Province and a national specialty, a specialty under the construction of "Excellent Engineer Education Training Program" in Shandong Province and a core specialty in the construction group of high-level specialty in Shandong Province. In 2019, it was selected as one of the first batch of first-class undergraduate majors in the national "Double Million Plan". A large number of technical backbones trained by this major are also distributed in large and medium-sized enterprises and institutions in the field of biological engineering.

At present, the major of bioengineering is a major member of the State Key Laboratory of Bio-based Materials and Green Paper, jointly built by the provincial ministry, and has the Key Laboratory of Industrial Microbial Fermentation Engineering of China Light Industry Federation, the Key Laboratory of Microbial Engineering of Shandong Province, the Industrial Technology Center of Food Fermentation Engineering of Shandong Province, the Collaborative Innovation Center of Clean Production and Refining of Bio-based Products in Shandong Province, the Shandong Provincial Experimental Teaching Demonstration Center, the Sino-German Beer Technology Center, Biological Engineering Training Center and a number of laboratories cooperated by the university and enterprises, all of which provide guarantees for the cultivation of biological engineering undergraduates.

2.3. Cultivation Objectives of Biological Engineering Major

This major is a key construction major of Shandong Province's Distinguished School Project, and the first batch of it is included in the provincial engineer excellence program. The programme aims to cultivate highly qualified engineering talents who can work in the fields of fermented food, biopharmaceuticals and biomaterials and related industries, such as engineering design and production, technology development and service, scientific research and application, production organization and management.

While emphasizing the learning of theoretical basic knowledge, it also pays full attention to the improvement and coordinated development of students' practical ability, innovation ability and comprehensive quality (Chen et al., 2022). In the construction and development of the major, the major has created a distinctive "integration of industry and education" talent training mode, with the objective of cultivating students' practical engineering ability and innovation ability, which is in line with the university's positioning and development requirements (Jiang et al., 2022).

3. Three Orientations of the Curriculum System

3.1. Practising the OBE Concept

Outcome-oriented education OBE means that the goal of teaching design and teaching implementation is the final learning outcome achieved by students

through the education process (Crawley et al., 2007). Using the OBE concept to guide the reform of engineering education has been regarded as the right direction for the pursuit of excellence in education in recent decades and has great practical significance (Jin et al., 2022; Guo et al., 2022).

The evaluation of the rationality of cultivation objectives is a necessary condition for revising and improving the cultivation objectives, and is also an important element for practicing the OBE concept. According to the Interim Measures for Revision of Professional Talent Cultivation Programme of the School of Biological Engineering, a Working Group for Evaluation and Revision of Talent Cultivation Programme Reasonableness was established, which in turn set up a Cultivation Objectives Reasonableness Evaluation and Revision Group to complete the comprehensive work of revising the cultivation objectives once every four years, and make appropriate revisions every two years according to the actual situation. The team will conduct questionnaires, research and data analysis on graduates, employers, industry, teachers and students to determine whether the training objectives are in line with the university's positioning, the training of professional talents and the needs of social and economic development. Based on the results of the comprehensive analysis and the comparison with the existing training objectives, the degree of conformity of the existing training objectives is evaluated (Kang et al., 2021; Wu et al., 2021; Wang et al., 2021; Lü et al., 2021) (**Table 1**).

All courses in the programme follow the OBE concept of output-oriented course quality assessment, using the "grade analysis method" for theory courses and the "ruler analysis method" for practical courses, in addition to the feedback from graduates and employers on the achievement of the graduation requirements, and the continuous improvement of the specific courses that support the graduation requirements. In addition, the feedback from graduates and employers on the achievement of graduation requirements is used to continuously improve the specific courses that support the graduation requirements. The evaluation criteria for the achievement of course objectives are based on the same

Table 1. Evaluation system of training objectives.

Evaluators	Evaluation targets	Evaluation methods	Focused evaluation content	Evaluation period
Training objectives Evaluation team	Graduates	Questionnaires	Service area, vocational ability, vocational characteristics, self-perception	2 - 4 years
	Current students	Interviews and questionnaires	Reasonableness of training objectives	
	Teachers	Interviews and questionnaires	Talent orientation, vocational competence, vocational characteristics and directions for improvement of training objectives	
	Employers	Visits and questionnaires	Graduates' vocational abilities, service areas, improvement of graduates' quality in enterprises	
	Industry and enterprise experts	Interviews and questionnaires	graduates' vocational characteristics and competencies	

principle as the evaluation criteria for the achievement of graduation requirements, and the minimum threshold is set at 0.68.

Achievement calculation by the achievement analysis method: each checkpoint (examination questions and/or usual assessment items) is assigned to the corresponding course objective and weighted (with a total weight of 1) based on the examination results and usual grades that support the achievement of the course objective, where

A = student score (or usual assessment score) for test questions related to that course objective/total score for test questions related to that course objective (or total score for usual assessment items)

Attainment of a particular course objective = ∑(A * corresponding weighting)

The results of the professional OBE-based graduation requirement attainment evaluation are statistically and analytically further used for continuous improvement, to evaluate and synthesise the overall situation of course (teaching session) objectives, index points and graduation requirement attainment, and after analysis, to make a basic judgement on whether the evaluated subject has attained the graduation requirements. At the same time, based on the results, the weak points in the process of achieving teaching objectives are identified, possible problems and shortcomings in the teaching process are analyzed and judged, and suggestions for continuous improvement of teaching work are put forward and fed back to the relevant departments and teachers in charge of the courses.

3.2. Keeping Abreast of Academic Frontiers

In order to make up for the lack of results orientation, the major always pays attention to the academic frontier and uses academic foresight to circumvent market lag. Take the continuous improvement of the course "Biological Separation Engineering" as an example.

In order to optimise the teaching content of the course, the number of cases and the breadth and depth of case studies are increased to enable students to update their knowledge and broaden their scope of knowledge; the course also introduces students to academic frontiers in conjunction with basic principles, so that students can understand the development directions of biological separation engineering in terms of scale, integration, extreme conditions and molecular level separation. The course also introduces students to the frontier of academic advances, so that they can understand the development direction of biological separation engineering in terms of scale up, integration, extreme conditions and molecular level separation, and grasp the new technology and development trend in biological separation engineering, and understand the frontier development in the field of biological separation; the teaching method of "teaching, learning and practicing" is adopted to help students master the course, in which "teaching" includes The teaching method includes lecture and case study methods, the learning method includes flipped classroom and classroom discussion, and the practice method includes classroom exercises and post-class assignments. Through these improvements, students are guided to engage in in-

dependent, research and collaborative learning to increase their participation, and to focus on process assessment and timely monitoring of their knowledge. In addition, several students who fell behind in achieving the objectives of this course were interviewed after the examination to fully analyse the reasons for this, with a view to helping them improve their performance and also to improve the subsequent teaching process in response to the problems.

The results of these improvements were first seen in the 2015 class, with significant improvements in the achievement of all course target assessment scores and indicator points, and the polarisation of grades largely eliminated. The number of students requiring attention and support has been significantly reduced, and through tutorials and support, they have passed the supplementary examinations and achieved the objectives of each course.

As with Biological Separation Engineering, other courses in Biological Engineering should use materials with the right level of content and depth, study the material in depth, and prepare lesson plans and lecture notes. The lesson plans should take into account both popularisation and improvement, incorporate new achievements in teaching reform and scientific research, and reflect cutting-edge academic developments in the subject and the course. Lesson plans must have a minimum of two weeks' advance. The focus and difficulties of the teaching content should be determined, and new achievements and developments in the subject should be incorporated into the teaching content according to the learning base of the students.

3.3. Emphasis on Production Practice

Production practice is an important compulsory part for students to consolidate the theoretical knowledge they have learnt and to cultivate professional skills and practical working ability, and it is also a necessary practical part for students after they have completed part of the professional courses. This practical teaching session is set up to enable students of biological engineering to understand the production process of various biological products, consolidate and deepen the theories and professional knowledge learned in class, and form a more comprehensive and systematic understanding of professional knowledge and professional skills.

The following is an example of the "Production Practice" of Class 2, Year 2015, to illustrate the "Ruler Analysis Method", one of the output-oriented course quality evaluation methods of this major.

Ruler analysis method: For practical courses, a ruler evaluation form was designed for various practical teaching sessions. Each student is evaluated on five levels (excellent, good, moderate, pass and fail, with scores of 90 - 100, 80 - 89, 70 - 79, 60 - 69 and 0 - 59 respectively) for the relevant course objectives in the assessment materials, and then the average student score for the relevant course objectives in the course is evaluated. The evaluation courses include: course design, experiments, engineering training, production practice, graduation practice, etc.

Table 2. Correspondence between course objectives and teaching contents and methods of "production practice".

Course objectives	Graduation requirements-indicator points	Teaching contents	Teaching methods
1) Understand the basic situation and production of the internship enterprise: through field study, understand the production situation, process flow, process conditions, equipment structure, workshop equipment and piping arrangement, plant layout of the bioengineering industry, and develop design thinking and innovative consciousness in conjunction with the new processes and technologies in the professional courses studied, which have a potential role in helping enterprises to maintain competitiveness in their future work	Be able to carry out biological system or process design and demonstrate a sense of innovation in the design	Basic knowledge of raw material characteristics, raw material storage methods, storage times, transport methods, pre-treatment methods, etc. Detailed knowledge and documentation of the production plant processes, post-processing of products, packaging and various process parameters (including workshop instrumentation and computer monitoring) to form a general understanding of the product production chain. Understand and master the structure and working principle of equipment, especially key equipment, and pay attention to the type and arrangement and orientation of auxiliary equipment and piping, valves, etc. Focus on the construction of corporate research platforms and the quality control methods and standards for raw materials and products, comparing theoretical basics and laboratory experimental techniques with the actual factory.	Internship mobilization; pre-placement information collection; field trips to enterprises; compilation of placement records and writing of placement reports
2) Through communication and exchange with engineers and front-line production personnel in the production process, learn the latest technology of production in enterprises, and conduct in-depth research on key technologies in production based on their knowledge and literature, write internship reports and express their views accurately through various means	Be able to express their views accurately and respond to queries on issues related to bioengineering, orally, in writing and graphically, and understand the differences in communication with industry peers and the public	Gather basic information about the plant's profile, production capacity, product range and specifications, etc. In-depth knowledge of the plant-wide layout and the plan and three-dimensional arrangement of key workshops. Detailed knowledge and documentation of the production plant processes, post-processing of products, packaging and various process parameters (including workshop instrumentation and computer monitoring) to form a general understanding of the product production chain. Understand and master the structure and working principle of equipment, especially key equipment, and pay attention to the type and arrangement and orientation of auxiliary equipment and piping, valves, etc. Understand and understand the recycling and comprehensive use of waste in the context of the actual plant situation. This includes the segregated management of solid waste and the high value utilisation of waste. Understand the process flow, equipment structure and working principle, various process parameters and other basic information of water treatment.	Internship mobilization; pre-placement information collection; field trips to enterprises; compilation of placement records and writing of placement reports

Continued

3) To experience the duties and job assignment system of staff in a bioengineering factory and to understand the corporate culture and management model	Understand the management and economic decision-making methods involved in bioengineering projects	Learn about the company's entrepreneurial history, corporate culture and the general management model and staffing of the company. Knowledge and understanding of the staffing and management style of the company and the sales of products and consumption of raw materials. Research into the way in which the company's capital and resources are deployed.	Internship mobilization; pre-placement information collection; field trips to enterprises; compilation of placement records and writing of placement reports

Table 3. List of key course information.

No.	Name of key course	Course category	Credits	Key support level 1 indicator points
1	Engineering Drawing	Compulsory foundation courses in disciplines (majors)	3	1, 5
2	Principles of Chemical Engineering		4.5	1, 2
3	Advanced Mathematics		9	1, 2
4	Biochemistry	Professional Core Courses	3.5	2, 4
5	Microbiology		2.5	2, 4
6	Molecular Biology and Genetic Engineering		2.5	2, 4, 8
7	Bioseparation Engineering		2	1, 3
8	Bioengineering Analysis and Testing		2	1, 4
9	Introduction to fermentation plant design		2.5	3, 5, 11
10	Environmental Biotechnology*		1.5	7
11	Internship	Intensive practical sessions	1	6, 10, 11
12	Production internships		3	3, 10, 11
13	Integrated Bioengineering Process Experiment		4	3, 4, 9
14	Graduation design (thesis)		10	3, 5, 7, 10, 12
15	Foundations of Ethics and Law	Compulsory general education courses	3	6, 8, 11
16	College English		12	10
17	Information search		1	12
	Total		67	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

*Environmental Biotechnology is set as an optional course for majors, but is actually a restricted course, and is calculated here under the category of core courses for majors.

B = student score of practical sessions related to the course objective/total score of practical sessions related to the course objective

Degree of achievement of the objectives of a particular course = ∑(B * corresponding weighting) (Table 2).

With the three orientations of practicing OBE concept, following the academic frontier and attaching importance to production practice as the curriculum design, the 12 graduation requirements achievement degrees are calculated and evaluated to diagnose the problems that need to be improved in the graduation requirements of the major, form suggestions for revising the talent training programme, and provide timely feedback to the teaching steering committee of the college and university for reference when revising the talent training programme, forming a closed loop for the evaluation of graduation requirements achievement within the university.

4. Main Sections of the Curriculum: Basic Subjects, OBE Practical Subjects, and Frontier Cross-Cutting Subjects

According to the 12 graduation requirements (Crawley et al., 2007; Zhang & Yao, 2021; Wang et al., 2020; Chen et al., 2020; Liu et al., 2019; Dai et al., 2019), combined with the 2015 version of the undergraduate talent cultivation program for biological engineering majors, we have taken the core courses of the major and some courses with strong correlation and supporting tasks for the graduation requirement index points as key courses. As shown in Table 3, the total number of credits of key courses is 67, accounting for 41.9% of the credits required for graduation, among which 23.9%, 24.6%, 24.6%, 24.6% and 26.9% of the total credits of the key courses are general education compulsory courses, disciplinary (professional) foundation compulsory courses, professional core courses and concentrated practical sessions respectively.

5. Conclusion

The major of Qilu University of Technology is one of the first majors in Shandong Province under the "Excellent Engineer Education and Training Program", and is also the core major of the high-level specialty construction group in Shandong Province. Since its establishment over 40 years ago, the major has trained more than 3000 outstanding talents for society, and many graduates have become leaders in industry, science and technology, and education. Shandong Province is an important gathering area for enterprises in the bioengineering industry in China, with well-developed related industries and a large number of bioresearch and development, manufacturing and biotechnology service enterprises and research institutions. 93.53% of the students in school are aware of the development trend of the bioengineering industry, and the awareness and recognition of the major by students are at a high level. With the improvement of the external environment in which the whole society pays renewed attention to manufacturing and engineering majors, and through teaching practice and

students' employment feedback, the curriculum system is constantly optimized and improved, and the teaching effect is significantly improved.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Chen, N., Ma, M. J., Song, H. J., & Sun, X. F. (2022). Exploration on Practical Teaching of "Environmental Impact Assessment" under the Background of Engineering Education Certification. *The Theory and Practice of Innovation and Entrepreneurship, 5,* 33-35. (In Chinese)

Chen, X. X., Zhang, P., & Hua, Z. A. (2020). Construction of Bioengineering Teaching Laboratory Based on Engineering Certification. *The Guide of Science & Education, No. 29,* 182-183. (In Chinese)

Crawley, E. F., Malmqvist, J., Östlund, S., & Brodeur, D. R. (2007). *Rethinking Engineering Education: The CDIO Approach.* Springer.

Dai, C. J., Liu, N., Gong, G. L., & Qian, W. D. (2019). Reformation and Exploration of Bioengineering Specialty Talent Training Mode Based on Engineering Education Professional Accreditation. *Education Teaching Forum, No. 12,* 67-68. (In Chinese)

Guo, J. L., Gong, D. C., Tu, Z. Y., Deng, Z. S., & Ren, L. W. (2022). Teaching Design and Practice of Biological Separation Engineering Based on Engineering Education Professional Accreditation. *Guangzhou Chemical Industry, 50,* 156-158. (In Chinese)

Jiang, A. L., Chen, L. H., & Yu, Z. (2022). Research and Practice of Bioengineering Factory Design Teaching Based on the OBE Concept. *Journal of Science and Education, No. 22,* 74-77. (In Chinese)

Jin, L. M., Zhang, Y. M., Yao, Z. A., & Quan, C. S. (2022). Construction of Evaluation Mechanism of Bioengineering Major under the Background of Engineering Education Accreditation. *Journal of Dalian Minzu University, 24,* 469-472+4476. (In Chinese)

Kang, X. H., Ren, A. M., & Tang, D. P. (2021). Practical Teaching Reform of Bioengineering Specialty Based on the OBE Concept. *Experiment Science and Technology, 19,* 54-57. (In Chinese)

Liu, C. X., Tu, Z. Y., Tang, M., & Tian, Y. H. (2019). Four Dimensions Research and Discussion the Model of Undergraduate Tutorial System under the Background of Engineering Education Professional Certification. *Education Teaching Forum, No. 51,* 137-138. (In Chinese)

Lü, Z., Cheng, B., Jiang, N., Zhao, X. H., & Hu, Y. L. (2021). Rationality Analysis of Training Objective Based on Employment Status of Graduates-Taking the Bioengineering Major of Wuhan Institute of Technology as an Example. *Higher Education in Chemical Engineering, 38,* 38-42. (In Chinese)

Wang, Q. Y., Wan, J. F., Bai, Y. P., Li, Y. Y., Zhang, X. Y., Ye, R. F., Gong, H., & Zhuang, Y. P. (2020). Exploration on the Teaching Model of Bioengineering Comprehensive Experiment Based on the Concept of Engineering Professional Certification. *Higher Education in Chemical Engineering, 37,* 54-58. (In Chinese)

Wang, Q. Y., Gao, S. H., Bai, Y. P., Zhang, X. Y., & Zhuang, Y. P. (2021). The Cultivation of Students' Non-technical Ability by Relying on the Innovative Practice Platform of Bioengineering Specialty. *Higher Education in Chemical Engineering, 38,* 36-39. (In Chinese)

Wu, L. T., Wu, J. N., Zhu, Y. B., Xu, D. L., Zhao, M. L., Yao, L. Y., & Ji, H. (2021). Development of a Practical Innovation Course for Biological Engineering Major under the Background of Engineering Education Certification. *Chinese Journal of Biotechnology, 37,* 4455-4464. (In Chinese)

Zhang, X. H., & Yao, S. J. (2021). Thinking on Engineering Education Accreditation of Biological Engineering Major. *Biology Teaching in University (Electronic Edition), 11,* 3-6. (In Chinese)