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ASSESSMENT OF THE EFFECTIVENESS OF MOLECULAR BIOLOGY METHODS IN LABORATORY SESSIONS FOR FOURTH-YEAR STUDENTS

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Summary

This study evaluates the effectiveness of molecular biology methods in laboratory sessions for fourth-year students. Molecular biology techniques, such as PCR, gel electrophoresis, gene cloning, and bioinformatics, are essential for understanding modern biological research. By integrating these methods into laboratory curricula, students gain hands-on experience that enhances their practical skills and conceptual understanding. This study examines the impact of molecular biology techniques on student engagement, comprehension, and performance. Through a combination of student surveys, quizzes, and experimental accuracy assessments, we analyze the benefits and challenges associated with implementing these methodologies in a laboratory setting. The findings highlight the positive impact of hands-on molecular biology training on student learning outcomes and suggest improvements for optimizing laboratory-based education. Ultimately, this research provides valuable insights into enhancing the effectiveness of molecular biology instruction and preparing students for future research and professional careers.

Keywords: *molecular biology, laboratory education, PCR, gel electrophoresis, bioinformatics, genetic analysis, educational technologies, students, practical skills*

Introduction. Molecular biology plays a fundamental role in modern life sciences, requiring hands-on experience for effective learning. Laboratory sessions provide an essential platform for students to develop practical skills and deepen their understanding of molecular techniques. The incorporation of molecular biology methods in education is crucial for bridging the gap between theoretical knowledge and real-world applications, preparing students for careers in research, medicine, and biotechnology [1].

Traditional biology education often focuses on memorization and theoretical concepts, which may limit students' ability to apply their knowledge in practical settings. By integrating molecular techniques into laboratory courses, students can develop a deeper appreciation for the scientific process and gain proficiency in techniques commonly used in research and industry [2]. Furthermore, hands-on training allows students to develop critical thinking skills, problem-solving abilities, and teamwork, which are essential for scientific inquiry and professional success [3, 4].

This study aims to assess the impact of using molecular biology methods in laboratory education for fourth-year students. We evaluate how exposure to advanced techniques, such as PCR, gel electrophoresis, and bioinformatics, influences students' engagement, learning outcomes, and preparedness for future scientific careers [5]. By analyzing student performance and feedback, this study seeks to identify best practices for improving laboratory-based biology education and ensuring that graduates are equipped with the necessary skills for modern biological research [6, 7].

Materials and methods. To evaluate the effectiveness of molecular biology methods, we conducted a study involving fourth-year biology students at a university laboratory setting. The study was structured around a series of laboratory sessions, each focusing on specific molecular biology techniques [8]. The participants were divided into groups, and each session included an introduction, hands-on experiments, data analysis, and discussion [9].

Participants: The study involved 50 fourth-year biology students enrolled in an advanced molecular biology course. The students were randomly assigned into

students were randomly assigned into groups to ensure equal exposure to different experimental conditions [10, 11].

Experimental Design: The laboratory sessions were designed to introduce students to key molecular biology techniques commonly used in research laboratories. The techniques included:

Polymerase Chain Reaction (PCR): Students extracted DNA from biological samples, designed primers, and performed PCR amplification. The reaction conditions and amplification results were analyzed using gel electrophoresis.

Gel Electrophoresis: Agarose gel electrophoresis was used to separate DNA fragments based on size. Students prepared gels, loaded DNA samples, and visualized results using UV transillumination.

Gene Cloning and Expression: Students cloned a target gene into a plasmid vector, transformed bacteria with recombinant DNA, and analyzed gene expression using selective media and protein assays.

Bioinformatics Tools: Computational tools such as BLAST and multiple sequence alignment software were used to analyze nucleotide and protein sequences. Students learned how to interpret sequencing data and predict functional regions of genes [12].

Next-Generation Sequencing (NGS) Analysis: Students were introduced to NGS principles and analyzed sample datasets to understand applications in genomics and transcriptomics.

Assessment Methods: The effectiveness of these laboratory techniques was evaluated using multiple assessment tools:

Pre- and post-laboratory quizzes to measure knowledge gains.

Lab reports assessing students' ability to document and interpret experimental results.

Student surveys collecting feedback on engagement, confidence levels, and perceived difficulty of the techniques [13,14].

Instructor observations to evaluate participation and problem-solving approaches.

Experimental accuracy assessment where the quality of student-generated data was compared to expected outcomes.

Data Analysis: Statistical analysis was performed on quiz scores, survey responses, and experimental accuracy assessments to determine the impact of molecular biology training on student learning outcomes. Comparative analysis was conducted between students with prior molecular biology experience and those without [15].

Results and discussion. The results of the study indicate a significant improvement in student learning outcomes after the implementation of molecular biology techniques in laboratory sessions. The data collected from quizzes, lab reports, and surveys were analyzed to assess the effectiveness of these methods.

Knowledge Gains: Pre- and post-laboratory quiz results showed a substantial increase in student knowledge across all molecular techniques. The average quiz scores improved from 58% (pre-test) to 85% (post-test), demonstrating a strong correlation between hands-on practice and conceptual understanding.

Table 1. Comparison of Pre- and Post-Laboratory Quiz Scores

Assessment Type	Average Score Before	Average Score After
PCR Quiz	60%	88%
Gel Electrophoresis Quiz	55%	82%
Cloning and Expression Quiz	57%	84%

Student Engagement and Confidence: Surveys indicated that 92% of students felt more confident in applying molecular techniques after laboratory training. Additionally, 85% of participants expressed increased interest in molecular biology-related careers.

Experimental Accuracy: The quality of student-generated data was assessed based on PCR band intensity, gel electrophoresis separation clarity, and cloning success rates. 78% of student experiments

yielded expected results, reflecting a high level of practical skill acquisition.

Challenges and Limitations: While the study revealed many benefits, certain challenges were identified. Some students reported difficulties in handling bioinformatics software, while others faced technical issues with laboratory equipment. Addressing these limitations through additional training and improved resources could further enhance the effectiveness of molecular biology education.

Table 2. Student Perceptions of Molecular Biology Laboratory Techniques

Technique	**Success Rate**
PCR	80%
Gel Electrophoresis	75%
Gene Cloning	78%

Conclusion. The findings of this study highlight the significant benefits of incorporating molecular biology techniques into laboratory education. Students demonstrated notable improvements in both theoretical understanding and practical application of key molecular methods, as evidenced by higher quiz scores, increased confidence in experimental techniques, and positive feedback on laboratory engagement. The hands-on experience provided by techniques such as PCR, gel electrophoresis, and bioinformatics not only reinforced students' comprehension of fundamental biological processes but also enhanced their problem-solving skills and critical thinking abilities.

Additionally, students expressed a greater interest in pursuing careers in molecular biology and biotechnology-related fields after engaging in laboratory sessions that emphasized modern techniques. This underscores the importance of practical training in shaping students' career aspirations and equipping them with skills relevant to contemporary research environments.

However, certain challenges remain, such as the need for improved access to high-quality laboratory equipment, more structured guidance for students unfamiliar with complex protocols, and the necessity of integrating computational biology tools more comprehensively into the curriculum. Addressing these issues through increased funding, improved instructional materials, and enhanced faculty support could further optimize the effectiveness of molecular biology education.

In conclusion, the integration of molecular biology methods into laboratory-based education is an invaluable approach to enhancing student learning outcomes and professional preparedness. Future research should focus on refining instructional strategies, exploring the long-term impact of laboratory training on career development, and identifying best practices for broader implementation of molecular techniques in undergraduate biology programs.

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Төртінші курс студенттері зертханалық сабақтарында биологияның молекулярлық әдістерін пайдалану тиімділігін бағалау

Аңдатпа

Бұл зерттеуде төртінші курс студенттерінің зертханалық сабақтарында молекулалық биология әдістерін пайдалану тиімділігі бағаланады. ПТР, гель-электрофорез, гендерді клондау және биоинформатика сияқты әдістер қазіргі заманғы биологиялық ғылымды түсінуде негізгі рөл атқарады. Бұл әдістерді зертханалық бағдарламаға біріктіру студенттерге практикалық тәжірибе алуға мүмкіндік береді, бұл олардың дағдыларын дамытуға және теориялық білімдерін тереңдетуге ықпал етеді. Зерттеуде молекулярлық әдістердің студенттердің қатысуына, олардың материалды түсінуіне және академиялық жетістіктеріне әсері талданады. Тиімділікті бағалау үшін студенттердің сауалнамалары, тесті-леу және эксперименттердің орындалу дәлдігін талдау пайдаланылды. Нәтижелер молекулалық әдістерді қолдана отырып зертханалық оқыту білім беру нәтижелеріне оң әсер ететінін және студенттердің кәсіби даярлығына ықпал ететінін көрсетеді. Зерттеу сондай-ақ молекулалық биологияны оқытуды одан әрі жетілдіру бойынша ұсынымдар ұсынады.

Түйінді сөздер: *молекулалық биология, зертханалық оқу, ПТР, гельдік электрофорез, биоинформатика, генетикалық талдау, білім беру технологиялары, студенттер, практикалық дағдылар*

Материал баспаға 21.11.24 түсті

Оценка эффективности использования молекулярных методов биологии на лабораторных занятиях у студентов четвертого курса

Аннотация

В данном исследовании оценивается эффективность использования методов молекулярной биологии на лабораторных занятиях у студентов четвертого курса. Такие методы, как ПЦР, гель-электрофорез, клонирование генов и биоинформатика, играют ключевую роль в понимании современной биологической науки. Интеграция этих методов в лабораторную программу позволяет студентам получить практический опыт, что способствует развитию их навыков и углублению теоретических знаний. В исследовании анализируется влияние молекулярных методов на вовлеченность студентов, их понимание материала и академические достиже- ния. Для оценки эффективности были использованы опросы студентов, тестирование и анализ точности выполнения экспериментов. Результаты показывают, что лабораторное обучение с применением молекулярных методов положительно влияет на образовательные результаты и способствует профессиональной подготовке студентов. Исследование также предлагает рекомендации по дальнейшему совершенствованию преподавания молекулярной биологии.

Ключевые слова: *молекулярная биология, лабораторное обучение, ПЦР, гель-электрофорез, биоинформатика, генетический анализ, образовательные технологии, студенты, практические навыки*

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Conflict of interest. The authors declare no conflict of interest.