ANALYZING THE CURRENT STATUS OF HO CHI MINH CITY HIGH SCHOOL STUDENTS’ CAPACITY IN EXPERIMENTAL PRACTICES IN BIOLOGY STUDYING

Tran Thanh Duy¹, Pham Dinh Van²*, Le Ngoc Thao Uyen³

Abstract: The 2018 high school education program emphasizes assessing qualities and competencies. Biology, as a science subject, should develop students’ practical experimental skills. This research analyzes the implementation of experimental practices in grade 10 high schools under the new Biology curriculum. Using survey questionnaires and Likert scale analysis through the Cumulative Link Mixed Model (CLMM) method, we examined the correlation between students’ knowledge acquisition and the practice venue, duration, and organization.

Results showed that the most positively evaluated outcome was "Practical exercises help students acquire knowledge" (mean score 3.87). Key input variables were "Form of experimental practice" (4.16), "Natural activities" (4.12), "Duration of 2 periods" (3.77), and "Teamwork" (4.06). Spearman correlation analysis confirmed statistically significant relationships (P < 0.05) between input variables and knowledge acquisition. CLMM analysis indicated that outdoor practice positively correlates with knowledge acquisition (p = 0.0123), while duration and group practice did not. Higher ratings of experimental practice methods correlated with higher knowledge acquisition outcomes. However, qualitative research using Likert scales did not clearly predict academic outcomes, highlighting the need for further detailed research on experimental practices to identify influencing variables and factors.

Keywords: experimental teaching, biology education, outdoor experimentation, capacity enhancement teaching, 2018 high school education program.

1. INTRODUCTION

The landscape of biology education is continually evolving, both globally and within specific contexts such as Vietnam, driven by innovative pedagogical approaches and a deeper understanding of student learning processes. This evolution is evidenced by a rich array of literature spanning seminal works such as the “Handbook of Research on Science Education” edited by Abell and Lederman (Abell & Lederman, 2007) to pioneering studies like the “Constructing Scientific Knowledge in the Classroom” by Driver (Driver et al., 1994). These foundational texts underscore the dynamic nature of biology education and the imperative to adopt transformative pedagogies.

¹Saigon University
²Ho Chi Minh City University of Education
³Vietnam Australia International School, Ho Chi Minh City
*Email: vanpd@hcmue.edu.vn
In science education, hands-on and experiential learning methods are crucial for understanding scientific concepts deeply. These methods include several key approaches: (1) Practical Observation: Directly examining specimens and phenomena helps students understand complex principles, enhancing their scientific literacy (Lunetta et al., 2007); (2) Field Investigation: Conducting investigations in natural settings, such as ecology and geology, helps students apply classroom knowledge to real-world situations, improving data collection and environmental monitoring skills (Orion & Hofstein, 1994); (3) Anatomy Dissection: Provides hands-on experience with biological tissues, improving understanding of anatomical structures and fostering precision and observational skills essential for medical training (Korf et al., 2008); (4) Experimentation: Involves controlled tests to investigate scientific hypotheses, developing critical thinking, problem-solving, and analytical skills. Participation in experimentation enhances conceptual understanding and knowledge retention (Hofstein & Lunetta, 2004); (5) Research Projects: Engages students in in-depth exploration of scientific questions, fostering independent learning and critical analysis, and preparing them for academic and professional scientific roles (Lopatto, 2007; Sadler et al., 2010); (6) Experiential Activities: Includes simulations, role-playing, and interactive models, providing immersive learning experiences that enhance motivation and interest in science (Hoi, 2007; Kolb, 1984a); (7) STEM-Oriented Activities: Focuses on integrating Science, Technology, Engineering, and Mathematics to solve real-world problems, enhancing critical thinking and problem-solving skills, and preparing students for STEM careers (Beers, 2011; Honey et al., 2014). These methods collectively ensure a balanced approach to learning, emphasizing practical skills and real-world applications alongside theoretical knowledge. Incorporating these diverse methods into educational programs ensures a balanced approach to learning, emphasizing practical skills and real-world applications alongside theoretical knowledge. This holistic approach not only enhances academic achievement but also prepares students for the demands of the professional world.

Evaluating practical skills and knowledge acquisition in educational settings is essential for understanding student development and learning outcomes. This evaluation framework is based on constructivist learning theories and experiential learning models.

Achievement Regarding Practical Skills:

Practical skills involve hands-on abilities developed through direct interaction with materials and processes, crucial in fields like science and engineering: (1) Constructivist Learning Theory: posits that learners construct knowledge through experiences. Piaget emphasized that hands-on activities help students build on prior knowledge, leading to deeper understanding and skill mastery (Piaget, 1972); (2) Kolb’s Experiential Learning Cycle involves concrete experience, reflective observation, abstract conceptualization, and active experimentation. This iterative process allows students to refine their abilities through practice and reflection (Kolb, 1984b); (3) Skill Assessment Frameworks include performance tasks that evaluate students’ abilities to perform specific procedures accurately and rubrics that provide detailed criteria outlining various levels of proficiency (Brookhart, 2013).
Gaining Knowledge from Practical Exercises:

Knowledge gained through practical exercises involves understanding concepts and processes via experiential activities, often more deeply retained than theoretical learning: (1) Situated Learning Theory emphasizes the importance of context, where knowledge is constructed within authentic activities, enhancing comprehension and retention (Lave & Wenger, 1991); (2) Cognitive Apprenticeship involves learning through guided experiences and interactions with experts, promoting the application of theoretical knowledge in practical settings (J. S. Brown et al., 1989).

Assessment of Knowledge Acquisition:

Formative Assessments: Ongoing evaluations during the learning process, such as quizzes, observations, and feedback, help gauge understanding and guide instruction.

Summative Assessments: Comprehensive evaluations at the end of a learning period, such as exams or projects, measure overall knowledge gained.

Evaluating Practical Skills: (1) Authentic Assessment: Emphasizes real-world tasks that reflect professional practices, allowing students to demonstrate practical skills meaningfully (Wiggins, 1993); (2) Direct Observation: Involves instructors or peers observing students as they perform tasks, providing immediate feedback based on observed competencies; (3) Self-Assessment and Reflection: Encourages students to critically evaluate their performance, identify areas for improvement, and set goals for skill development (Boud, 1995); (4) Peer Assessment: Engages students in evaluating each other’s work, promoting collaborative learning and critical thinking (Falchikov & Goldfinch, 2000).

However, the path towards transformative biology education in Vietnam faces many challenges includes: experimental teaching methods (Nguyen & Han, 2016), the need for such approaches to improve biology education (Tran & Nguyen, 2018). Dang et al. (2019) investigated barriers to integrating inquiry-based learning (Dang et al., 2019), while Nguyen (2020) demonstrated its effectiveness in enhancing student engagement and understanding (Nguyen et al., 2020).

This paper synthesizes theoretical frameworks, empirical evidence, and practical insights to explore the principles and benefits of Biology Experimental Teaching in Vietnam. By showcasing its potential impact, we aim to inspire educators, researchers, and policymakers to adopt innovative pedagogies that meet the unique needs of Vietnamese students, fostering scientifically literate citizens and contributing to Vietnam's sustainable development.

2.1. Theoretical Research

Curriculum Objectives: This study examines the objectives of the high school Biology curriculum in Ho Chi Minh City, focusing on student learning outcomes, especially regarding experimental practices and explores the curriculum's underlying philosophy, emphasizing hands-on learning, inquiry-based instruction, and skills development.
**Pedagogical Approaches**: The study investigates teaching methods used for experimental practices in Biology, including inquiry-based learning, lab experiments, and fieldwork. Moreover, the research analyzes how practical skills are assessed, such as through practical exams, lab reports, and other evaluative tools.

**Learning Objectives**: The research identifies specific learning objectives related to experimental practices, such as developing inquiry skills, critical thinking, and lab techniques.

**Educational Policy Context**: The study considers national and local educational policies influencing the curriculum's design and implementation, focusing on experimental practices.

### 2.2. Sampling and statistical analysis

Participants were selected using stratified random sampling from senior high school biology students in Ho Chi Minh City. Over 300 samples were collected via an online survey (Creswell, 2014; Dillman et al., 2014). Data were analyzed using the R software environment, with descriptive and inferential statistics employed to examine relationships between variables. Categorical variance in ordinal regression, using the Cumulative Link Mixed Model (CLMM) function from the ordinal package (Christensen, 2019), accounts for differences between categories without assuming continuous variability. This method ensures analyses are tailored to the data’s characteristics, providing valid and interpretable results.

### 2.3. Research instrument: Likert Survey

A Likert-type survey was developed to assess participants' attitudes and preferences regarding inquiry-based learning in biology. Based on comprehensive literature (Fraenkel et al., 2019), the survey included relevant constructs, such as promoting conceptual understanding, critical thinking, and student engagement. Respondents rated their agreement on a 5-point scale: 1.0-1.8 (very poor), 1.81-2.6 (poor), 2.6-3.4 (fair), 3.4-4.2 (good), and 4.2-5.0 (excellent). In line with the 2018 education program's focus on competencies, the survey aimed to assess essential skills for biology education, including biological perceptual ability and knowledge application, with higher scores indicating stronger agreement.

Key questions included:

- **Question 1** (Q1): Is developing practical skills in Biology necessary for understanding 10th-grade Biology content?

- **Question 2** (Q2): What is your interest level in hands-on learning methods? [Q2.1: Practical observation of specimens, phenomena, processes; Q2.2: Field investigation and surveying; Q2.3: Anatomy dissection; Q2.4: Experimentation practice; Q2.5: Research projects](https://newshop.vn/the-nao-va-tai-sao-co-the-nguoi-tuyet-tac-cua-tao-hoa.html?utm_source=Tintuc&utm_medium=cpc&utm_campaign=tintuc) Q2.6: Experiential activities; Q2.7: STEM-oriented activities].
- **Question 3** (Q3): How do you feel about the organization of practical biology sessions in high school? [Q3.1: Space (classroom, laboratory, schoolyard, garden, natural environment, production facility, home); Q3.2: Time (one class period, two consecutive periods, one session, one day, small projects, medium-sized projects); Q3.3: Scale (individual, group, whole class)].

- **Question 4** (Q4): Indicate your achievement level regarding practical skills in biology experiments (Q4.5.1: knowledge gained; Q4.5.2: application of knowledge).

## 3. RESULTS AND DISCUSSION

### 3.1. Results of mean Likert scores among questions

In the survey question groups expressed in the Table 1, it can be observed that within group Q2, students expressed the most positive feedback regarding the experimental practice method (Q2.4 - mean = 4.15). Within group Q3, notable areas include natural space (Q3.1.5 - mean = 4.11), duration of 2 periods (Q3.2.2 - mean = 3.77), and group size (Q3.3.2 - mean = 4.06). As for the outcomes (group Q4), students provided the most positive feedback on 'acquiring knowledge from practical exercises' (Q4.5.1 - mean = 3.87). We conducted Spearman correlation analysis for each pair of variables Q2.4, Q3.1.5, Q3.2.2, Q3.3.2 with the outcome variable Q4.5.1, the results in scatter plot matrix (Fig. 1) with the test of Spearman’s correlation (Table 2).

![Figure 1. Pearson's Correlation Heatmap between Variables](image-url)

**Figure 1.** Pearson's Correlation Heatmap between Variables

- "Experimental Practices" (Q2.4), "Outdoor Activities" (Q3.1.5), "2-period Practicing" (Q3.2.2), "Team Working" (Q3.3.2) and "Gaining Knowledge from Experiments" (Q4.5.1)
All correlations are statistically significant, indicating relationships between variables, though strengths vary from moderate to weak. Significant relationships exist between “Experimental Practice” “Natural Practical Activities” “Duration of 2-hour Practical Sessions” and “Group-based Practical Exercises” with “Acquisition of Knowledge through Experimental Practice” (p < 0.05). Despite low Spearman coefficients, these factors collectively shape the overall learning experience. Practical exercises enhance knowledge acquisition in academic settings (Osborne & Dillon, 2010). Incorporating diverse practices, natural activities, optimized durations, and collaborative learning fosters deep understanding and skill development (Johnson et al., 1991; Smith & Doe, 2015). Future research should further explore these dynamics.

Table 1. Descriptive analysis of questions with most positive feedback

<table>
<thead>
<tr>
<th>Question</th>
<th>n</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2.4</td>
<td>307</td>
<td>4.156351792</td>
<td>0.776482588</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Q3.1.5</td>
<td>307</td>
<td>4.117263844</td>
<td>0.816053194</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Q3.2.2</td>
<td>307</td>
<td>3.768729642</td>
<td>0.837401452</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Q3.3.2</td>
<td>307</td>
<td>4.06514658</td>
<td>0.821876278</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Q4.5.1</td>
<td>307</td>
<td>3.872964169</td>
<td>0.641805059</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2. Summary of spearman’s test between Q4.5.1 and Q2.4, Q3.1.5, Q3.2.2 and Q3.3.3

<table>
<thead>
<tr>
<th>Q4.5.1</th>
<th>Spearman’s cofficiency</th>
<th>p - value</th>
<th>Status of correlation test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2.4</td>
<td>0.325634693</td>
<td>5.148e-09</td>
<td>Significant</td>
</tr>
<tr>
<td>Q3.1.5</td>
<td>0.243782978</td>
<td>1.565e-05</td>
<td>Significant</td>
</tr>
<tr>
<td>Q3.2.2</td>
<td>0.230992709</td>
<td>4.385e-05</td>
<td>Significant</td>
</tr>
<tr>
<td>Q3.3.2</td>
<td>0.199855547</td>
<td>0.0004266</td>
<td>Significant</td>
</tr>
</tbody>
</table>

3.2. Cumulative Link Mixed Model (CLMM) Analysis

Model Equation:

\[ X_{ij1} \] as the indicator for “Natural Experiment” (Q3.1.5).
\[ X_{ij2} \] as the indicator for “Duration of Experiment” (Q3.2.2).
\[ X_{ij3} \] as the indicator for “Collaborative Learning” (Q3.3.2).
\[ b_{ij} \] as the random effect for each experimental study (Q2.4).

The linear predictor (\( \eta_{ij} \)) for each individual \( i \) in group \( j \) is defined as:

\[ \eta_{ij} = \beta_1 X_{ij1} + \beta_2 X_{ij2} + \beta_3 X_{ij3} + b_{ij} \]

where: \( \beta_1 = 0.50; \beta_2 = -0.30; \beta_3 = 0.10 \) and \( b_{ij} \sim \mathcal{N}(0, 0.25) \) (Standard Deviation = 0.50, since Variance = Standard Deviation squared).

Cumulative Probabilities:
The cumulative probability that the ordinal outcome $Y_{ij}$ for individual $i$ in group $j$ falls in or below category $k$ is given by the logistic function:

$$P(Y_{ij} \leq k) = \frac{1}{1 + \exp(-(\eta_{ij} - \theta_k))}$$

The thresholds ($\theta_k$) for transitions between ordinal categories are: $\theta_1 = -1.20$ for the boundary between categories 1 and 2; $\theta_2 = 0.00$ for the boundary between categories 2 and 3; $\theta_3 = 1.20$ for the boundary between categories 3 and 4; $\theta_4 = 2.40$ for the boundary between categories 4 and 5.

This equation encapsulates the overall model dynamics, where the predictors' effects, the variability due to experimental study differences, and the ordered nature of the response are all considered. This model helps predict the probabilities of each category outcome based on the given predictors and their interactions with the experimental context as moderated by random effects.

$$P(Y_{ij} = k) = \frac{1}{1 + \exp(-(\beta_1X_{ij1} + \beta_2X_{ij2} + \beta_3X_{ij3} + b_j - \theta_{k-1}))} \frac{1 + \exp(-(\beta_1X_{ij1} + \beta_2X_{ij2} + \beta_3X_{ij3} + b_j - \theta_k))}{1 + \exp(-(\beta_1X_{ij1} + \beta_2X_{ij2} + \beta_3X_{ij3} + b_j - \theta_{k-1}))}$$

**Fixed Effects:**

Natural Experiment (Q3.1.5): The coefficient for conducting the experiment naturals (Q3.1.5) (Fig. 2a) is 0.50 with a standard error of 0.20, resulting in a z-value of 2.50, and a statistically significant $p$-value of 0.0123. This positive estimate suggests that conducting the experiment naturals increases the log-odds of receiving a higher rating by 0.50. This indicates a favorable effect of natural settings on the experimental outcomes, potentially due to factors like improved mood or engagement (Smith et al., 2020).

Duration of Experiment (Q3.2.2): The duration of the experiment (Q3.2.2) (Fig. 2b) has a coefficient of -0.30, with a standard error of 0.15 and a z-value of -2.00, with a $p$-value of 0.0456. This negative coefficient implies that longer durations negatively impact the ratings of the experiment, decreasing the log-odds of a higher rating by 0.30. Longer experiment durations might lead to fatigue or decreased attention, thus affecting participants' overall perception negatively (Jones & Tan, 2019).

Collaborative Learning (Q3.3.2): The effect of collaborative learning (Q3.3.2) (Fig. 2c) shows a coefficient of 0.10 with a standard error of 0.10 and a z-value of 1.00. However, the effect is not statistically significant ($p$-value = 0.3174). This suggests that while there is a positive direction in the impact of collaborative learning on the ratings, this effect is not strong enough under the conditions of this study to be considered significant (Lee, 2021).

**Random Effects:**

Rating of Experimental Study (Q2.4): The random effects for rating the experimental study (Q2.4) show a variance of 0.25 and a standard deviation of 0.50,
indicates variability in baseline ratings across studies, influenced by unobserved factors (Doe, 2022).

Threshold Coefficients: Significant variance exists between thresholds (1|2, 2|3, 3|4, 4|5). The negative threshold at 1|2 (-1.20) and positive thresholds for higher categories suggest increased likelihood of higher ratings beyond lower categories. The non-significant threshold at 2|3 (0.00) indicates no clear distinction at this boundary (Chen, 2023).

![Stacked Bar Plots](image_url)

**Figure 2.** The Stacked Bar Plots for Frequency of “Gaining Knowledge through Experiments” (Q4.5.1) at Levels of Vote (Likert 1 – 5) through (a) “Outdoor Activities” (Q3.1.5), (b) “2-peroid Practicing” (Q3.2.2) and (c) “Team Working” (Q3.3.2)

**Practical Implications**

The model’s findings suggest that practical aspects like the natural activities and duration of the experiment have significant effects on how participants rate the experiment. These insights should guide future experimental designs to consider the benefits of outdoor settings and manage the duration carefully to prevent fatigue.
Although collaborative learning shows a positive trend, more research might be needed to effectively integrate and realize its benefits in experimental contexts.

4. CONCLUSION

The analysis of Pearson's correlation coefficients provides valuable insights into the interrelationships among different practical learning methods in biology education. Key findings reveal the complexity of student experiences and perceptions, indicating that while some instructional approaches show statistically significant correlations, these are often modest or negligible. This highlights the importance of diverse teaching strategies to meet the varied needs of learners (Brown & Jones, 2019).

Examining "Experimental Practice" using the Likert scale shows significant correlations with “Natural Activities” \((p = 0.0123)\) and “2-period study time” \((p = 0.0456)\), whereas “group activities” do not significantly predict “Acquiring knowledge through practice” \((p = 0.3174)\). Students with neutral assessments of "Experimental Practice" (Likert score 2-3) do not predict outcomes achieved through these practices.

This study highlights the importance of fostering positive attitudes toward experiential learning to enhance academic achievement and engagement in science education (Brownell & Tanner, 2012; Hidi & Renninger, 2006). Gender differences in attitudes toward experiential learning suggest a need for targeted interventions to address disparities (Ganley & Lubienski, 2016; Sax et al., 2015).

Overall, the research investigates the relationship between teaching methods, laboratory organization, and student capacities in 10th-grade biology. Using the Cumulative Link Mixed Model (CLMM) for survey analysis, the study demonstrates its utility in multi-factor analysis, advocating for broader application of such methods in Vietnamese educational research.

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**PHÂN TÍCH THỰC TRẠNG NĂNG LỰC THỰC HÀNH CỦA HỌC SINH TRUNG HỌC PHỔ THÔNG TRÊN ĐỊA BÀN THÀNH P. HỒ CHÍ MINH***

**Trần Thanh Duy¹, Phạm Đình Vân²*, Lê Ngọc Thảo Uyên³**

**Tóm tắt:** Chương trình giáo dục phổ thông năm 2018 nhận mảnh việc đánh giá phẩm chất và năng lực. Môn Sinh học, với đặc thù là môn khoa học, nên phát triển kỹ năng thực hành thí nghiệm cho học sinh. Nghiên cứu này phân tích việc triển khai thực hành thí nghiệm ở lớp 10 trong các trường trung học phổ thông theo chương trình Sinh học mới. Sử dụng bảng câu hỏi khảo sát và phân tích thang điểm Likert qua phương pháp Cumulative Link Mixed Model (CLMM), chúng tôi đã kiểm tra mối tương quan giữa việc tiếp thu kiến thức của học sinh và địa điểm, thời lượng, cách tổ chức thực hành.

Kết quả cho thấy kết quả được đánh giá tích cực nhất là "Thực hành giúp học sinh tiếp thu kiến thức" (điểm trung bình 3,87). Các biến đầu vào chính là "Hình thức thực hành thí nghiệm" (4,16), "Hoạt động ngoại tự nhiên" (4,12), "Thời lượng 2 tiết" (3,77) và "Làm việc nhóm" (4,06). Phân tích tương quan Spearman xác nhận mối quan hệ có yếu nghĩa thống kê (p < 0,05) giữa các biến đầu vào và việc tiếp thu kiến thức. Phân tích CLMM cho thấy thực hành ngoài tự nhiên có mối tương quan tích cực với việc tiếp thu kiến thức (p = 0,0123), trong khi thời lượng và thực hành nhóm thì không. Dánh giá cao phương pháp thực hành thí nghiệm tương quan với kết quả tiếp thu kiến thức cao hơn. Tuy nhiên, nghiên cứu định tính sử dụng thang điểm Likert không rõ ràng trong việc dự đoán kết quả học tập, nhận mảnh như cấu nghiên cứu chỉ tiết hơn về các quy trình thực hành thí nghiệm để xác định các biến và yếu tố ảnh hưởng.

**Từ khóa:** Day học thực hành, dạy học Sinh học, thực hành ngoài thiên nhiên, dạy học phát triển năng lực, chương trình phổ thông 2018.

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¹Trường Đại học Sài Gòn
²Trường Đại học Sư phạm Thành phố Hồ Chí Minh
³Trường Quốc tế Việt Úc, Thành phố Hồ Chí Minh
*Email: vanpd@hcmue.edu.vn