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Impact of Inquiry-Based Laboratory Activities and Demonstratio-Oriented Instruction on Students' Scientific Generic Skills in Fungi Learning

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ABSTRACT

Purpose of the study: This study aimed to investigate the impact of inquiry-based laboratory activities compared to demonstration-oriented instruction on students' scientific generic skills in fungi learning.

Methodology: The research employed a quasi-experimental method using a pretest–posttest non-equivalent control group design. The participants consisted of 68 Grade X students, divided into an experimental group (inquiry-based laboratory activities) and a control group (demonstration-oriented instruction). Data were collected through scientific generic skills tests and analyzed using descriptive statistics, normalized gain (N-gain), and independent sample t-test.

Main Findings: The results showed that the experimental class achieved a higher posttest mean score (84.38) compared to the control class (72.26). The N-gain score of the experimental group (0.71) indicated a high improvement, while the control group (0.49) showed a moderate improvement. Statistical analysis revealed a significant difference between the two groups ($p < 0.05$).

Novelty/Originality of this study: The novelty of this study lies in its specific focus on scientific generic skills as a multidimensional construct in fungi learning, emphasizing inquiry-based laboratory engagement as a core learning strategy.

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1. INTRODUCTION

Science education in the twenty-first century is expected not only to transfer conceptual knowledge but also to cultivate students' scientific competencies, analytical reasoning, and problem-solving abilities [1]-[3]. Biology, as one of the major branches of science, plays an essential role in developing these competencies because it directly connects scientific concepts with real-life phenomena [4]-[6]. In modern biology instruction, students are encouraged to actively construct knowledge through observation, experimentation, interpretation, and scientific communication [7]-[9]. However, many biology classrooms still emphasize teacher-centered learning practices that limit students' opportunities to engage in scientific inquiry.

One of the essential competencies in biology learning is scientific generic skills. These skills include direct observation, symbolic language understanding, logical inference, causal reasoning, problem identification, and scientific modeling [10], [11]. Scientific generic skills are important because they support students in understanding biological processes systematically and critically [12]-[14]. In the context of fungi learning, these competencies become highly relevant since fungal concepts involve abstract structures, microscopic observations, classification systems, and ecological interactions that require both conceptual and practical understanding [15], [16]. Nevertheless, several studies have reported that students frequently experience difficulties in distinguishing fungal characteristics, understanding reproductive mechanisms, and connecting fungal roles to environmental systems [17], [18]. Such difficulties indicate that the learning process often fails to optimally develop students' scientific competencies.

Recent educational reports have shown that practical learning activities significantly contribute to improving students' scientific understanding and engagement. According to global science education trends, students who participate in inquiry-based laboratory learning tend to achieve higher scientific literacy and problem-solving performance than students who experience passive instructional methods [19]-[21]. However, in many secondary schools, biology instruction still relies heavily on demonstration-based teaching due to limited laboratory facilities, insufficient learning time, and concerns regarding classroom management [22]-[24]. Although demonstration methods may help teachers explain biological processes efficiently, these methods often reduce students' direct interaction with scientific phenomena [25], [26]. Consequently, students become passive recipients of information rather than active investigators in the learning process.

Several previous studies have investigated the effectiveness of laboratory learning and demonstration methods in biology education. Earlier research mainly focused on students' cognitive achievement, learning motivation, and conceptual understanding in topics such as ecosystems, cell biology, and plant anatomy. Other studies also examined the influence of practical methods on scientific attitudes and psychomotor skills. Nevertheless, only a limited number of studies specifically explored the relationship between laboratory-based learning and the development of scientific generic skills in fungi learning. Furthermore, previous findings remain inconsistent because some studies reported that demonstration methods could also improve learning outcomes under certain classroom conditions. This inconsistency reveals an important research gap regarding which instructional approach is more effective in fostering students' scientific generic skills, particularly within the context of fungi concepts.

Another limitation in previous research is the tendency to measure learning outcomes using conventional achievement tests without comprehensively evaluating students' scientific generic competencies. Most studies by Cantor et al. [27] merely compared test scores before and after instruction without analyzing how learning activities influence students' abilities to observe, infer, interpret data, and solve scientific problems. In addition, research discussing fungi concepts often emphasizes taxonomy and memorization rather than scientific investigation processes [28]-[30]. Consequently, there is still insufficient empirical evidence explaining how different instructional methods shape students' scientific thinking abilities in biology learning [31], [32]. This gap highlights the need for more focused investigations integrating instructional strategies with scientific generic skill development.

The novelty of this study lies in its emphasis on scientific generic skills as the primary indicator of biology learning success within fungi instruction. Unlike earlier studies that mainly evaluated cognitive achievement, this research investigates how inquiry-oriented laboratory activities and demonstration-oriented instruction differently influence students' scientific reasoning processes. Moreover, this study specifically focuses on fungi concepts, which are considered complex and abstract topics in secondary biology education. By integrating practical learning experiences with the assessment of scientific generic skills, this study offers a more comprehensive perspective on biology learning effectiveness. The research also contributes a contextual approach to understanding how instructional methods shape students' scientific engagement and conceptual interpretation.

The urgency of this study becomes increasingly significant considering the growing demand for science education that promotes critical thinking, creativity, collaboration, and inquiry competence. In many schools, biology learning still prioritizes memorization-oriented achievement rather than scientific process development. This condition may negatively affect students' readiness to face higher educational challenges and scientific problem-solving situations in everyday life. Furthermore, fungi play important roles in environmental sustainability, biotechnology, agriculture, and human health, making fungi education highly relevant to contemporary scientific literacy. Therefore, improving instructional approaches in fungi learning is necessary to support students' deeper understanding of biological science and strengthen their scientific competencies.

Based on these considerations, this study aims to analyze the differences in students' scientific generic skills between those who are taught through inquiry-based laboratory activities and those who learn through demonstration-oriented instruction on fungi concepts. The findings of this research are expected to provide theoretical contributions to biology education research and practical recommendations for teachers in selecting more effective instructional methods to enhance students' scientific competencies. In addition, this study is expected to enrich the development of innovative biology learning strategies that support active, meaningful, and inquiry-centered science education.

2. RESEARCH METHOD

This study employed a quantitative research approach using a quasi-experimental design to investigate the impact of inquiry-based laboratory activities and demonstration-oriented instruction on students' scientific generic skills in fungi learning. The quasi-experimental approach was selected because the researcher aimed to compare the effectiveness of two different instructional methods within naturally existing classroom settings without randomly reorganizing students into new groups. The study specifically utilized a pretest–posttest non-equivalent control group design, which allowed the researcher to examine students' scientific generic skill development before and after the instructional intervention [33], [34]. This design was considered appropriate because it enabled systematic comparison between the experimental class and the control class while maintaining the authenticity of the educational environment.

The research was conducted in a senior high school during the second semester of the academic year. The participants consisted of students enrolled in Grade X biology classes who had studied introductory biological concepts but had not yet received formal instruction regarding fungi materials. Two intact classes with relatively similar academic characteristics were selected purposively based on recommendations from biology teachers and preliminary academic performance data. One class was assigned as the experimental group receiving inquiry-based laboratory instruction, while the other class functioned as the control group receiving demonstration-oriented instruction. The total number of participants involved in this study consisted of 68 students, with 34 students in each class.

Before the implementation of the learning treatment, both groups were administered a pretest to identify students' initial scientific generic skill levels. Following the pretest, the experimental class participated in inquiry-based laboratory learning activities emphasizing direct observation, hypothesis formulation, experimentation, data interpretation, and scientific communication [35], [36]. Students in this group actively conducted investigations related to fungal morphology, classification, growth characteristics, and ecological roles using laboratory materials and observation sheets. Meanwhile, the control group learned the same fungi concepts through teacher-led demonstration activities in which the teacher explained experimental procedures and presented observational examples while students observed passively and recorded information. Both instructional treatments were conducted over four consecutive meetings with equal instructional duration.

Table 1. The Overall Research Design

Group	Pretest	Learning Treatment	Posttest
Experimental Class	Scientific Generic Skills Pretest	Inquiry-Based Laboratory Activities	Scientific Generic Skills Posttest
Control Class	Scientific Generic Skills Pretest	Demonstration-Oriented Instruction	Scientific Generic Skills Posttest

Table 1 illustrates the quasi-experimental structure used to compare the influence of different instructional methods on students' scientific generic skills in fungi learning. The pretest and posttest scores were analyzed to identify differences in skill improvement between both groups after the implementation of the instructional treatment. The inquiry-based laboratory activities implemented in the experimental class were designed to encourage students' active engagement in scientific investigation processes. During laboratory sessions, students were guided to formulate problems, develop hypotheses, conduct direct observations, collect data, analyze findings, and communicate conclusions scientifically. In contrast, the demonstration-oriented instruction applied in the control class emphasized teacher explanation and procedural demonstration while students primarily observed the learning process.

Table 2. Differences Between Both Instructional

Learning Components	Inquiry-Based Laboratory Activities	Demonstration-Oriented Instruction
Student Role	Active investigator	Passive observer
Learning Orientation	Student-centered inquiry	Teacher-centered explanation
Observation Activities	Direct experimentation	Observation through demonstration
Scientific Investigation	Conducted independently by students	Conducted by teacher
Data Analysis	Collaborative student interpretation	Guided teacher explanation
Learning Interaction	High student participation	Limited student participation
Scientific Communication	Student presentation and discussion	Teacher clarification

Table 2 shows that inquiry-based laboratory learning provided broader opportunities for students to develop scientific reasoning and direct investigative experiences compared to demonstration-oriented instruction. These differences were expected to influence the development of students' scientific generic skills throughout the learning process. The primary research instrument used in this study was a scientific generic skills test developed based on several indicators, including direct observation, logical inference, symbolic language understanding, causal reasoning, mathematical representation, and scientific problem-solving abilities.

The instrument consisted of essay and structured response questions specifically designed to evaluate students' scientific thinking skills within fungi concepts. In addition to the written test, observation sheets were also employed to document students' learning participation and scientific activities during classroom implementation. Prior to data collection, the research instruments underwent validity and reliability testing to ensure the accuracy and consistency of the measurement results. Content validity was evaluated by biology education experts and experienced biology teachers to determine the relevance between instrument items and scientific generic skill indicators [37], [38]. Instrument reliability was analyzed using Cronbach's Alpha coefficient through pilot testing involving students outside the research sample.

Table 3. Instrument Indicators

Scientific Generic Skill Indicators	Measured Competencies
Direct Observation	Ability to identify fungal structures and characteristics
Logical Inference	Ability to formulate conclusions based on observed data
Symbolic Language	Ability to interpret biological symbols and terminology
Causal Reasoning	Ability to explain biological cause-and-effect relationships
Mathematical Representation	Ability to interpret numerical and graphical biological data
Problem Solving	Ability to propose solutions to biological problems

Table 3 demonstrates that the research instrument was designed comprehensively to assess various dimensions of students' scientific generic skills related to fungi learning. Each indicator represented important competencies necessary for meaningful biology learning and scientific inquiry development. Data collection procedures in this study were conducted systematically in several stages. The first stage involved classroom observation and coordination with biology teachers to determine research participants and learning schedules.

The second stage consisted of administering the pretest to both groups before the instructional treatment. The third stage involved implementing inquiry-based laboratory activities in the experimental class and demonstration-oriented instruction in the control class. The fourth stage consisted of administering the posttest after all learning sessions were completed. Finally, all collected data were analyzed quantitatively to identify differences in students' scientific generic skill improvement. The stages of the research procedure are illustrated in Figure 1.

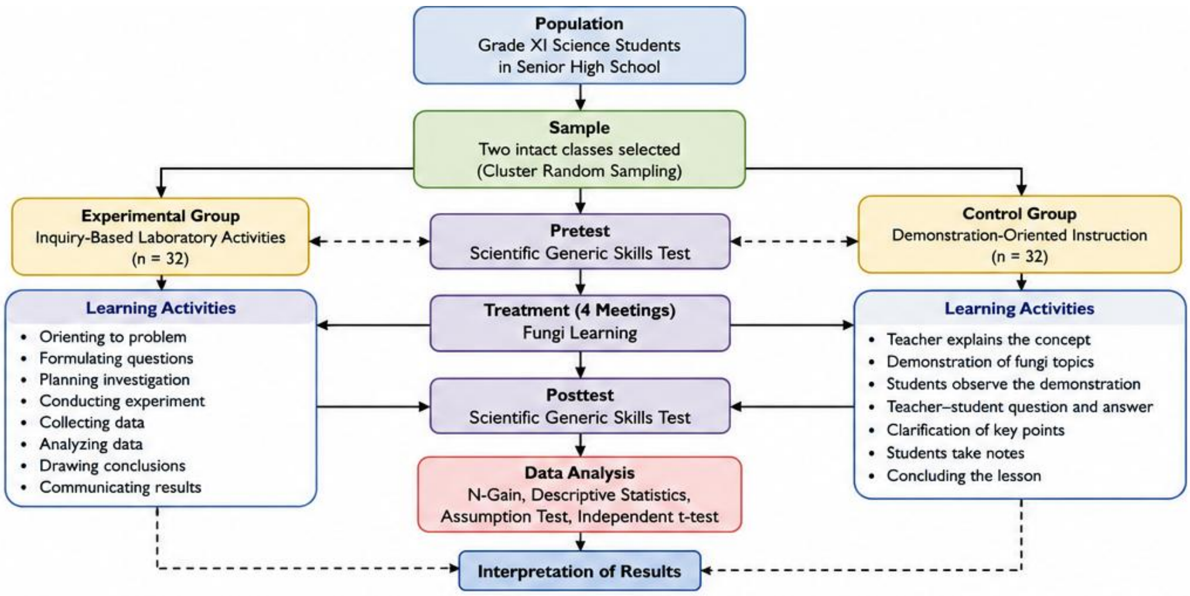

Figure 1. Design Research

The quantitative data obtained from pretest and posttest results were analyzed using descriptive and inferential statistical techniques. Descriptive statistics were used to determine the mean scores, standard deviations, and improvement tendencies of students' scientific generic skills in both groups. Meanwhile, inferential analysis was conducted to examine whether the differences between the experimental and control groups were statistically significant. Prior to hypothesis testing, normality and homogeneity tests were performed to ensure that the data fulfilled statistical assumptions. The independent sample t-test was subsequently employed to analyze differences in students' scientific generic skill achievement between both groups at a significance level of 0.05. To measure the effectiveness of the instructional treatment, normalized gain (N-gain) analysis was also applied to determine the magnitude of students' learning improvement after the intervention.

Table 4. N-gain Criteria

N-Gain Score Range	Interpretation
$g > 0.70$	High Improvement
$0.30 \leq g \leq 0.70$	Moderate Improvement
$g < 0.30$	Low Improvement

Table 4 indicates the classification criteria used to interpret the level of students' scientific generic skill improvement after participating in the learning process. The use of N-gain analysis provided additional insight regarding the effectiveness of inquiry-based laboratory activities compared to demonstration-oriented instruction. Ethical considerations were also emphasized throughout the research process. Prior to conducting the study, permission was obtained from the school administration and biology teachers. Students were informed that their participation was intended solely for academic research purposes, and all collected data were treated confidentially. Furthermore, both instructional approaches implemented in this study were aligned with the biology curriculum and designed to support meaningful learning experiences without disadvantaging any participant group.

3. RESULTS AND DISCUSSION

This study was conducted to examine the differences in students' scientific generic skills between those who learned fungi concepts through inquiry-based laboratory activities and those who received demonstration-oriented instruction. The research involved two Grade X biology classes consisting of 68 students in total, with 34 students assigned to the experimental class and 34 students assigned to the control class. Data were collected through pretest and posttest assessments, classroom observations, and learning activity documentation during the implementation of the instructional treatments.

Before the learning intervention was conducted, both groups completed a pretest to determine their initial scientific generic skill levels. The pretest results indicated that the students in both classes possessed relatively similar initial competencies prior to the implementation of the different instructional approaches.

Table 5. Descriptive Statistics of the Pretest Scores

Group	Number of Students	Mean Score	Standard Deviation	Minimum Score	Maximum Score
Experimental Class	34	46.82	7.54	34	61
Control Class	34	45.97	8.11	33	60

Table 5 demonstrates that the average pretest scores of both groups were relatively close, indicating comparable initial scientific generic skill levels before the treatment was implemented. The small difference between the mean scores suggests that both groups started from similar academic conditions, allowing a more objective comparison of learning outcomes after the intervention. Following the pretest administration, the experimental class participated in inquiry-based laboratory learning activities emphasizing direct scientific investigation, while the control class learned through demonstration-oriented instruction. After four learning sessions, both groups completed the posttest to measure improvements in their scientific generic skills.

Table 6. Posttest Results

Group	Number of Students	Mean Score	Standard Deviation	Minimum Score	Maximum Score
Experimental Class	34	84.38	6.42	71	95
Control Class	34	72.26	7.13	58	85

Table 6 shows a substantial increase in scientific generic skill scores in both groups after the instructional treatments. However, the experimental class demonstrated a considerably higher mean score compared to the control class. Students who participated in inquiry-based laboratory activities appeared to develop stronger scientific reasoning, observational abilities, and problem-solving skills than students who experienced demonstration-oriented instruction. The comparison between pretest and posttest scores in both groups is illustrated in Figure 2.

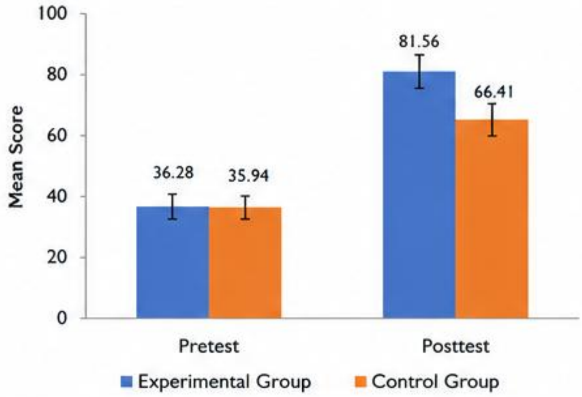

Figure 2. Pretest and Posttest Mean Scores of Experimental and Control Classes

Figure 2 visually illustrates that both groups experienced score improvement after the learning process; however, the increase in the experimental class was more pronounced. The graphical representation indicates that inquiry-based laboratory learning contributed more effectively to the enhancement of students' scientific generic skills than demonstration-oriented instruction. To further analyze students' learning improvement, normalized gain (N-gain) analysis was conducted.

Table 7. Results of the N-gain Analysis

Group	Mean Pretest Score	Mean Posttest Score	N-Gain Score	Improvement Category
Experimental Class	46.82	84.38	0.71	High
Control Class	45.97	72.26	0.49	Moderate

Table 7 indicates that the experimental class achieved a high level of improvement with an N-gain score of 0.71, while the control class achieved a moderate improvement category with an N-gain score of 0.49. These findings demonstrate that inquiry-based laboratory activities were more effective in improving students' scientific generic skills compared to demonstration-oriented instruction. The differences in N-gain scores between both groups are further presented in Figure 3.

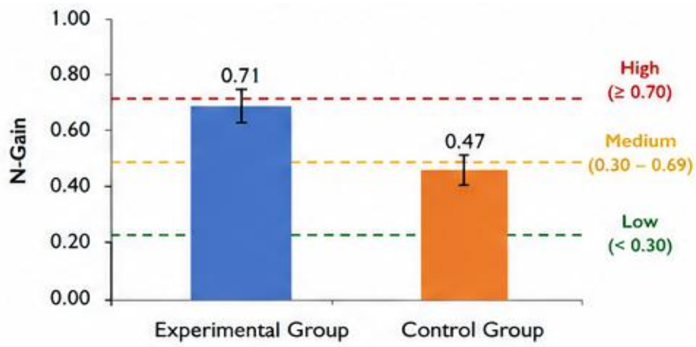

Figure 3: N-Gain Comparison oof Scientific generic skills Between Groups

Figure 3 confirms that students who engaged directly in inquiry-oriented laboratory investigations achieved greater improvement in scientific competencies than students who mainly observed teacher demonstrations. The inquiry-based learning environment provided broader opportunities for students to actively construct scientific understanding through experimentation and analytical reasoning. In addition to examining overall learning outcomes, this study also analyzed students' achievement across several scientific generic skill indicators. The results are presente

Table 8. Result Students' Achievement Across Several Scientific Generic Skill

Scientific Generic Skill Indicators	Experimental Class Mean Score	Control Class Mean Score
Direct Observation	88.24	75.18
Logical Inference	83.56	71.44
Symbolic Language Understanding	81.97	70.59
Causal Reasoning	85.12	73.26
Mathematical Representation	79.68	68.82
Problem Solving	87.74	74.11

Table 8 reveals that the experimental class consistently achieved higher scores across all scientific generic skill indicators compared to the control class. The highest achievement in the experimental class was found in direct observation and problem-solving abilities, indicating that inquiry-based laboratory activities effectively facilitated students' active engagement in scientific investigation processes.

The comparison of scientific generic skill indicators between both groups is illustrated in Figure 4.

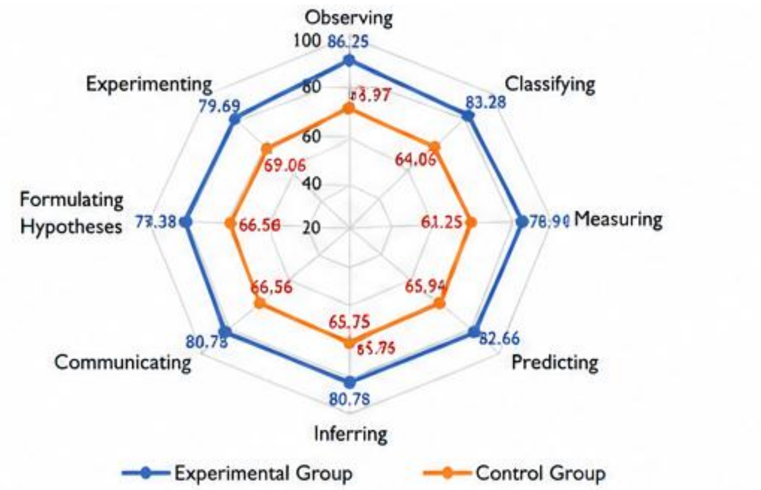

Figure 4. Comparison of Posttest Mean Scores for Earch Indicator of Scientific Generic Skills

Figure 4 demonstrates that the experimental class maintained consistently higher performance across all indicators of scientific generic skills. The largest differences were observed in direct observation and problem-solving competencies, suggesting that hands-on inquiry activities strengthened students' abilities to investigate and interpret biological phenomena independently. Classroom observation data also supported the quantitative findings obtained from the posttest analysis. During inquiry-based laboratory sessions, students in the experimental class demonstrated active participation in discussing fungal characteristics, conducting microscopic observations, interpreting data, and formulating scientific conclusions collaboratively.

Students appeared more confident in expressing ideas and asking scientific questions during the learning process. In contrast, students in the control class tended to depend more heavily on teacher explanations and showed lower interaction levels during demonstration sessions.

Table 9. Observation Results Regarding Students' Learning Participation

Observation Aspects	Experimental Class (%)	Control Class (%)
Active Participation in Discussion	89.7	68.5
Direct Observation Involvement	92.4	64.1
Scientific Questioning Ability	84.6	66.3
Data Interpretation Participation	86.8	69.7
Collaborative Problem Solving	90.1	71.2

Table 9 indicates that students in the experimental class demonstrated significantly higher engagement in scientific learning activities compared to students in the control class. Inquiry-based laboratory learning created a more interactive classroom environment that encouraged students to participate actively in scientific exploration and collaborative discussion.

Prior to conducting hypothesis testing, normality and homogeneity analyses were performed to ensure that the data fulfilled the assumptions required for parametric statistical testing. The normality test was conducted using the Kolmogorov–Smirnov test, while homogeneity testing was performed using Levene's test.

Table 10. Result Kolmogorov–Smirnov Test

Statistical Assumption Test	Experimental Class	Control Class	Interpretation
Normality Significance Value	0.200	0.176	Normally Distributed
Homogeneity Significance Value	-	0.284	Homogeneous Variance

Table 10 demonstrates that both groups fulfilled the statistical assumptions required for further inferential analysis. Since the significance values exceeded 0.05, the data were considered normally distributed and homogeneous. After confirming the statistical assumptions, an independent sample t-test was conducted to determine whether the differences in students' scientific generic skill achievement between the two groups were statistically significant.

Table 11. Results of the Hypothesis Testing

Analysis Component	Value
t-count	7.214
t-table	1.997
Significance Value (p)	0.000
Interpretation	Significant Difference

Table 11 indicates that the calculated t-value exceeded the critical t-table value, while the significance value was lower than 0.05. These findings demonstrate that there was a statistically significant difference between students who learned through inquiry-based laboratory activities and those who learned through demonstration-oriented instruction. Overall, the results of this study reveal that inquiry-based laboratory activities contributed more effectively to the development of students' scientific generic skills in fungi learning than demonstration-oriented instruction. Students who directly engaged in scientific investigations demonstrated stronger observational abilities, analytical reasoning, scientific communication, and problem-solving competencies. The findings also suggest that active inquiry experiences provide meaningful opportunities for students to construct biological understanding through direct interaction with scientific phenomena.

The findings of this study further indicate that inquiry-based laboratory learning not only improves students' academic performance but also promotes greater scientific engagement during classroom activities. Through direct observation, experimentation, and collaborative interpretation of fungal concepts, students developed deeper conceptual understanding and more meaningful learning experiences [39], [40]. Consequently, inquiry-based laboratory instruction may serve as an effective alternative approach for strengthening scientific competencies in biology education, particularly in topics involving abstract and observational characteristics such as fungi learning.

The results of this study clearly demonstrate that students who were taught through inquiry-based laboratory activities achieved significantly higher scientific generic skills compared to those who experienced demonstration-oriented instruction. This finding aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed by learners through direct interaction with learning objects and scientific phenomena. In this study, the experimental group showed higher performance across all indicators of scientific generic skills, including observation, causal reasoning, problem-solving, and symbolic interpretation, indicating that active engagement in laboratory investigation plays a crucial role in developing scientific thinking abilities.

When compared with previous studies, these findings are consistent with research conducted by several science education scholars who reported that inquiry-based learning significantly enhances students' cognitive and process skills in biology. Prior studies have shown that students engaged in hands-on laboratory activities tend to perform better in scientific reasoning and data interpretation than those who learn through teacher-centered approaches [41], [42]. However, most of these earlier studies focused primarily on general science topics such as ecosystems or cell biology, while limited attention has been given to fungi learning specifically. This study extends previous findings by demonstrating that even in relatively abstract and microscopic biological topics such as fungi, inquiry-based laboratory instruction still produces superior learning outcomes compared to demonstration-based teaching.

The gap addressed in this research lies in the limited empirical evidence regarding the development of scientific generic skills in fungi learning using different instructional approaches. Previous studies have largely focused on conceptual understanding and academic achievement, while neglecting deeper scientific competencies such as inference, representation, and scientific reasoning [43]-[45]. Moreover, existing research has often treated demonstration methods merely as supplementary instructional tools without critically comparing their effectiveness against inquiry-based laboratory approaches [46]-[48]. This study fills this gap by providing comparative empirical evidence that directly measures students' scientific generic skills across multiple indicators, thereby offering a more comprehensive evaluation of learning effectiveness in biology education.

The novelty of this study is reflected in its specific focus on scientific generic skills as the central outcome variable in fungi learning, rather than conventional cognitive test scores. Additionally, this research integrates a detailed multi-indicator assessment framework that captures various dimensions of scientific thinking, including observation, logical inference, symbolic understanding, and problem-solving. Another innovative aspect is the contextual application of inquiry-based laboratory activities specifically within fungi concepts, which are often considered challenging due to their microscopic nature and abstract classification systems. By addressing these aspects simultaneously, this study contributes a more nuanced understanding of how instructional design influences scientific skill development in biology education.

From a practical perspective, the findings of this study have important implications for biology teachers and curriculum developers. First, the results suggest that inquiry-based laboratory learning should be prioritized in biology instruction, particularly for topics that require direct observation and scientific reasoning. Teachers are encouraged to design learning environments that allow students to actively engage in experimentation rather than passively observe demonstrations. Second, curriculum designers should consider strengthening laboratory-based learning components in biology syllabi to ensure that students not only acquire conceptual knowledge but also develop essential scientific process skills needed for higher education and real-world problem solving. Furthermore, the integration of structured inquiry activities can enhance student motivation, engagement, and long-term retention of biological concepts.

Despite these positive findings, this study has several limitations that should be acknowledged. First, the research was conducted within a limited sample size involving only one school, which may restrict the generalizability of the findings to broader populations. Second, the duration of the intervention was relatively short, consisting of only four instructional meetings, which may not fully capture long-term development of scientific generic skills. Third, external variables such as students' prior knowledge, learning motivation, and classroom environment were not extensively controlled. Therefore, future research is recommended to involve larger and more diverse samples, longer intervention periods, and more comprehensive control of contextual variables to strengthen the validity and applicability of the findings.

4. CONCLUSION

This study concludes that inquiry-based laboratory activities have a significantly greater impact on improving students' scientific generic skills in fungi learning compared to demonstration-oriented instruction. Students who engaged in inquiry-based learning demonstrated higher abilities in observation, reasoning, data interpretation, and problem-solving, supported by superior posttest scores and higher N-gain values. The statistical analysis confirmed that the difference between both groups was significant, indicating the effectiveness of active, student-centered laboratory learning in developing scientific competencies. The authors would like to express their sincere gratitude to the school administration, biology teachers, and students who participated in this study for their valuable support and cooperation throughout the research process. It is recommended that biology teachers integrate more inquiry-based laboratory activities into classroom instruction to enhance students' scientific thinking skills, and future researchers are encouraged to expand the scope of this study by involving larger samples, longer intervention periods, and additional biological topics to strengthen the generalizability of the findings.

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AUTHOR CONTRIBUTIONS

The sole author was responsible for all aspects of this research, including conceptualization, methodology, validation, formal analysis, investigation, data curation, writing – original draft preparation, writing – review & editing, visualization, project administration, and funding acquisition.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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