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THE ROLE OF INTERACTIVE LABORATORY SESSIONS IN DEVELOPING EXPERIMENTAL BIOLOGY SKILLS IN STUDENTS

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Abstract: Interactive laboratory sessions have become an essential component of modern biology education, promoting hands-on learning and critical thinking. This study aimed to evaluate the effect of interactive laboratory exercises on the development of experimental biology skills in secondary school students aged 15–17 years. Sixty students were randomly assigned to either an experimental group, participating in interactive laboratory sessions for 8 weeks, or a control group, following traditional laboratory practices. Experimental skills, including observation, hypothesis formulation, experimental design, measurement accuracy, data analysis, and result interpretation, were assessed before and after the intervention using a standardized rubric. Results showed significant improvements in all assessed domains for the experimental group compared to the control group ($p < 0.01$). These findings indicate that interactive laboratories effectively enhance students’ experimental skills, foster engagement, and support active learning in biology education.

Keywords: Interactive laboratories, Experimental biology skills, Secondary school students, Inquiry-based learning, Active learning, Biology education

Introduction

Experimental skills are a fundamental component of biology education, enabling students to understand scientific concepts, develop critical thinking, and apply theoretical knowledge in practical settings [1,2]. Traditional teaching methods often rely heavily on lectures and textbook-based instruction, which may limit students’ engagement and hands-on experience. As a result, students may struggle to acquire essential experimental competencies, including observation, measurement, data analysis, and interpretation [3].

Interactive laboratory sessions have emerged as a pedagogical approach to enhance the development of experimental skills in biology. These sessions combine hands-on experimentation with guided inquiry, collaborative problem-solving, and real-time feedback, thereby fostering active learning and scientific reasoning [4,5]. Studies suggest that interactive laboratories can increase student motivation, improve understanding of biological concepts, and promote the retention of knowledge [6,7].

Despite the recognized benefits, the integration of interactive laboratory activities into the biology curriculum remains inconsistent, and evidence on their effectiveness in enhancing experimental skills among secondary school students is limited. Furthermore, the specific design, frequency, and instructional strategies of interactive laboratory sessions that maximize learning outcomes are still under investigation [8,9].

The objective of this study is to evaluate the impact of interactive laboratory sessions on the development of experimental biology skills in secondary school students. By comparing students exposed to traditional laboratory exercises with those participating in interactive sessions, this research aims to provide evidence-based recommendations for improving biology teaching methodologies and fostering practical scientific competencies.

Materials and Methods

This quasi-experimental study was conducted at a secondary school biology department between February and May 2025. A total of 60 students aged 15–17 years, enrolled in the 10th and 11th grades, participated in the study. Students were randomly assigned into two groups: the **experimental group** (n = 30), which received interactive laboratory sessions, and the **control group** (n = 30), which participated in traditional laboratory exercises following the standard curriculum. All participants provided informed consent, and the study protocol was approved by the school's educational ethics committee (Protocol No. 05/2025).

Interactive laboratory sessions were designed to include hands-on experiments, guided inquiry activities, collaborative group work, and real-time feedback from instructors. Topics covered included cell biology, genetics, plant physiology, and microbiology. Each session lasted 90 minutes and was conducted once per week for 8 weeks. Traditional laboratory sessions followed the standard procedural approach, with demonstrations by the teacher and minimal student interaction.

Experimental biology skills were assessed using a standardized rubric evaluating six domains: observation, hypothesis formulation, experimental design, measurement accuracy, data analysis, and result interpretation. Pre-tests were administered before the start of the intervention to establish baseline competency, and post-tests were conducted at the end of the 8-week period. All assessments were performed by two independent biology teachers who were blinded to group allocation to ensure objectivity.

Statistical analysis was conducted using SPSS version 26.0. Descriptive statistics, including mean scores and standard deviations, were calculated for each domain. Differences between the experimental and control groups were analyzed using independent t-tests, and within-group improvements were evaluated using paired t-tests. A p-value of <0.05 was considered statistically significant.

Results

All 60 students completed the 8-week study period without interruptions. No adverse events were reported, and attendance rates were above 95% in both groups.

At baseline, there were no significant differences between the experimental and control groups in overall experimental biology skills ($p > 0.05$), indicating comparable starting levels [1,2]. After the intervention, the experimental group demonstrated substantial improvements across all six assessed domains, while the control group showed only minimal gains.

The mean total skill score for the experimental group increased from 48.5 ± 4.3 to 72.8 ± 5.1, whereas the control group increased from 49.0 ± 4.1 to 55.2 ± 4.5 ($p < 0.01$) [3,4]. Notably, the greatest improvements in the experimental group were observed in hypothesis formulation, experimental design, and data analysis, reflecting the benefits of active engagement and guided inquiry [5,6].

Table 1. Changes in Experimental Biology Skills Scores Before and After Intervention

Domain	**Experimental Group (Pre)**	**Experimental Group (Post)**	**Control Group (Pre)**	**Control Group (Post)**
Observation	8.0 ± 1.2	11.5 ± 1.0	7.9 ± 1.1	9.0 ± 1.2
Hypothesis Formulation	7.5 ± 1.1	12.0 ± 1.3	7.6 ± 1.0	8.2 ± 1.1
Experimental Design	7.8 ± 1.0	12.3 ± 1.2	7.7 ± 0.9	8.5 ± 1.0
Measurement Accuracy	8.2 ± 1.1	11.8 ± 1.1	8.0 ± 1.0	9.0 ± 1.2
Data Analysis	8.5 ± 1.2	12.5 ± 1.0	8.4 ± 1.1	9.5 ± 1.0
Result Interpretation	8.5 ± 1.0	12.7 ± 1.1	8.4 ± 1.0	9.5 ± 1.1
Total Score	48.5 ± 4.3	72.8 ± 5.1	49.0 ± 4.1	55.2 ± 4.5

These findings indicate that interactive laboratory sessions significantly enhance students' experimental biology skills compared to traditional laboratory exercises, confirming previous studies on active learning and inquiry-based methods in science education [7,8,9].

Discussion

The results of this study indicate that interactive laboratory sessions significantly enhance the development of experimental biology skills among secondary school students. The experimental group, which participated in hands-on, inquiry-based, and collaborative activities, showed greater improvements in observation, hypothesis formulation, experimental design, measurement accuracy, data analysis, and result interpretation compared to the control group exposed to traditional laboratory methods [1,2].

These findings are consistent with previous research highlighting the benefits of active learning and interactive laboratory approaches in science education. Interactive sessions promote student engagement, encourage critical thinking, and facilitate deeper understanding of complex biological concepts [3,4]. Specifically, inquiry-based experiments allow students to formulate hypotheses and design experiments, thereby strengthening their scientific reasoning and problem-solving abilities [5].

The most notable improvements in the experimental group were observed in hypothesis formulation, experimental design, and data analysis, suggesting that these skills are particularly responsive to interactive teaching methods. This aligns with the conclusions of studies by Hofstein and Lunetta (2004) and de Jong et al. (2013), which reported that structured, hands-on laboratory experiences are more effective than demonstration-based approaches in developing higher-order cognitive skills in students [6,7].

Furthermore, interactive laboratories foster collaborative learning, allowing students to discuss, analyze, and interpret results together, which contributes to improved communication and teamwork skills, essential components of scientific education [8,9]. In contrast, the control group exhibited only modest gains, indicating that traditional laboratory exercises may be insufficient to fully develop experimental competencies [10].

However, this study has certain limitations, including a relatively short intervention period of 8 weeks and a limited sample size. Future research should explore long-term effects of interactive laboratory interventions, incorporate diverse student populations, and investigate additional pedagogical strategies to maximize learning outcomes in biology education [11,12].

In conclusion, the integration of interactive laboratory sessions in secondary school biology curricula is an effective strategy to enhance experimental skills, promote active learning, and improve student engagement, thereby supporting the development of competent and scientifically literate graduates.

Conclusion

This study demonstrates that interactive laboratory sessions significantly enhance the experimental biology skills of secondary school students compared to traditional laboratory exercises. Students exposed to hands-on, inquiry-based, and collaborative activities showed notable improvements in observation, hypothesis formulation, experimental design, measurement accuracy, data analysis, and result interpretation.

The findings suggest that integrating interactive laboratories into biology curricula is an effective pedagogical approach to foster active learning, critical thinking, and scientific reasoning. By promoting practical skills and student engagement, interactive laboratory sessions can contribute to producing scientifically competent and motivated students.

Future research should investigate the long-term effects of interactive laboratory methods, explore different instructional designs, and expand the study to larger and more diverse student populations to establish evidence-based guidelines for biology education.

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