

Teaching Reform of the 'Synthetic Biology' Course for Postgraduates Based on OBE

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Abstract: Guided by Outcome-Based Education (OBE) principles, this study systematically investigates teaching reforms implemented in the postgraduate Synthetic Biology course. To address limitations including obsolete textbook content, insufficient alignment between case studies and practical applications, and unbalanced assessment criteria in conventional instruction, we implemented comprehensive reforms encompassing curricular content, instructional methodologies, and multifaceted evaluation systems. By integrating current research advances and application-oriented case studies, employing problem-based and case-driven instructional approaches, and implementing a holistic assessment framework comprising assignments, case analyses, seminar participation, and comprehensive examinations, these reforms significantly improved student engagement and innovative competencies. This study offers substantial support for developing high-caliber, interdisciplinary professionals.

Keywords: Outcome-Based Education (OBE); Synthetic Biology; Teaching Reform.

1. Introduction

Synthetic biology is an emerging interdisciplinary field that applies engineering principles to deconstruct biological systems into standardized, modular components and reassemble them to create novel biological systems or organisms with desired functions. Originating in the early 20th century, its modern conceptualization was established by Eric Kool in 2000. Initially driven by molecular biology breakthroughs, early research focused on designing biomacromolecules and genetic circuits. The field has since gained transformative momentum through deep integration with chemistry, bioinformatics, engineering, and physics, significantly expanding its research frontiers. Today, synthetic biology demonstrates profound potential across diverse sectors: biomedicine (e.g., advanced therapeutics), renewable energy (e.g., biofuel production), environmental protection (e.g., pollutant degradation), food technology (e.g., cultured meat), and agriculture (e.g., crop enhancement).

To keep pace with cutting-edge advancements and cultivate high-quality interdisciplinary talents that meet the demands of future technological development, thereby promoting the flourishing growth of national frontier biotechnology, an increasing number of universities are actively incorporating 'Synthetic Biology' courses into graduate programs (e.g., biotechnology, biopharmaceuticals, fermentation engineering) and related undergraduate education. However, given the notably interdisciplinary nature of synthetic biology and its status as an emerging discipline, teaching practices across institutions remain in a continuous phase of exploration and refinement. Domestic universities have consistently engaged in pedagogical research and reform regarding course content, teaching methodologies, and other aspects to better align with disciplinary development and talent cultivation requirements [1, 2].

With the deepening of China's educational reform, the problems in traditional education models - "emphasizing knowledge transmission while neglecting ability cultivation, prioritizing theoretical learning over practical application,

valuing conventional knowledge at the expense of innovative development, and focusing on campus-based learning while overlooking social practice" - have become increasingly evident. In this context, the introduction of the Outcomes-Based Education (OBE) concept holds significant practical importance for the development of China's educational undertakings.

Outcomes-Based Education (OBE), also known as result-oriented or output-oriented education, originated in the educational reforms of the United States and Australia [3]. In 1981, American scholar Spady first proposed this concept, which was soon widely regarded as the correct path to educational excellence and gained rapid attention and application. Spady's book *Outcome-Based Education: Critical Issues and Answers* provides an in-depth exploration of the OBE model, defining it as "clearly focusing and organizing the education system to ensure students gain the experiences necessary for substantial success in future life." The OBE philosophy drives transformation and restructuring of traditional education systems, emphasizing outcome-based value orientation, student-centered educational concepts, and a culture of continuous quality improvement. It shifts education from teacher-centered to student-centered approaches and from knowledge-focused systems to competency-based goals.

2. Problems in Traditional 'Synthetic Biology' Course Teaching

2.1. Obsolescence of Current Teaching Materials Relative to Disciplinary Advances

In 2020, Sichuan University of Science & Engineering introduced a synthetic biology course for graduate students in the biomedical program. At that time, there were very few available textbooks, so *Synthetic Biology* (2019) by Li Chun was selected as the primary teaching material. While this book covers fundamental knowledge and core concepts in

synthetic biology, its heavy theoretical focus—combined with the field's rapid advancement—has rendered some of its content and case studies outdated after just six years. Key recent developments, such as advances in the minimal genome project[4], the construction of single-chromosome yeast[5], further progress in CRISPR gene editing technology, and breakthroughs in artificial starch synthesis pathways, were not included in the 2019 edition.

2.2. Disconnection Between Case Studies and Reality

As a rapidly evolving discipline, synthetic biology demands case studies that reflect current breakthroughs. Yet, reliance on obsolete textbooks perpetuates outdated case studies, severing their connection to cutting-edge applications. Instructors seldom update materials to incorporate recent advances, leaving students disengaged. First, obsolete examples fail to convey the field's innovative spirit, dampening students' curiosity. Second, this disconnect denies students access to contemporary innovations, ultimately constraining their capacity for creative problem-solving.

2.3. Imbalanced Assessment Criteria

The current evaluation system excessively emphasizes the memorization of factual knowledge, while formative assessment indicators such as class participation, teamwork skills, and the quality of literature reviews are not incorporated into the final grading system. This fails to effectively guide the cultivation of students' innovative thinking and practical abilities.

3. Teaching Reform of 'Synthetic Biology' Based on OBE Concept

3.1. Content Development for Synthetic Biology

The rapid advancement of synthetic biology in China has catalyzed the publication of new educational resources. The *Synthetic Biology Series* (Science Press, 2024–2025), a 12-volume collection, comprehensively covers recent breakthroughs across energy, industrial synthesis, materials science, pharmaceutical synthesis, environmental applications, microbiome research, cell factory design, food biotechnology, agricultural synthesis, and ethical/legal considerations. These textbooks integrate both foundational theories and cutting-edge applications, including state-of-the-art case studies and technological innovations. By incorporating these materials, the teaching team ensures students acquire up-to-date scientific knowledge while remaining current with field advancements. This approach not only bridges the gap between theory and practice but also sparks students' passion for pioneering research.

In content reform, emphasis is placed on systematicity and cutting-edge relevance. First, a systematic teaching framework is established, building upon the foundations of molecular biology and genetics, then progressively introducing the design principles and applications of synthetic biology. The course covers key areas such as gene synthesis, standardization of biological parts, genetic circuit design, and biosystem synthesis, ensuring students gain a comprehensive understanding of both the scientific foundations and engineering applications of synthetic biology. To maintain the content's relevance to the forefront of the field, a dynamic updating mechanism is implemented to regularly integrate the

latest research literature and industry reports. This ensures students are exposed to the most recent developments and emerging trends in the discipline. For example, the teaching team carefully selects high-impact research findings from internationally renowned journals such as *Nature Chemical Biology* and seamlessly incorporates the latest advancements in synthetic biology into classroom instruction, keeping teaching content synchronized with the cutting edge of the field. Additionally, the course will pay special attention to innovative applications of synthetic biology in fields such as medicine, agriculture, and environmental science, as well as how it drives technological progress and industrial transformation in related sectors.

3.2. Adoption of Diverse Teaching Approaches

In our "Synthetic Biology" instruction, we actively explore student-centered teaching models. To address the limitations of traditional didactic methods in stimulating student engagement, we implement the following measures to emphasize student agency: By utilizing the university's online learning platform and communication tools like QQ groups, we provide comprehensive learning support including pre-class preparatory materials (e.g., case background knowledge), in-class interaction, and post-class reinforcement. The interactive features of "Rain Classroom" enable real-time monitoring of preparation status while facilitating extended online discussions and Q&A sessions after class. Furthermore, we actively implement collaborative learning models in which instructors design challenging problems beforehand and organize small study groups (3-5 members) for cooperative problem-solving and knowledge exploration. Through group project implementation and discussions, students not only deepen their understanding of specialized knowledge but also demonstrate significant improvement in teamwork and communication skills. Additionally, we have established a robust dynamic feedback mechanism that involves regular collection of student feedback and analysis of instructional data (including class participation rates and assignment quality), allowing for timely adjustments to teaching strategies.

Problem-based learning is a teaching model driven by questions, which guides students to transform from passive knowledge receivers to active thinkers and explorers by proposing key questions. In teaching the CRISPR/Cas9 gene editing technology, we meticulously designed a series of questions: First, students were asked to compare the fundamental differences in principles between the CRISPR/Cas9 system and traditional gene editing technologies such as ZFN and TALEN; second, they were required to analyze the advantages of CRISPR technology in terms of operational convenience, editing efficiency, and cost control; finally, they explored why this technology won the Nobel Prize in Chemistry within just seven years (2013-2020)[6]. Additionally, open-ended questions were set to discuss whether gene editing technology should be applied to human gene editing, as well as ethical issues in synthetic biology[7]. Students needed to consult literature to answer these questions, a process that not only effectively cultivated their autonomous learning abilities but also enhanced their critical thinking and ethical awareness.

Case-based teaching serves as a crucial pedagogical approach for understanding and applying synthetic biology theories. While this course primarily focuses on theoretical instruction, it emphasizes integrating theory with practice

through representative case studies. The course content carefully selects applications of synthetic biology across various fields, such as: - The biosynthesis of artemisinin in pharmaceuticals[8] - Engineered microorganisms for rapid conversion of lignocellulose to fermentable sugars in energy[9] - Representative cases in environmental protection and other domains Through analyzing these concrete cases, students gain profound insights into the practical value of synthetic biology theories. Teaching methods like group discussions and case presentations effectively enhance classroom engagement and interactivity.

3.3. Establishing a Diversified Teaching Evaluation System

Based on the OBE concept, this course has established a diversified teaching evaluation system that incorporates various assessment methods including regular assignments, case reports, classroom discussions, and final examinations to comprehensively evaluate students' learning outcomes. In the case study sessions, students are required to independently research literature before class, prepare PPT presentations, and systematically explain the core content in class. Instructors and fellow students then provide feedback and pose questions, fostering students' communication skills and critical thinking through such interactive approaches. The final examination adopts an open-book format, with a focus on assessing students' learning progress, comprehensive abilities, and innovative thinking. The essay questions specifically include exploratory, design-oriented, and comprehensive question types to thoroughly evaluate students' ability to flexibly apply knowledge. This diversified evaluation system not only comprehensively reflects students' learning achievements but also effectively motivates them to actively participate in classroom activities while enhancing their overall competencies.

4. Conclusion

Guided by the principles of Outcome-Based Education (OBE), this study has carried out comprehensive teaching reforms in the Synthetic Biology course, focusing on three key aspects: content optimization, pedagogical innovation, and assessment system refinement. The implemented reforms

have effectively stimulated students' learning motivation and autonomy, transforming their learning experiences into more active and engaging processes. These systematic improvements are expected to bring qualitative breakthroughs in Synthetic Biology education, ultimately cultivating interdisciplinary talents with the competencies needed to meet future technological challenges.

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