

ORIGINAL

Improving the Conceptual Understanding of Grade 9 Learners Using Biotrail-Larong Pinoy: A Photosynthesis Quest

Mejorando la comprensión conceptual de estudiantes de 9.º grado mediante Biotrail-Larong Pinoy: Una búsqueda de la fotosíntesis

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ABSTRACT

Introduction: this study examined the effectiveness of *Biotrail-Larong Pinoy: A Photosynthesis Quest*, a culturally responsive, game-based instructional intervention, in improving the conceptual understanding of photosynthesis among Grade 9 learners at Mat-i (Naawan) National High School, Philippines.

Method: a one-group pretest-posttest design under a quantitative approach was employed. The intervention consisted of a series of interactive activities based on traditional Filipino games (Larong Pinoy) contextualized to photosynthesis concepts, including the light-dependent and light-independent reactions, chlorophyll function, and glucose formation.

Results: findings revealed a significant increase in students' posttest scores (mean increase from 10,00 to 11,81, $p < 0,05$), suggesting improved conceptual understanding. A strong positive correlation was observed between pretest and posttest scores ($r = 0,819$), and a reduced standard deviation in posttest results indicated more consistent learner performance.

Conclusions: the integration of culturally relevant and game-based strategies enhanced learner engagement, motivation, and understanding of abstract scientific concepts. The intervention demonstrated promise as an inclusive instructional tool. Incorporating collaborative learning strategies and expanding its application to other science topics are recommended to deepen learning and foster interdisciplinary connections.

Keywords: Conceptual Understanding; Culturally Relevant; Game-Based Learning; Larong Pinoy; Photosynthesis.

RESUMEN

Introducción: este estudio examinó la eficacia de *Biotrail-LarongPinoy: Una Aventura de Fotosíntesis*, una intervención educativa lúdica y culturalmente sensible, para mejorar la comprensión conceptual de la fotosíntesis en estudiantes de 9.º grado de la Escuela Secundaria Nacional Mat-i (Naawan), Filipinas.

Método: se empleó un diseño de pretest y posttest de un solo grupo con un enfoque cuantitativo. La intervención consistió en una serie de actividades interactivas basadas en juegos tradicionales filipinos (LarongPinoy) contextualizadas en conceptos de fotosíntesis, incluyendo las reacciones dependientes e independientes de la luz, la función de la clorofila y la formación de glucosa.

Resultados: los hallazgos revelaron un aumento significativo en las puntuaciones de los estudiantes en la prueba posterior (incremento medio de 10,00 a 11,81; $p < 0,05$), lo que sugiere una mejor comprensión conceptual. Se observó una fuerte correlación positiva entre las puntuaciones de la prueba previa y la posterior ($r = 0,819$), y una desviación estándar reducida en los resultados de la prueba posterior indicó un

rendimiento más consistente del estudiante.

Conclusiones: la integración de estrategias culturalmente relevantes y basadas en juegos mejoró la participación, la motivación y la comprensión de conceptos científicos abstractos por parte del estudiante. La intervención demostró ser prometedora como herramienta de enseñanza inclusiva. Se recomienda incorporar estrategias de aprendizaje colaborativo y ampliar su aplicación a otros temas científicos para profundizar el aprendizaje y fomentar las conexiones interdisciplinarias.

Palabras clave: Comprensión Conceptual; Culturalmente Relevante; Aprendizaje Basado en Juegos; Larong Pinoy; Fotosíntesis.

INTRODUCTION

The study of photosynthesis is a fundamental concept in biology, essential for understanding the intricate balance of life on Earth. However, it is widely regarded as one of the more challenging topics within the biology curriculum due to its abstract nature and the complex interactions of various biochemical processes. Students often harbor misconceptions about photosynthesis, such as misunderstanding the role of light or failing to see its connection to respiration.⁽¹⁾

Despite its importance, traditional teaching methods often fall short in helping students develop a deep and accurate understanding of photosynthesis. Conventional classroom strategies tend to lack engagement and creativity, which can lead students to perceive lessons as dull and uninspiring.⁽²⁾ This disengagement frequently results in decreased motivation and learning outcomes. In contrast, students who participate in active learning environments demonstrate improved knowledge retention and application compared to those who rely solely on passive lecture-based instruction.⁽³⁾

To promote better learning outcomes, educators are increasingly turning to game-based learning, an approach that encourages active participation and critical thinking. Games can serve as powerful educational tools by creating interactive and low-risk environments where learners can explore and internalize complex concepts. Educational games provide opportunities for discovery-based learning, allowing students to test ideas and grasp difficult material in an engaging and non-threatening manner.⁽⁴⁾

In this context, integrating traditional Filipino games—collectively known as Larong Pinoy—into the science curriculum offers a culturally relevant and innovative approach to teaching photosynthesis. Abstract scientific concepts often require higher-order thinking skills, which can be difficult for many students to master. Using Larong Pinoy as a teaching resource can help bridge this gap by offering familiar, hands-on, and contextualized learning experiences. Beyond improving conceptual understanding, this strategy fosters cultural appreciation and a sense of national identity. It also aligns with 21st-century educational goals that emphasize learner-centered and context-based instruction.

Culturally responsive teaching further enhances the effectiveness of this approach. Incorporating students' cultural backgrounds, prior knowledge, and preferred learning styles leads to more inclusive and impactful educational experiences.⁽⁵⁾ Traditional Filipino games, as part of the country's cultural heritage, serve as an ideal medium for making science education both meaningful and accessible to Filipino learners.

To address persistent challenges in effectively teaching photosynthesis, this study introduces *Biotrail-Larong Pinoy: A Photosynthesis Quest*—an instructional intervention that merges active learning strategies with traditional Filipino games. Designed specifically for Grade 9 students at Mat-i (Naawan) National High School in the Philippines, the intervention aims to provide a contextualized and culturally responsive learning experience that fosters both engagement and deeper conceptual understanding.

The intervention focuses on fundamental photosynthesis concepts, such as the light-dependent and light-independent reactions, the role of chlorophyll, and the ecological significance of the process. Through a series of structured, Larong Pinoy-inspired activities, the approach promotes student participation, collaboration, and meaningful learning. This study aims to evaluate the effectiveness of *Biotrail-Larong Pinoy: A Photosynthesis Quest* in enhancing the conceptual understanding of Grade 9 learners. Specifically, it seeks to:

- a. Identify the level of conceptual understanding of Grade 9 learners before and after the implementation of *Biotrail-Larong Pinoy: A Photosynthesis Quest*
- b. Compare the results of the level of conceptual understanding of Grade 9 learners before and after the implementation of *Biotrail-Larong Pinoy: A Photosynthesis Quest*

METHOD

Research Design

This study adopts a quantitative research design to examine the effectiveness of *Biotrail-Larong Pinoy: A Photosynthesis Quest* in improving the conceptual understanding of photosynthesis among Grade 9 learners at

Mat-i (Naawan) National High School in the Philippines. The research involves the administration of a pre-test to establish baseline data on students' initial understanding, followed by the implementation of the intervention—a culturally relevant and gamified instructional strategy that incorporates traditional Filipino games. After the intervention, a post-test will be administered to assess the extent of conceptual improvement. The difference between the pre-test and post-test results will serve as the basis for evaluating the effectiveness of the intervention.

Respondents

This study intentionally selected Grade 9 learners from Mat-i (Naawan) National High School as participants. The school is a public secondary institution that provides inclusive education to learners from diverse backgrounds. All sections across curriculum levels, from Grade 7 to Grade 12, are composed of heterogeneous groups, reflecting a range of academic abilities and learning needs. Located in Mat-i, an interior barangay in the municipality of Naawan, Misamis Oriental, the school spans a total land area of 2,534 hectares, with a dry creek running through its center. Situated approximately 5.5 kilometers from the town proper, the school is accessible via all types of land transportation (figure 1).

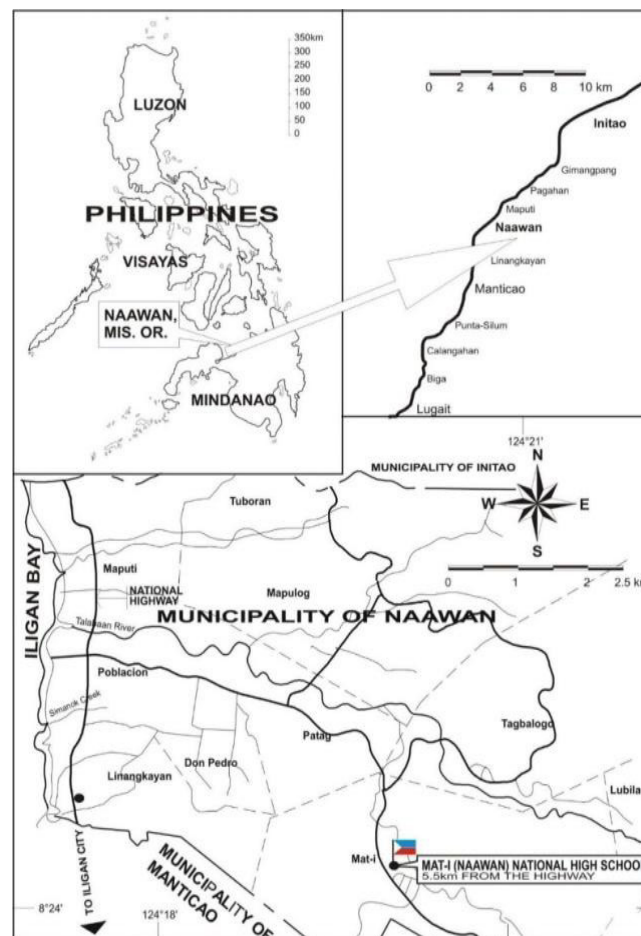


Figure 1. Locality of the study

Instruments

This study utilized the following research instruments:

1. Pretest and Posttest Questionnaire:

The researcher utilized an adapted 15-item questionnaire,⁽⁶⁾ as both a pretest and posttest to assess the conceptual understanding of photosynthesis among the participants, before and after the implementation of *Biotrail-Larong Pinoy: A Photosynthesis Quest*. The pre-test was administered prior to the intervention, while the posttest was conducted afterward to evaluate any changes in the students' understanding.

2. Larong Pinoy: A Photosynthesis Quest

The researcher developed a series of traditional Filipino games, titled *Biotrail-Larong Pinoy: A Photosynthesis*

Quest, which includes games such as *Bahug-Bahug na Buntot*, *Perya Game: Coin Toss*, and *Photosynthesis Message Relay*. These games were designed to enhance learners' conceptual understanding of photosynthesis through interactive activities, leveraging cultural Filipino games to engage students and facilitate learning.

Intervention

The intervention incorporates traditional Filipino games (*Larong Pinoy*) into the teaching of photosynthesis to create an engaging, interactive, and culturally relevant learning experience. Restructured with photosynthesis-related concepts, these games aim to enhance learners' understanding by integrating play with academic content.

The intervention conducted over a span of two week, one week for preparation and one week for implementation and consisting of five sessions. Each session will last approximately 45 minutes. Grade 9 learners participated in the intervention during their regular science classes. Table 1 shows the flow of the implementation of the intervention of *Biotrail-Larong Pinoy-A Photosynthesis Quest*.

Table 1. Implementation Flow of LarongPinoy: A Photosynthesis Quest

Phase	Activity	Details	Time Frame
Preparation Phase	Development of <i>Biotrail-Larong Pinoy: A Photosynthesis Quest</i>	Design and adapt traditional Filipino games to incorporate photosynthesis concepts.	1 week prior to intervention
	Preparation of Materials	Create diagrams, puzzle pieces, labels, flags, and instructional materials for the games.	
Implementation Phase	Pre-Test	Administer a 15-item pre-test to assess baseline understanding of photosynthesis.	Day 1 (Session 1)
	Introduction to Biotrail-Larong Pinoy: A Photosynthesis Quest	Explain the rules, objectives, and connection of the games to the photosynthesis topic.	
	Larong Pinoy 1: Bahug-Bahug na Buntot	Objective: Identify components of photosynthesis. Mechanics: Capture flags representing sunlight, water, carbon dioxide, and chlorophyll. Discuss the role of each component.	Day 2 (Session 2)
	Game 2: Perya Game: Coin Toss	Objective: Understand the stages of photosynthesis (light-dependent and light-independent reactions). Mechanics: Toss coins into containers labeled with stages and products of photosynthesis. Explain the process and outputs of each stage.	Day 3 (Session 3)
	Game 3: Photosynthesis Message Relay	Summarize the entire photosynthesis process. Mechanics: Complete a photosynthesis diagram by collecting puzzle pieces and relaying messages representing inputs and outputs. Review the completed diagram and its importance.	Day 4 (Session 4)
Evaluation Phase	Posttest	Administer the same 15-item test used in the pre-test to measure learning gains.	Day 5 (Session 5)
	Focus Group Discussion	Gather learners' perception on the effectiveness and enjoyment of the games. To explore their experiences and insights	

Data Gathering Procedure

The data gathering process for this study involves steps to ensure the collection of quantitative data necessary to address the research objectives. These steps conducted in stages to ensure the smooth implementation of the study and the reliability of results.

The study was conducted in four stages. In Stage 1: Preparation and Planning, the researcher secured approval from the school administration and obtained consent from learners and their parents to ensure ethical compliance. Research instruments, including adapted pre-test and post-test questionnaires, were prepared, and learners were oriented on the study's objectives and the mechanics of *Larong Pinoy: A Photosynthesis Quest*.

In Stage 2: Quantitative Data Collection, the pre-test was administered to identify learners' initial understanding of photosynthesis. The intervention, *Biotrail-Larong Pinoy: A Photosynthesis Quest*, was implemented over a designated period, with learner engagement and participation observed. Following the

intervention, the post-test was conducted to measure improvements in conceptual understanding.

In Stage 3: Data Organization, the researcher compiled pre-test, post-test, and qualitative data into a secure database for analysis.

Data Analysis

To evaluate the effectiveness of *Biotrail-Larong Pinoy: A Photosynthesis Quest* in improving Grade 9 learners' conceptual understanding of photosynthesis and in capturing their perceptions of the intervention, quantitative data were analyzed using statistical methods. Pre-test and post-test scores were compared using paired t-tests to determine whether the intervention resulted in a statistically significant improvement in learners' understanding of photosynthesis. Descriptive statistics, including mean, standard deviation, and range, were also computed to provide an overview of learners' performance.

Table 2. Interpretation of Learners' Level of Conceptual Understanding

Raw Score	Transmuted Grade	Interpretation
15	100	Excellent
14	93-99	Very Good
13	87-92	Good
12	81-86	Satisfactory
11	75-80	Acceptable
10	70-74	Needs Improvement
9 and below	Below 70	Unsatisfactory

Source: Department of Education (2012).

RESULTS

Results on Level of conceptual understanding of Grade 9 learners before and after the implementation of *Biotrail-Larong Pinoy: A Photosynthesis Quest*

Table 3. Learners' Pretest Score, Transmuted Grade and Interpretation before the implementation of *Biotrail-Larong Pinoy: A Photosynthesis Quest* (15-item test)

Learner	Pretest Score	Transmuted Grade	Interpretation
1	13	87	Good
2	6	70	Unsatisfactory
3	12	81	Satisfactory
4	11	75	Acceptable
5	10	74	Needs Improvement
6	8	70	Unsatisfactory
7	9	70	Unsatisfactory
8	11	75	Acceptable
9	10	74	Needs Improvement
10	12	81	Satisfactory
11	6	70	Unsatisfactory
12	10	74	Needs Improvement
13	14	93	Very Good
14	8	70	Unsatisfactory
15	9	70	Unsatisfactory
16	5	70	Unsatisfactory
17	11	75	Acceptable
18	10	74	Needs Improvement
19	14	93	Very Good
20	11	75	Acceptable
21	11	75	Acceptable
22	12	81	Satisfactory
23	7	70	Unsatisfactory
24	7	70	Unsatisfactory

25	10	74	Needs Improvement
26	10	74	Needs Improvement
27	10	74	Needs Improvement
Source: Department of Education (2012).			

The table provides an overview of the pretest performance of 27 learners, showcasing their raw scores, transmuted grades, and corresponding interpretations. The pretest scores, ranging from 5 to 14, were converted into transmuted grades using a standard grading table. These grades were then categorized into performance levels such as Good, Acceptable, Needs Improvement, and Unsatisfactory.

Several learners demonstrated high performance, achieving scores of 86 or higher, which were interpreted as Good or Very Good (e.g., Learners 1, 10, 13, and 19). On the other hand, some learners scored lower, with transmuted grades of 60 or below, earning an Unsatisfactory interpretation (e.g., Learners 6, 8, 14, and 23). These learners may require additional support to improve their understanding and skills. A majority of learners fell within the Acceptable range, with transmuted grades around 75-76, indicating they met basic requirements but still had room for improvement. A few learners were categorized as needing improvement, with scores close to 70.

Table 4. Learners' Posttest Score, Transmuted Grade and Interpretation after the implementation of Biotrail-Larong Pinoy: A Photosynthesis Quest (15-item test)

Learner	Posttest Score	Transmuted Grade	Interpretation
1	14	93	Very Good
2	10	74	Needs Improvement
3	14	93	Very Good
4	13	87	Good
5	13	87	Good
6	10	74	Needs Improvement
7	10	74	Needs Improvement
8	12	81	Satisfactory
9	12	81	Satisfactory
10	14	93	Very Good
11	9	70	Unsatisfactory
12	11	75	Acceptable
13	12	81	Satisfactory
14	10	74	Needs Improvement
15	9	70	Unsatisfactory
16	8	70	Unsatisfactory
17	13	87	Good
18	14	93	Very Good
19	15	100	Excellent
20	11	75	Acceptable
21	12	81	Satisfactory
22	13	87	Good
23	10	74	Acceptable
24	10	74	Acceptable
25	13	87	Good
26	12	81	Satisfactory
27	12	81	Satisfactory

Source: Department of Education (2012).

The posttest results reveal a positive learning outcome for most learners. A notable number achieved "Very Good" (5 learners) and "Good" (4 learners) scores, suggesting a strong understanding of the subject matter. This is encouraging as it indicates that the teaching methods and learning activities were effective for a significant portion of the class.

However, the results also highlight areas where further attention is needed. Two learners scored "Unsatisfactory," indicating a need for additional support and targeted interventions to address their specific learning gaps. This could include personalized tutoring, remedial instruction, or alternative learning strategies.

Furthermore, the presence of a significant difference between the highest score (100) and the lowest scores (70) suggests a range of learning levels within the class. While this is not uncommon, it necessitates

differentiated instruction to cater to the diverse needs of learners. This could involve providing additional challenges for high-achieving learners while offering extra support to those who are struggling.

Overall, the posttest results provide valuable insights into the learning progress of the students. By carefully analyzing the data and implementing appropriate strategies, educators can ensure that all learners have the opportunity to succeed and reach their full potential.

	Pretest	Posttest	Paired Differences (Pretest - Posttest)
Mean	10,0000	11,8148	-1,8148
Std. Deviation	2,27021	1,81949	1,30198
Std. Error Mean	43690	35016	25057
Correlation			0,819
Sig. (2-tailed)			.000
95 % Confidence Interval of the Difference			Lower: -2,32986 Upper: -1,29977
t			-7,243
df			26
Sig. (2-tailed)			,000

The results of the paired samples t-test indicated a statistically significant improvement in learners' conceptual understanding of photosynthesis following the implementation of *Biotrail-Larong Pinoy: A Photosynthesis Quest*. Descriptive statistics revealed an increase in the mean score from 10,00 on the pretest to 11,81 on the posttest, reflecting a positive learning gain. Additionally, the standard deviation decreased from 2,27 (pretest) to 1,82 (posttest), suggesting greater consistency in student performance after the intervention.

The correlation between pretest and posttest scores was strong and positive ($r = 0,819$), with a significance value of $p = 0,000$, indicating that learners' scores on the pretest were closely associated with their posttest outcomes. The paired t-test also showed a mean difference of -1,81, with a 95 % confidence interval ranging from -2,33 to -1,30. This confirms that the improvement in scores was not due to chance. The t-value of -7,243 and the corresponding degrees of freedom ($df = 26$) yielded a p-value of 0,000, which is well below the standard significance threshold of 0,05.

These findings demonstrate that the intervention had a meaningful and statistically significant impact on learners' understanding of photosynthesis. The consistent increase in scores and the reduced variability in posttest results suggest that *Biotrail-Larong Pinoy* effectively supported conceptual development and contributed to improved learning outcomes across the group.

DISCUSSION

The varying levels of achievement among the learners provided valuable insights for tailoring future instructional interventions. The pretest and posttest results revealed that while most learners showed measurable gains, there was a range of performance outcomes. Learners who initially performed in the *Unsatisfactory* and *Needs Improvement* categories benefited the most from the intervention, demonstrating significant increases in their posttest scores. This suggests that *Biotrail-Larong Pinoy: A Photosynthesis Quest* was particularly effective in supporting students with lower prior knowledge. On the other hand, higher-performing learners maintained or slightly improved their scores, indicating the potential of enrichment strategies to further challenge and engage them.

These findings affirm the value of culturally relevant, gamified instruction in addressing persistent learning gaps in science education. Compared to traditional teaching methods, this intervention fostered greater engagement and deeper understanding, particularly among students who often struggle with abstract topics like photosynthesis. This outcome echoes the study of Espinosa and Aquino⁽⁷⁾, who observed a 20 % average increase in posttest scores when students engaged in culturally rooted game-based learning. Similarly, the current study recorded significant improvements, highlighting the effectiveness of integrating traditional Filipino games into science instruction.

Zhou et al.⁽⁸⁾ also reported that students with weaker foundational knowledge experienced the greatest benefits from gamified approaches, reinforcing our observation that learners with low pretest scores improved most significantly. This suggests that educational games offer an inclusive and equitable approach, enabling diverse learners to grasp complex concepts through familiar and interactive formats.

The intervention's success also aligns with the findings of Smith et al.⁽⁹⁾, who demonstrated that thematic relay games enhanced retention and conceptual understanding. The *Photosynthesis Relay* in our study functioned similarly, facilitating teamwork, motivation, and active learning—conditions that are often absent

in conventional classrooms. These results further support the argument that dynamic, culturally embedded educational tools can bridge cognitive and motivational barriers.

Moreover, Miller and Johnson⁽¹⁰⁾ emphasized the role of contextual and engaging activities in improving students' comprehension of biology topics. This resonates with the current study's use of *Larong Pinoy*, which not only contextualized scientific content but also honored learners' cultural identities—adding a layer of relevance and emotional connection to the learning process.

Perez et al.⁽¹¹⁾ and Smith and Li⁽¹²⁾ provided additional evidence supporting the positive impact of game-based learning environments on knowledge retention and performance. Their conclusions mirror our findings, particularly in showing that learners with minimal prior understanding gained the most from interactive, game-based approaches.

In summary, this study contributes to the growing body of evidence supporting gamified and culturally responsive pedagogies in science education. By comparing our findings with previous research, it is clear that *Biotrail-Larong Pinoy: A Photosynthesis Quest* effectively enhanced learners' conceptual understanding, especially for those who initially struggled. This underscores the need to integrate play, culture, and collaboration into instructional design to make science learning more inclusive, engaging, and impactful.

CONCLUSION

The study confirmed that integrating culturally relevant and game-based strategies, such as *Biotrail-Larong Pinoy: A Photosynthesis Quest*, effectively enhances conceptual understanding among Grade 9 learners. The intervention demonstrated the value of contextualized instruction in fostering meaningful engagement with complex scientific content, highlighting how cultural integration and active learning promote deeper cognitive processing. To optimize its pedagogical impact, the approach may be further enriched through collaborative strategies like peer teaching and group discussions. Additionally, expanding its application across other science topics through interdisciplinary integration is recommended to ensure continuity in conceptual learning and strengthen cultural relevance in science education.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to the conduct and publication of this study.

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