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Article

Research and practice of biochemistry curriculum reform to serve the cultivation of innovative talents among engineering majors

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Abstract: On the basis of the enlightenment of international engineering education accreditation for the reform and development of higher education in China, combined with the important measures of the national "double first-class" construction, new challenges have been proposed for innovative talent cultivation among engineering majors in the context of promoting national development. These challenges also promote the reform of science-oriented courses among engineering majors. As a core mandatory course for engineering majors, biochemistry plays a crucial role in the entire educational process at universities, serving as a bridge between basic and specialized courses. To address challenges such as limited course resources, insufficient development of students' advanced thinking and innovation skills, and overly standardized assessment methods, the bioengineering major from Guilin University of Technology restructured the biochemistry course content. A blended teaching model termed "three integrations, three stages, one sharing", was implemented. This effort has yielded significant results, providing a research foundation for constructing an innovative talent cultivation system that is oriented toward industry needs within modern industrial colleges. It also offers valuable insights into and reference points for the cultivation of engineering talents and curriculum reform in local universities.

Keywords: higher education; innovative education; professional foundation course; biochemistry course; science and engineering; industry and education; research and education

1. Introduction

As China's economic development enters a "new normal," the Ministry of Education, the National Development and Reform Commission, and the Ministry of Finance have issued the "Opinions on Guiding Some Local Ordinary Undergraduate Colleges to Transform into Applied Types," guiding universities to shift their educational focus toward serving local economic and social development, integrating industry and education, cooperating with enterprises, cultivating applied talents, and enhancing students' employment and entrepreneurial abilities (Li et al., 2016; Liu et al., 2024; Zhou et al., 2021). This guide aims to comprehensively improve the capacity to achieve regional economic and social development and drive innovation-driven development.

In recent years, the proactive efforts by the Ministry of Education to promote engineering education accreditation and the New Engineering Education initiative have brought issues such as improving education quality, innovating talent cultivation mechanisms, and building "golden courses" characterized by high-level content, innovation, and challenge ("two highs and one degree") into focus for universities (Zhao et al., 2024). Engineering education accreditation and the New Engineering

Education initiative have presented new challenges for bioengineering higher education. Traditional engineering disciplines must now aim to cultivate innovative, multidisciplinary engineering talent with an international perspective. Reforming the content, methods, and assessment of professional courses is a crucial step toward enhancing talent cultivation quality (Gong et al., 2024).

Biochemistry is a core mandatory course in the bioengineering curriculum. It serves as a crucial prerequisite for specialized courses and is vital for postgraduate entrance examinations in related biological fields. The subject includes extensive knowledge, rapid content updates, and strong applicability, playing a key role in cultivating professional talent (Lyu et al., 2023; Xie et al., 2023). In light of national engineering education accreditation and the New Engineering Education framework, this course is now subject to new requirements. This paper systematically analyzes the issues encountered in the biochemistry course offered in the bioengineering program at the authors' institution. It also proposes reform strategies to address these challenges and evaluates the outcomes of existing reforms.

2. Current status and issues of the curriculum

2.1. Development history of curriculum construction

The biochemistry curriculum has undergone three stages of development.

During the initial stage (2006–2008), the Department of Bioengineering was established in 2005, and biochemistry was designated as a core course for bioengineering majors and an elective course for the entire college. In 2006, biochemistry was recognized as a university-level quality course, providing an opportunity to initiate curriculum development and accumulate experience.

During the period of digital transformation (2009–2018), effort in digital resource construction was intensified. Projects, such as the development of online courses, the creation of high-quality video courses on "Polysaccharides in Cognitive Life," innovation and entrepreneurship education, and the establishment of massive open online course (MOOC) platforms, were implemented.

During the period of multidimensional reforms (2019–present), curriculum development is driven by professional certification requirements. Online teaching is conducted through "XueTang X" (https://next.xuetangx.com/) to enhance the teaching resource repository. Achievements include winning the school-level exemplary ideological and political education course, reforming hybrid online and offline teaching, curriculum ideological and political construction projects, "XueTang X" MOOC development, publication of two textbooks, and obtaining district-level first-class courses.

2.2. Course positioning objectives and goal positioning

Biochemistry is a fundamental course for biology and related majors, occupying a central position within the professional curriculum group (Voet et al., 2016). It requires a foundation in scientific courses, such as chemistry and biology. In turn, it lays the groundwork for engineering courses, such as fermentation engineering, bioseparation engineering, genetic engineering, enzyme engineering, and cell engineering (**Figure 1**).

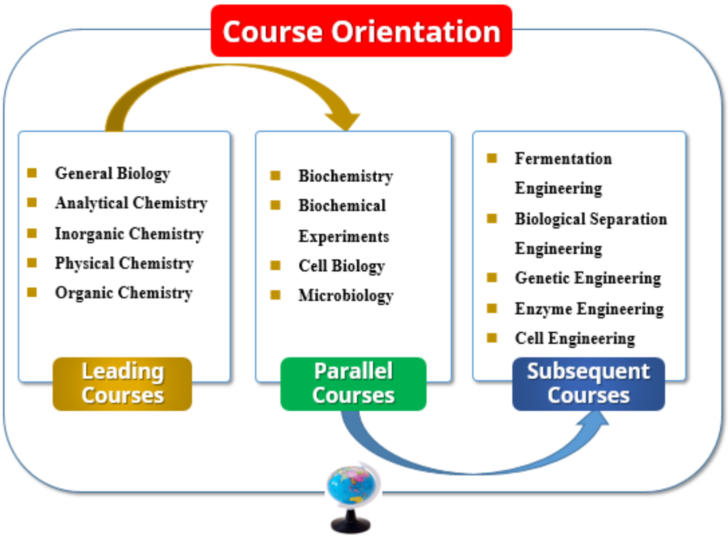

Figure 1. Sketch of course orientation.

The course is guided by the fundamental task of implementing the 'cultivation of both ability and moral integrity'. Adhering to the educational philosophy of "priority on moral education, student-centeredness, outcome-oriented, and continuous improvement," biochemistry closely revolves around the school's responsibility to serve the major needs of the country and the development of the local economy and society (Qi et al., 2004). With focus on the characteristics of serving the high-quality development of the natural resource industry and industrial sectors, it is aligned with the graduation requirements of "engineering knowledge" and "problem analysis" to define the objectives of this course.

(1) Knowledge objectives: Students will be able to articulate the relationship between the structure and function of biomacromolecules after studying their structure and properties. They will also be able to explain the processes of substance, energy, and genetic information metabolism within organisms.

(2) Competency Objectives: Students' ability to apply knowledge of biochemistry will be enhanced to understand the essence and laws of life phenomena, analyze medical phenomena related to human health and disease, and develop the capability to address biochemistry-related issues in future research in various industries, such as industry, agriculture, and medicine.

(3) Quality objectives: Students will be cultivated with a scientific spirit, understanding the role of biochemistry in human health, environmental science, and social development. Students' attention toward societal issues and engineering ethics education will be strengthened, instilling them with a sense of patriotism and mission to contribute to the nation through science and technology.

2.3. Key issues to address in curriculum and teaching reform

2.3.1. Existing teaching resources prioritize theory over practice, and course objectives fail to effectively support professional graduation requirements

Through research on online course resources and visits to universities, existing biochemistry course resources on MOOC platforms have been found to be mostly geared toward medical and science majors. By contrast, teaching resources for engineering majors are relatively scarce. For science courses of engineering majors in Western universities, educational resources that reflect engineering skills and culture in the course content are lacking, leading to asymmetrical information for students with regard to industrial applications and demands (Wang et al., 2024; Xi et al., 2022). For engineering majors, biochemistry courses are extensive and play a crucial role in guiding them toward understanding the profession, cultivating research interests, and laying the foundation for engineering thinking. However, these courses frequently struggle to demonstrate engineering characteristics in teaching and fail to align with the goals of local universities' education.

2.3.2. Insufficient cultivation of students' higher-order thinking and innovation abilities

In accordance with the characteristics of students in the Western region, traditional classroom teaching lacks the ability to internalize and transform knowledge, weakening the cultivation of students' higher-order thinking and innovation abilities (Liang et al., 2024; Wang et al., 2017). At present, the participation of multiple parties, including "Industrial-Agricultural-Medical/Industry Direction" (cultivation community), in talent development is reflected more in practical and engineering courses, but not adequately emphasized in basic courses. Courses, as the medium for students' interaction with enterprises, fail to strongly stimulate the effectiveness of learning and are not conducive to improving the quality of innovation talents among engineering majors (Miller et al., 2019).

2.4. Reform ideas

Adhering to the principles of solidifying the foundation, integrating with professional disciplines, and strengthening ideological and political education, and following the reform approach of aligning with industry development needs and supporting professional teaching, we have integrated cases of ideological and political education, scientific research, and innovation and entrepreneurship into the biochemistry curriculum in recent years. This action has resulted in the creation of the "three-integration" curriculum resources with the characteristics of engineering education in Western China.

By leveraging the university's online teaching platform, national teaching resource repositories, provincial high-quality resource sharing courses, and self-made micro-lecture videos and animations, we divide online and offline blended teaching into three phases, constructing a problem-oriented "three-stage" teaching process. Through task-sharing teaching, we develop a student-centered "task-driven sharing" teaching method, forming a "three integrations, three stages, one sharing" curriculum teaching model that serves professional education. The practical effectiveness of this teaching model has been tested using diverse assessment methods (**Figure 2**).

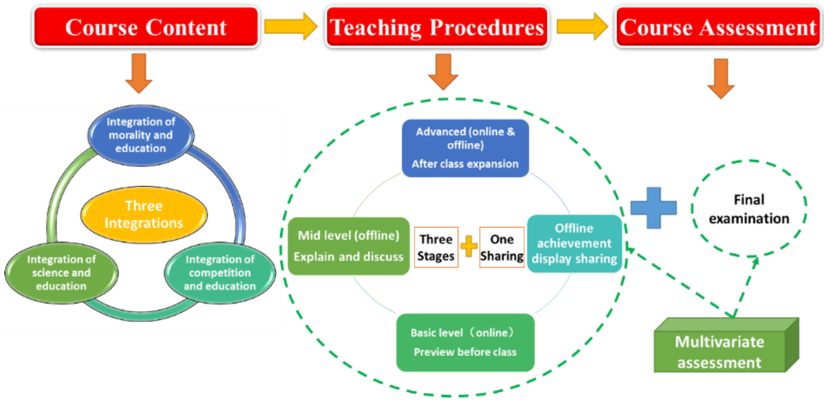

Figure 2. "Three integration, three stages and one sharing" teaching model for biochemistry courses.

3. Reform and practice

3.1. Create "three-integration" curriculum resources with the distinctive characteristics of engineering education in western China to achieve the integration of science and engineering

Using the timeline of the development of the discipline of biochemistry (from the mid-19th century to the present) as the primary content thread, and guided by a defined curriculum of ideological and political education principles, the teaching content is reconstructed following a problem-oriented approach, interspersed with research examples, innovations, and entrepreneurship cases, forming three major modules. (1) What substances constitute life? Students are guided to understand the close connection between matter and life, and correctly view the dialectical relationship between the whole and the parts. Learning with a scientific spirit, as demonstrated by scientists in their hard work, relentless exploration, and pursuit of truth, is encouraged. Research cases that involve Guangxi's unique resources, such as "Gui Shiwei" or "Ten flavors of Guangxi" medicinal materials (including ten kinds of authentic medicinal materials unique to Guangxi Zhuang Autonomous region), sugarcane, and cassava, are integrated to enhance students' sense of patriotism. (2) What changes do nutrients undergo within living organisms? Guiding students is emphasized to establish correct health concepts, enhance their sense of responsibility and mission toward building a biologically strong nation, and improve their professional skills. Students' dialectical thinking ability is developed by exploring the unity and opposition of nutrients. Research stories of renowned domestic scientists are incorporated to inspire students' interest in scientific research. (3) How is the information required for the growth, development, and reproduction of organisms stored and transmitted? Confidence in our system is strengthened through "nucleic acid testing," and a sense of national pride is fostered. Research achievements and experiences from major national scientific projects are integrated to help students appreciate the power of design and teamwork. In addition, the course team has created micro-lecture videos on various knowledge points as online resources. Student-designed innovation and entrepreneurship projects based on these knowledge points, along with innovative breakthroughs from renowned biotech companies, are incorporated into the curriculum as case studies. This action has led to the creation of "three-integration" curriculum resources with the distinctive characteristics of engineering education in Western China, successfully bridging the gap between science courses, such as chemistry and biology, and engineering courses, such as fermentation engineering, bioseparation engineering, genetic engineering, and enzyme engineering, achieving the integration of science and engineering (**Figure 3**).

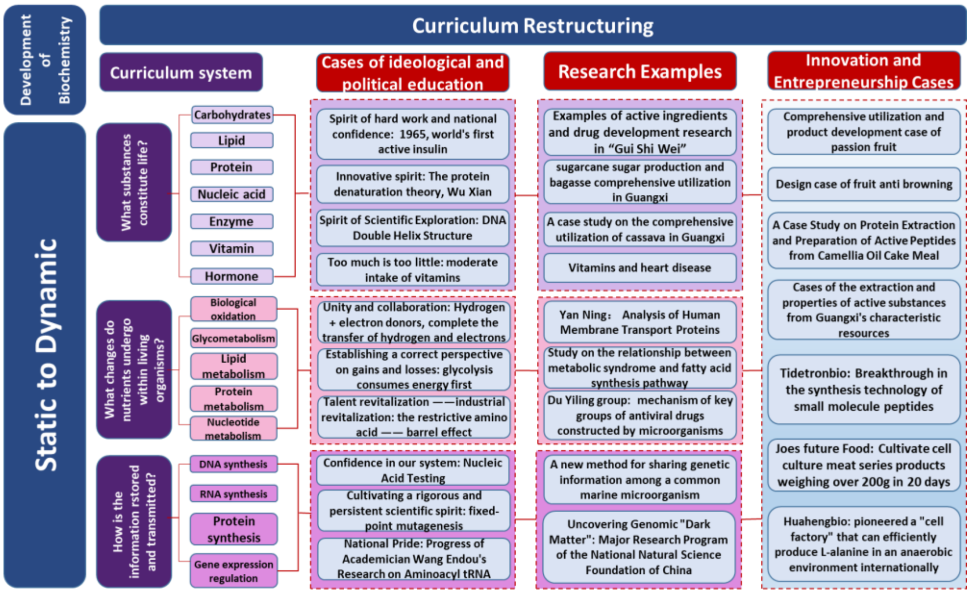

Figure 3. Chart of course content reorganization reconfiguration design.

The currently developed course resources include a self-made teaching video library (49 videos, 500 min), a mind map library (126 items), an innovation and entrepreneurship case library (39 cases), an ideological and political case library (28 cases), a micro-lecture competition resource library (167 items), a biochemistry talk show resource library (40 items), a student PowerPoint presentation library (16 items), a Bilibili video library (41 videos), a micro-lecture video library (SPOC) (51 videos), a courseware resource library (20 items), an excellent assignment library (47 items), a test question bank (52 sets, 277 questions), and an exercise library (31 sets). These resources provide a solid foundation for the transition to blended online and offline teaching and assessment methods.

3.2. Constructing a problem-oriented "three-stage" teaching process and implementing blended online and offline teaching

Before class, teachers will assign pre-learning tasks online, requiring students to complete online learning activities and assessments. Simultaneously, teachers will monitor students' progress in real time, assess learning outcomes promptly, conduct learning analysis, and facilitate online discussions and interactions with students. This stage focuses on developing students' basic-level skills.

Based on the analysis of students' learning situations, teachers design offline teaching activities. During class, teachers provide explanations for key and difficult points, integrating ideological and political education (case analyses, micro-lecture competitions, and talk shows), scientific research (research case studies and cutting-edge topics), and innovation and entrepreneurship (group tasks and discipline competitions) into the teaching process. Classroom discussions and group task presentations are conducted to cultivate students' intermediate-level skills.

After class, teachers provide feedback on students' overall performance and assign comprehensive tasks. Students apply their learned knowledge comprehensively through group cooperation or independent completion of post-class tasks. Then, they share their results either online or offline. This stage focuses on cultivating students' advanced-level skills (Chen et al., 2023).

By combining online and offline methods, the three teaching stages, namely, pre-class, in-class, and post-class, are effectively connected, promoting the achievement of low-level, intermediate-level, and advanced-level learning objectives. At present, the course has conducted three rounds of blended online and offline teaching, reaching three top-tier majors and one emerging engineering major within the university and benefiting 400 students per year, with positive results (**Figure 4**).

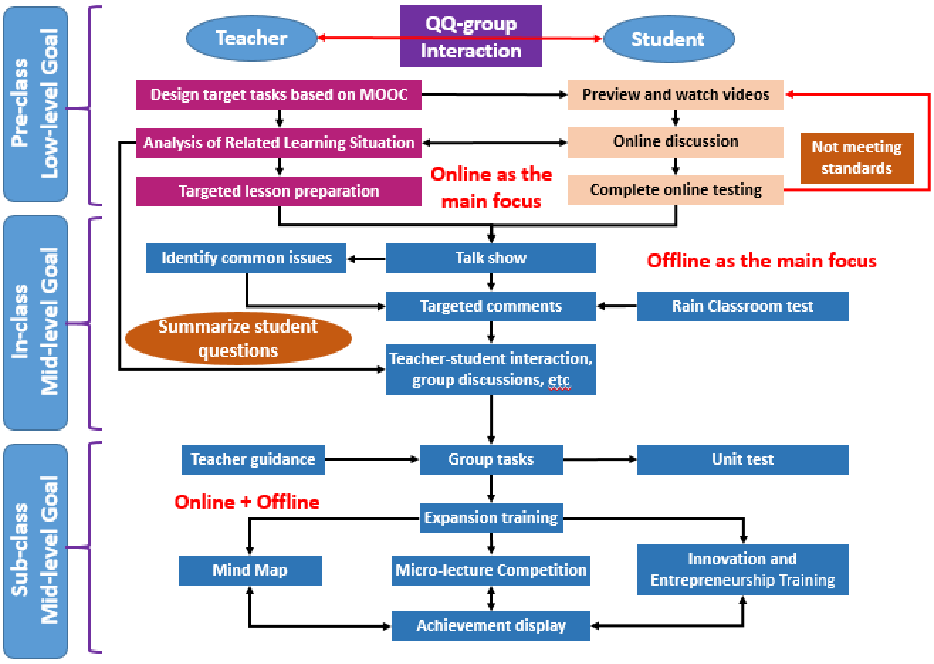

Figure 4. Schematic diagram of the "three-stages" teaching process.

3.3. Constructing a student-centered task-driven sharing teaching method to enhance students' practical and communication skills

Centered around students and focusing on the cultivation of practical abilities, a task-driven "learn-do-share" teaching approach has gradually emerged. Initially, tasks, such as pre-class quizzes and in-class assignments, drive students to engage in pre-class and in-class learning, emphasizing improvement in students' learning abilities. Subsequently, teachers design and implement classroom tasks (e.g., problems and discussions) and post-class tasks (e.g., talk shows, mind maps, and micro-lecture competitions) based on students' learning situations. Students actively participate in classroom interactions and complete various tasks offline individually or in teams, emphasizing the enhancement of students' practical and collaborative abilities. Finally, students share their outcomes in class or competitions, focusing on improving students' communication and presentation skills. Through this training process, the practical and communication skills of students are enhanced, laying a solid foundation for future engineering-related courses (**Figure 5**).

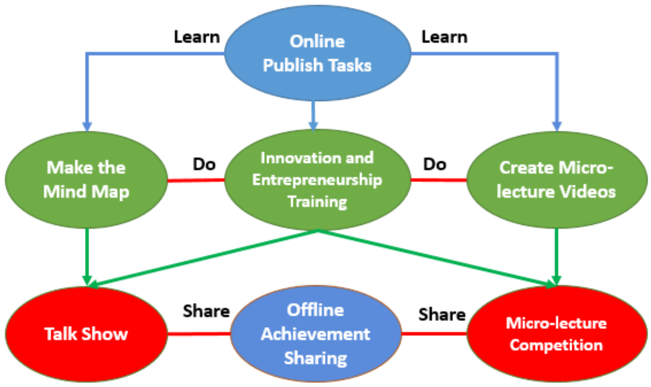

Figure 5. Task-driven "sharing" teaching methodology.

3.4. Constructing a diversified grading system, emphasizing process and nonstandard assessments

The course adopts a diversified evaluation system that combines online and offline elements, integrates formative and summative assessments, and combines self-assessment with peer assessment. This system can better reflect individual differences among students and the characteristics of the course, providing a clearer picture of students' learning outcomes.

The course grades consist of formative and summative assessments, each accounting for 50%. Formative assessment covers online and offline tasks, including online videos (10%), online assignments (12.5%), online discussions (5%), online quizzes (7.5%), group tasks (micro-lecture production + talk show + innovation and entrepreneurship competition + mind map) (10%), and classroom performance (5%), each with its own assessment criteria. It is evaluated comprehensively based on diverse requirements. Summative assessment comprises the final exam grade (**Figure 6**).

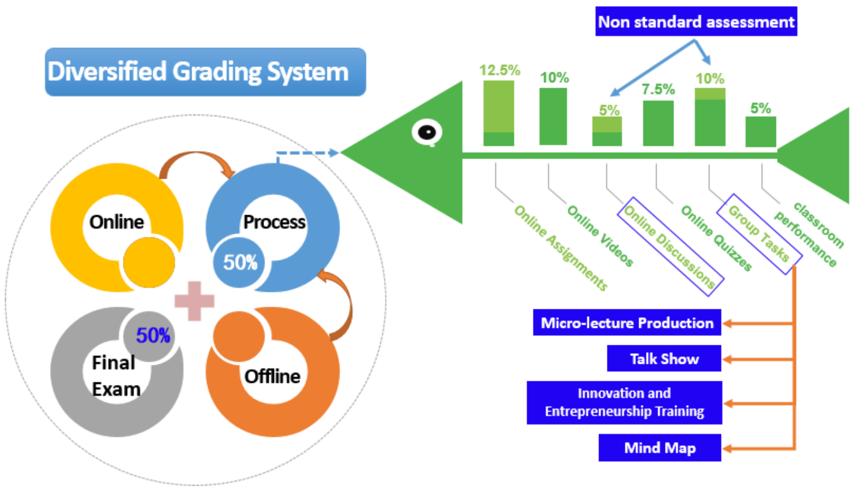

Figure 6. Diversified grading system.

3.5. Course evaluation and reform effectiveness

Teachers' lectures emphasize the integration of theory with practice, with innovative materials and cases. Strong emphasis is placed on student engagement and interaction in the classroom (Innocent et al., 2023). The teaching effectiveness of course team members has been recognized via internal supervision, and course evaluations have consistently ranked high over the years. The course content is innovative, practical, and receives excellent peer evaluations.

By updating the teaching concept and integrating elements of ideology, cases and innovation and entrepreneurship into the biochemistry course, the classroom has become more flexible and enriched, which is no longer confined to book knowledge, and enables students to learn, think, practice and summarize while learning, so as to achieve the mutual integration of teaching content and practice, and to ensure the balance between absorption and digestion (Hu et al., 2021; Lei, 2023). The teaching effect has also been praised by students, school supervisors and peers, and has been ranked among the top in the evaluation of teaching in previous years. Through the course reform, a curriculum team with rich professional knowledge, reasonable age structure, and sustainable development has been gradually formed. The teaching capabilities of the teachers have significantly improved. Faculty teaching capabilities have significantly improved, highlighted by achievements such as a second prize in the Teaching Innovation Competition, the promotion of two professors, and two associate professors.

The quality of talent development has steadily improved, evidenced by increased student motivation, enthusiasm for learning, and academic performance (**Table 1**). The guidance participation rate of students in competitions is over 80%, with over fifty awards won each year， especially for the "Innovative Entrepreneurship Training Program for College Students", "Undergraduate Life Science Contest, CULSC" "Internet Plus" etc. The course covers nationally top-tier majors, such as bioengineering, chemical engineering and technology and applied chemistry. Universities in the region, including Guangxi University of Science and Technology, participate in exchange visits, and the demonstrative radiance effect inside and outside the university is significant. The effort has received unanimous recognition from experts of the National Teaching Steering Committee, Professional Accreditation Committee, and peers in the field.

Table 1. Distribution table of overall evaluation scores for the 2022–2023 autumn biochemistry course.

Semester	Average	Score range	< 60	60–69	70–79	80–89	≥ 90
2022 Autumn	71.9	Number	6	32	30	23	0
		Ratio	6.6%	35.2%	32.9%	25.3%	0
2023 Autumn	80.5	Number	3	4	30	45	13
		Ratio	3.2%	4.2%	31.6%	47.4%	13.7%

4. Curriculum continuous development plan

The biochemistry course, based on the educational characteristics and student demographics of the Western region, and in line with the positioning of applied talent cultivation in Western engineering colleges, utilizes modern educational technology, information technology, and the continuous evolution and development of Internet technology. By leveraging platforms, such as “Guigong Xuetang Cloud” and MOOC, it implements blended online and offline teaching reforms. It innovatively proposes a hybrid teaching model called “three integrations, three stages, one sharing,” which effectively addresses the lack of advanced thinking and innovation skills among students. This approach achieves deep integration and innovation between information technology and education in Western engineering colleges. The following statements outline the continuous development plan for the course.

(1) A knowledge map of biochemistry is constructed based on mind maps combined with ideological and political cases and dynamic frontiers. Using this map as a cornerstone, core courses in bioengineering are linked and radiated, forming a course network with knowledge points as nodes. This condition optimizes the content of core courses related to bioengineering, promotes teaching reforms and practices in relevant courses, optimizes talent training programs, and improves the quality of talent cultivation.

(2) Inter-school and school–enterprise exchanges are strengthened, and optimization strategies for the talent cultivation model of bioengineering in Western universities are proposed under the background of the Association of Southeast Asian Nations (ASEAN) from multiple dimensions, such as training objectives, processes, systems, and evaluations. Bilingual teaching is increased to cultivate innovative and compound talents with international perspectives and competitiveness, meeting talent needs for the development of Guangxi and the ASEAN region.

(3) A curriculum teaching loop that integrates knowledge imparting, skill development, and value shaping, is constructed, completing the curriculum mind map, promoting continuous improvement of the course, and further enhancing the course’s “two sexes and one degree” and reflecting the advantages of national first-class professional construction and courses. From its establishment to its development, the course has developed its own characteristics, demonstrating its effectiveness from within the college to the university, and then extending to the region. However, its leading role should be further strengthened.

(4) A teaching team with a high level of international perspective, teaching and research abilities, strong bilingual teaching skills, and reasonable structure is built. Teaching conditions are improved, guiding teachers to fully utilize information technology and continuously enhancing teachers’ educational and teaching abilities and the quality of course teaching.

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