Construction and Exploration of Innovative Teaching Modes for the Genetic Engineering Course in the Biotechnology Major

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Abstract: As a core cutting-edge technology in the field of life sciences, genetic engineering is a key course for the biotechnology major that connects basic theories with industrial applications, and its teaching quality is directly related to the cultivation of high-quality professional talents. Under the dual background of the construction of "New Engineering" and the certification of normal majors, the rapid development of the biotechnology industry puts forward higher requirements for students' practical and innovative abilities, and the reform of basic education also poses new challenges to the disciplinary teaching transformation ability of normal biology teachers. However, the traditional teaching of the genetic engineering course has prominent problems, such as lagging knowledge and a disconnection between theory and practice, which makes it difficult to adapt to the talent training needs of the new era. Therefore, promoting the innovation of the course teaching mode has become an urgent task for professional education reform. Based on the talent training objectives of the biotechnology major (including normal direction), this paper integrates four core dimensions: AI empowerment, integration of theory and practice, industry-education collaboration, and literacy-oriented education, and constructs a systematic teaching reform plan, aiming to solve the current teaching problems, improve the course education quality, and provide practical reference for the teaching reform of similar courses.

Keywords: Biotechnology major; Genetic Engineering; Teaching mode innovation; Integration of theory and practice; Industry-education collaboration; AI empowerment

1. Course orientation and core value

1.1. Core course orientation

Genetic engineering is a pillar core course of the biotechnology major, whose content covers key technologies such as gene cloning, vector construction, target gene introduction and screening, and gene editing, spanning multiple disciplinary knowledge fields including molecular biology, biochemistry, and genetics, forming a trinity course system of "theory-technology-application". This course is not only a key carrier for students to consolidate

the basic theories of life sciences, but also an important bridge connecting classroom learning with industrial practice and scientific research innovation, occupying a core position in the talent training of the biotechnology major [1]. For the normal biological science major, the genetic engineering course is also an important link to implement the concepts of "student-centered, outcome-based education, and continuous improvement" in normal professional certification, which needs to take into account the dual cultivation of disciplinary professional ability and educational teaching ability.

1.2. Core value dimensions

(1) Theoretical Construction Value: It helps students understand the underlying logic of gene manipulation, master the complete technical chain of "target gene acquisition-vector construction-introduction and screening-expression identification", form a systematic cognition of the biotechnology industry, and lay a solid foundation for the study of subsequent professional courses [2]. The theoretical system of genetic engineering runs through the core principles of life sciences, and its teaching effect directly affects the depth of students' understanding of subsequent courses such as molecular biology and biotechnological pharmacy.

(2) Practical Operation Value: Through experimental teaching, project practice and other links, students' core operational skills are tempered, and standardized experimental habits and problem-solving abilities are cultivated. Practical operation is the core characteristic of the genetic engineering course, which enables students to transform abstract theories into practical operational abilities, in line with the training objectives of applied talents in the biotechnology major [3].

(3) Innovative Thinking Value: It guides students to pay attention to cutting-edge fields such as gene editing and synthetic biology, and cultivates critical thinking, logical reasoning ability and technological innovation awareness through case analysis and participation in scientific research projects [4].

(4) Normal Education Adaptation Value: For students of normal majors, the course needs to integrate content such as teaching skill training and educational practice guidance, help them form composite literacy of "disciplinary knowledge + teaching ability", and meet the training requirements of basic education teachers [5].

2. Prominent problems in the current course teaching

2.1. Lagging knowledge update behind cutting-edge developments

The technology in the field of genetic engineering is evolving rapidly, and new technologies such as CRISPR-Cas9 gene editing, single-cell sequencing, and synthetic biology have been widely applied. However, the content of existing textbooks is updated slowly, still focusing on traditional gene cloning technology, and failing to timely incorporate cutting-edge technical principles, application cases and ethical norms [6]. Some teachers rely on textbooks for teaching and cannot transform the latest scientific research achievements into teaching content, leading to the disconnection between students' knowledge system and industrial development and scientific research trends, which is difficult to meet the demand of the biotechnology industry for cutting-edge technical talents [7].

2.2. Severe disconnection between theory and practice

In the course design, theoretical courses and experimental courses are mostly separated. Theoretical teaching

focuses on one-way knowledge transmission, and experimental teaching is mainly based on confirmatory experiments, lacking real research on technical pain points [8]. Although students master basic theories, they are unable to effectively connect theory-technology-application when facing complex projects, resulting in the phenomenon of "understanding knowledge but not being able to apply it, and mastering skills but not being proficient", which cannot meet the actual needs of industrial practice and scientific research innovation [9]. In addition, problems such as insufficient practical teaching resources and the loose combination of experimental projects and industrial reality have further aggravated the disconnection between theory and practice.

2.3. Single and rigid teaching methods

Traditional teaching is still dominated by the cramming mode of teacher lecture and student listening, with insufficient interactivity and inquiry [10]. The teaching methods lack diversified design, and modern teaching methods such as case teaching, project-driven learning, and group collaboration are limited in application, which is difficult to stimulate students' willingness to learn actively. For abstract molecular mechanisms and technical processes such as gene expression regulation and vector construction, there is a lack of support from visual and immersive teaching methods, leading to students' difficulty in understanding and low learning interest [11].

2.4. One-sided and rigid evaluation system

The existing evaluation is mainly based on the final written examination results, focusing on the assessment of knowledge, memory, and basic skills, and lacking a comprehensive evaluation of scientific research thinking, innovation ability, and practical application ability. The evaluation dimension is single, and the proportion of process evaluation is insufficient, which makes it difficult to fully reflect students' learning process and comprehensive literacy, and cannot effectively guide students to transform from knowledge acquisition to ability improvement [12]. This one-sided evaluation method is not conducive to the cultivation of students' practical ability and innovative thinking, and is also inconsistent with the training objectives of applied talents in the biotechnology major.

3. Core ideas of teaching and research reform: Construction by integrating four dimensions

In response to the prominent problems in the current teaching of the genetic engineering course, taking the concepts of "student-centered, outcome-based education, and continuous improvement" as the core, this paper integrates four core dimensions: "AI Empowerment, Integration of Theory and Practice, Industry-Education Collaboration, and Literacy-Oriented Education", and incorporates specific teaching modes, practical mechanisms and evaluation methods to construct a systematic and all-round teaching and research reform plan [13], so as to realize the all-round improvement of course teaching quality and the accurate connection of talent training objectives.

3.1. AI empowerment: Technology-driven precision upgrading of teaching

Build an intelligent full-process teaching system with the help of AI technology to realize the precision and personalization of the teaching process [14]. On the one hand, build a dual-track platform of virtual simulation + data-driven, develop virtual simulation experiment systems for gene cloning, vector construction and other technologies by using AI technology, and solve the problems of expensive experimental consumables, high

operational risks and limited experimental conditions [15]; with the help of learning management systems such as Zhihuishu and Chaoxing, collect data such as students' pre-class preview duration, classroom interaction frequency and post-class homework completion quality, identify students' weak learning points through big data analysis, generate personalized learning paths and real-time feedback, and improve the pertinence of teaching [16]. On the other hand, introduce digital scientific research tools and integrated paper-digital textbook resources, integrate SnapGene software, Primer5 primer design tools, CRISPR-Cas9 target prediction tools and other resources into teaching, and combine the knowledge framework of paper textbooks with the interactive advantages of digital resources, allowing students to temper their core skills in a multi-dimensional learning environment and adapt to the digital trend of modern scientific research [17]. At the same time, innovate the AI-integrated teaching process, adopt the teaching method of knowledge graph and case-driven learning, clarify the knowledge correlation and learning objectives relying on the genetic engineering knowledge graph, introduce real scientific research case scenarios, organize peer learning to complete virtual simulation experiments, and form a closed-loop teaching mode of diagnosis-teaching-feedback-optimization.

3.2. Integration of theory and practice: Reconstructing a three-dimensional interactive teaching system

With the three-stage course content of basic, application and cutting-edge as the core, reconstruct a three-dimensional interactive teaching system of integrating theory and practice. The basic module focuses on core theoretical knowledge, takes the central dogma as the core, consolidates detailed knowledge points, and strengthens knowledge accuracy; the application module designs project-based tasks combined with the real needs of local industries and industry pain points such as biotechnological pharmacy, covering the whole process of literature research, experimental design, operation implementation and data processing, realizing the deep integration of theoretical knowledge and practical application; the cutting-edge module sets up special topics on the frontiers of genetic engineering, introduces cutting-edge technology cases such as base editing, single-cell sequencing and synthetic biology every week, explains technical principles and application prospects combined with the latest scientific research achievements through the form of "literature study-group report-teacher comment", and allows students to keep up with the disciplinary trends. At the same time, implement the "four-step scientific research teaching method", and integrate the cultivation of scientific research thinking into the whole teaching process through four links: knowledge teaching, thinking exercise, practical operation and feedback evaluation, so as to improve students' scientific research and practical ability.

3.3. Industry-education collaboration: Constructing a two-way empowerment practice mechanism

Build a diversified collaborative education platform of "universities-enterprises-research institutes-primary and secondary schools" to realize the deep integration and two-way empowerment of industry-education resources. For non-normal majors, implement the tripartite collaboration mode of "universities-enterprises-research institutes", jointly build genetic engineering practice bases and industrial colleges, and implement the "two-way employment" mechanism - enterprise technical backbones enter the university as practical tutors and jointly develop courses, and university teachers go deep into enterprises to participate in project research and development; introduce real enterprise projects, allow students to participate in the whole process of "demand analysis-scheme design-achievement transformation", and cultivate compound technical talents. Innovate the practice-driven mechanism, set up "Special Projects for Basic Education Teaching Reform" and "School-

Enterprise Collaborative Scientific Research Innovation Small Topics", guide students to participate in actual scientific research and teaching reform projects, and improve the transformation rate of practical achievements.

3.4. Literacy-oriented education: Improving the three-dimensional integrated education system

Taking the three-dimensional integration of "value shaping, ability training, and knowledge transmission" as the goal, integrate ideological and political elements and professional literacy cultivation into the whole teaching process. In terms of the integration of ideological and political elements, construct a curriculum ideological and political case database for genetic engineering, convey the craftsman spirit of perseverance and striving for perfection by introducing the scientific research experiences of scientists such as Gregor Mendel, Yuan Longping and Tong Dizhou; carry out special discussions on scientific ethics combined with cases such as gene editing ethics and academic fraud to strengthen the sense of social responsibility; introduce China's achievements in the Human Genome Project, hybrid rice, gene therapy and other fields to enhance national self-confidence. In terms of professional literacy cultivation, non-normal majors focus on scientific research integrity, experimental safety norms, industry quality standards and other content, and strengthen professional literacy through the assessment of experimental operation norms and the report of scientific research achievements; normal majors strengthen the cultivation of teachers' ethics and teaching sense of responsibility, and improve the ability of teaching design, classroom management and disciplinary knowledge transmission through "microteaching + classroom training + educational probation". At the same time, construct a multi-dimensional and three-dimensional evaluation system, adopt an evaluation structure of "knowledge (30%) + ability (40%) + literacy (30%)", covering multiple evaluation dimensions such as theoretical written examination, experimental operation, project design, scientific research report and teaching practice; the evaluation subjects are diversified, absorbing teachers, enterprise tutors, middle school instructors and students to participate in the evaluation together; implement value-added evaluation, comprehensively reflect the teaching effect through the comparative analysis of students' individual growth range by pre-test and post-test.

4. Expected effects of teaching reform

4.1. More solid and systematic mastery of knowledge by students

Through AI-empowered personalized teaching and the course system of integrating theory and practice, students can proficiently master the core theories of genetic engineering and cutting-edge technologies such as CRISPR-Cas9, and form a complete knowledge system of "basic-application-cutting-edge". Students' sensitivity to disciplinary development trends is significantly improved, and knowledge update keeps pace with industrial development and scientific research trends; their cross-disciplinary knowledge integration ability is enhanced, and they can flexibly use relevant knowledge, such as bioinformatics and nucleic acid chemistry to solve practical problems, and the depth and breadth of knowledge mastery are comprehensively improved.

4.2. Significant improvement of practical ability and innovative thinking

Relying on the industry-education collaboration platform and project-based practical teaching, students' experimental operation skills are more standardized and proficient; they can independently complete the design and implementation of complex projects, and the experimental success rate is increased by more than 30%. Scientific research thinking, critical thinking and innovation ability are effectively cultivated, the proportion of

students participating in the College Students' Innovation and Entrepreneurship Training Program and scientific research projects is increased from 30% to more than 60%, the number of academic achievements and awards in disciplinary competitions is significantly increased, and students can better adapt to the talent needs of the biotechnology industry and scientific research fields.

4.3. Comprehensive enhancement of teaching adaptability for normal majors

Through the UGS collaborative training mode and the double tutor system, the educational teaching ability of normal students is comprehensively improved. They can transform the genetic engineering disciplinary knowledge into basic education teaching content based on the UbD model, proficiently master core skills such as teaching design, classroom teaching and educational research, and the excellent rate of microteaching is increased from 50% to 80%. The performance in educational practice is more in line with the requirements of normal professional certification, the adaptation period of graduates after entering basic education positions is shortened, the employment competitiveness is significantly enhanced, and they can better meet the demand of basic education for high-quality biology teachers.

4.4. Comprehensive optimization of teaching quality and education effect

The attractiveness and effectiveness of course teaching are significantly improved, students' learning interest and active participation are obviously increased, and the frequency of classroom interaction is increased by more than 40%. The implementation of the multi-dimensional and three-dimensional evaluation system can effectively guide students to transform from knowledge acquisition to ability improvement and literacy cultivation. The demonstration and leading role of the genetic engineering course is highlighted, and its reform experience can provide reference for the teaching reform of other courses in the biotechnology major, promoting the continuous improvement of the talent training quality of the entire major.

5. Conclusion

The core goal of the teaching reform of the genetic engineering course is to stimulate students' internal learning motivation, promote the formation of scientific research and innovative thinking, and the continuous improvement of knowledge application and practical operation abilities, while adapting to the educational practice needs of normal majors. Through the four-dimensional integrated layout of AI empowerment, integration of theory and practice, industry-education collaboration, and literacy-oriented education, and with the help of teaching management tools such as data analysis, real-time feedback and resource integration of learning management platforms such as virtual simulation systems and Zhihuishu, the close combination of technology empowerment and teaching practice is realized, and a systematic teaching reform mode that emphasizes both teacher guidance and students' active participation is constructed. Teaching is a process of continuous evolution and improvement. Under the background of Internet + education, the introduction of digital scientific research tools and cutting-edge technology cases, the continuous optimization of course content and collaborative education mechanism, form a comprehensive teaching reform system centered on students and improved in the whole cycle, which effectively promotes students' systematic mastery of the core knowledge of genetic engineering, significantly improves students' scientific research and innovative thinking, and strengthens their practical operation and teaching transformation skills. With the advantages of digitalization and modern educational technology, the teaching reform team has fully stimulated students' enthusiasm in the learning process, thus improving the

teaching effect and cultivating high-quality professional talents adapted to industrial needs and basic education. The expected results of the teaching reform show that this four-dimensional integrated teaching reform mode has clear educational value, but in future educational practice, it is still necessary to continue to explore and optimize in combination with the cutting-edge development of disciplines and the needs of talent training.

Disclosure statement

The author declares no conflict of interest.

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