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Application of Blended Online-Offline PBL Teaching Model in Undergraduate Molecular Biology

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Abstract

Aiming at the challenges of abstract concepts and insufficient practical ability cultivation in undergraduate molecular biology teaching, this study adopted a cross-cohort continuous improvement design to compare the teaching effects between the traditional teaching cohort and the blended PBL teaching cohort of biotechnology majors. The PBL-cohort implemented a three-stage blended PBL model of "pre-class online exploration-in-class offline collaborative problem-solving - post-class practical extension", with targeted PBL questions designed around core modules. Results showed that the PBL-cohort achieved a significantly higher final exam score. Questionnaire surveys indicated that the PBL-cohort students perceived improved self-directed learning abilities, and recognized the model's value in knowledge application. Additionally, the pass rate of the subsequent Genetic Engineering course was also high in the PBL-cohort. In conclusion, the blended online-offline PBL model effectively enhances molecular biology teaching outcomes and provides an ethically compliant practical pathway for science curriculum reform.

Keywords

Blended Online-Offline; PBL; Molecular biology; Undergraduate teaching.

1. Introduction

Molecular biology serves as a core curriculum connecting basic biology and applied biotechnology, encompassing both microscopic mechanisms and cutting-edge technologies. The knowledge content covers the principles of genetic information transmission, regulation of gene expression, and mechanism of cutting-edge technologies， which are nonrepresentational and difficult to understand. In addition, the bridge between theoretical knowledge learning and the scientific practice is difficult to build. Traditional lecture-based learning (LBL) is difficult to solve these, which causes the lacking of ability to solve real-world problems (Yan et al., 2017). With the digital transformation of education, blended learning has emerged as an effective approach to address these limitations by combining the flexibility of online learning with the interactivity of offline instruction. In addition, problem-Based Learning (PBL)(Lian and He, 2013), centered on authentic problems, further drives students' active exploration and collaborative problem-solving, aligning well with the knowledge logic of molecular biology which integrates "theory-practice-application". \8

2. Teaching Design and Implementation

2.1. Research Objects and Baseline Calibration

The study included 38 students from the 2021 cohort (LBL-cohort) and 48 students from the 2022 cohort (PBL-cohort) majoring in biotechnology at a university. Both cohorts were taught

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by the same instructor using identical textbooks and bibliography. Baseline calibration using scores from the pre-requisite course Cell Biology showed no significant difference between the T-cohort (75.1±6.9) and I-cohort (74.8±7.1) (P>0.05), ensuring the validity of cross-cohort comparison.

2.2. PBL Model Optimization Based on T-Cohort Feedback

In response to the LBL-cohort's feedback, the PBL-cohort's blended PBL model was optimized in three key aspects. Firsty, addressing the LBL-cohort's weakness in practical application, "mechanism-application" dual-dimensional PBL questions were designed for six core modules. Secondly, to enhance autonomous learning, a three-stage closed-loop process which contains Pre-class online exploration, In-class offline collaboration and Post-class practical extension, was established. Finally, process evaluation (40%) was added, including online exploration quality, in-class participation, and practical outcomes, addressing the LBL-cohort's limitation of "examination-only assessment" (Rangachari, 2002).

2.3. Controlled Variables Between Cohorts

To ensure comparison validity, core variables were standardized: Firstly, both cohorts use the same instructor, textbook, and bibliography. Secondly, the difficulty of the final exam is the same (50 points for objective questions, 50 for subjective questions). In addition, both cohorts have consistent class hours (48 theory hours, 16 practical hours).

3. Cross-Cohort Comparison of Teaching Effects

Based on the previous data collection and student feedback, "mechanism-application" dual-dimensional PBL questions were designed for six core modules (Table 1).

Table 1. Part of the PBL questions used in this study

Course Module	Traditional Focus	PBL Question Design
DNA Replication	Replication process and enzyme functions	A patient with helicase mutation suffers from DNA replication arrest. Analyze the underlying mechanism and design a preliminary gene therapy protocol
Transcription	The process of transcription and the post-transcriptional processing	Analysis of the pathogenic causes of patients with early-onset Parkinson's disease caused by abnormal post-transcriptional processing
Translation	Translation of relevant biological macromolecules and translation processes	By analyzing the experimental evidence during the research process, the similarities and differences in the translation processes of prokaryotes and eukaryotes are compared.
Gene Expression Regulation	Promoter-transcription factor interaction	Design an experiment using the Luciferase reporter gene to verify the regulatory effect of a traditional Chinese medicine component on p53 gene expression in liver cancer cells
CRISPR-Cas9 Technology	Technical principles and procedures	Design a CRISPR-Cas9 strategy to edit the OsSWEET14 gene in rice for blast resistance while avoiding off-target effects
Experiments of molecular biology	The actual operations of different molecular biology experiments	Design experiments to analyze molecular phenotypes

3.1. Academic Performance and Subsequent Course Performance

Students in PBL-cohort showed a 2.5-fold increase in in-class interaction frequency compared to the LBL-cohort. Students posed more in-depth questionsand their experimental reports showed 40% improvement in protocol design completeness.

In order to investigate the impact of different teaching methods on students' mastery of knowledge, we collected the final exam scores of both cohort as well as the scores of the subjective and objective questions. As showed in Figure 1, the PBL-cohort showed significant advantages in subjective questions. For example, in the "gene therapy protocol design" question, the PBL-cohort students systematically elaborated the logic chain of "mutation mechanism - target selection - vector design", while LBL-cohort responses were limited to theoretical restatement.

In order to verify the impact of different teaching methods on students' subsequent knowledge acquisition, we also collected the follow-up Genetic Engineering course exam scores. In the Genetic Engineering course (a sequel to molecular biology), the PBL-cohort achieved a higher pass rate (95.8% vs. 86.7%) and significantly higher average score (80.2±6.3 vs. 73.1±7.4, $P<0.05$), demonstrating the long-term effectiveness of the blended PBL model.

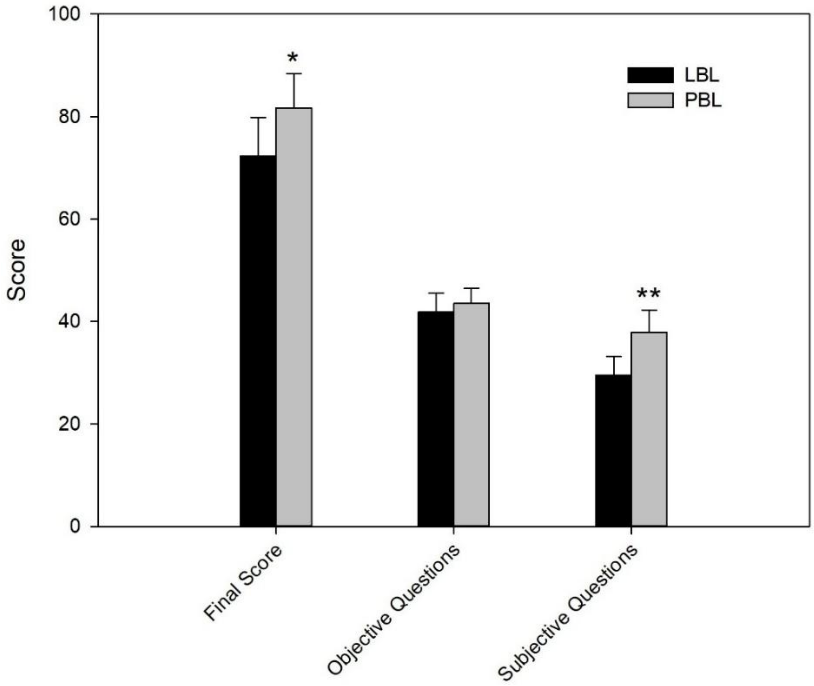

Figure 1. Final exam score of different corhort

3.2. Feedback and Ability Evaluation

In order to investigate students' evaluations of different teaching methods, we conducted a wide-ranging questionnaire survey. Both cohort have 100% response rate. For PBL-cohort, 87.5% reported the blended PBL model improved abilities in literature retrieval and problem analysis; 90.2% recognized that "blended online-offline learning makes abstract knowledge more comprehensible"; 79.2% desired this model in other courses. For LBL-corhort, 53.3% noted the lack of practical training in traditional teaching and 66.7% stated that "PBL would have facilitated better mastery of molecular biology applications".

4. Discussion

The blended online-offline PBL model with cross-cohort improvement design effectively addresses the pain points of traditional molecular biology teaching, enhancing students' knowledge application and autonomous learning abilities while avoiding ethical issues of

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concurrent controls. This model provides a replicable and ethically compliant solution for science curriculum reform, which can be further promoted in related courses such as genomics and biotechnology.

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