Developing, Designing and Enhancing a Photosynthesis Card Game: Integrating in Teaching Science Education

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ABSTRACT

This study explores the innovative development, design, and implementation of a photosynthesis-themed card game to address the persistent challenges of teaching complex scientific concepts in secondary education. As traditional pedagogical methods have their limitations, the photosynthesis card game leverages gamification principles to transform abstract photosynthesis processes into an interactive and engaging learning experience. The game aims to enhance conceptual understanding, knowledge retention, and student motivation in science education by fostering collaboration, competition, and active participation. An iterative design process, informed by educators', students', and experts' feedback, ensured that the game aligned with educational objectives while maintaining entertainment value.

The research utilized a mixed methods approach to evaluate the card game's impact on Grade 9 students' understanding of photosynthesis. Quantitative analysis revealed a significant improvement in students' performance, with average test scores increasing from 54.67% in the pretest to 76.67% in the post-test, indicating a notable shift from "Near Mastery" to "Mastery." Qualitative findings from focus group discussions and observations underscored the game's ability to spark enthusiasm, foster teamwork, and simplify complex ideas. Despite minor initial challenges, such as understanding game mechanics, refinements addressed these issues to optimize learning outcomes. The study highlights the photosynthesis card game as a promising tool for integrating interactive, gamified strategies into STEM curricula, promoting deeper engagement and comprehension in science education.

Keywords: *Photosynthesis, Educational Games, Science Education, Game Design, Interactive Learning*

1. INTRODUCTION

Teaching complex scientific processes such as photosynthesis challenges educators and learners alike. Despite advancements in educational tools and methods, students frequently struggle to comprehend the intricate biochemical pathways involved in this vital process (Brown, 2018; Carter, 2019). Traditional teaching techniques, such as lectures and textbook-based learning, may fail to engage students fully, leading to a gap in understanding fundamental concepts (Thompson, 2021). Innovative pedagogical approaches, including interactive and game-based learning, have emerged as potential solutions (Smith, 2020).

Educational games are powerful tools for fostering engagement and improving conceptual understanding, particularly in science education. These tools create interactive learning environments that encouraging active participation and curiosity (Garcia, 2021; Rivera, 2018). Educational games can break complex topics into manageable and enjoyable experiences by incorporating play elements like competition and collaboration. Within this context, designing a card game centered on photosynthesis allows one to address learning biology's cognitive and affective aspects (Harris, 2020; White, 2019).

This study aims to explore how a photosynthesis-themed card game can bridge the gap between abstract scientific concepts and tangible learning experiences. Grounded by constructivist learning theory, the game promotes knowledge construction through active engagement (Barnes, 2018). The game's design process, educational principles, and classroom implementation offer a framework for integrating similar tools into science education. By evaluating the game's impact on students' understanding, engagement, and retention, this research contributes to the growing field of innovative educational methodologies in STEM.

2. RESEARCH QUESTIONS

1. What are the students' pretest scores before implementing the photosynthesis card game as instructional material?
2. What are the post-test scores of the students after implementing the photosynthesis card game as instructional material?
3. Is there a significant difference in students' pretest and post-test scores after implementing the photosynthesis card game as instructional material?
4. Based on the study's results, how did students describe their learning experience and engagement using the photosynthesis card game as an instructional material in science education?

3. RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN

This study utilized a mixed-methods design to develop and assess a photosynthesis card game instructional material for students to learn about photosynthesis in science instruction. The quantitative aspect consisted of pretests and post-tests of the student's knowledge acquisition of photosynthesis concepts before and after using the card game. Besides that, qualitative data were obtained through FGDs and interviews to evaluate students' level of engagement and perception regarding the card game. As such, this study will combine these methods to synthesize an assessment of the cognitive improvements and the interactive aspects of this game in order to contribute to better science education

3.2 RESEARCH LOCALE

The study was held at Jose Sanvictores Sr. National School in La Purisima, Cagwait, Surigao del Sur. Data gathering and the intervention occurred in the Grade 9 Section A classroom, where students dealt with the photosynthesis card game as part of their science education curriculum. The research carried on for six months with design, testing, implementation, and evaluation to test the improvement of students' understanding of photosynthesis concepts due to the game.

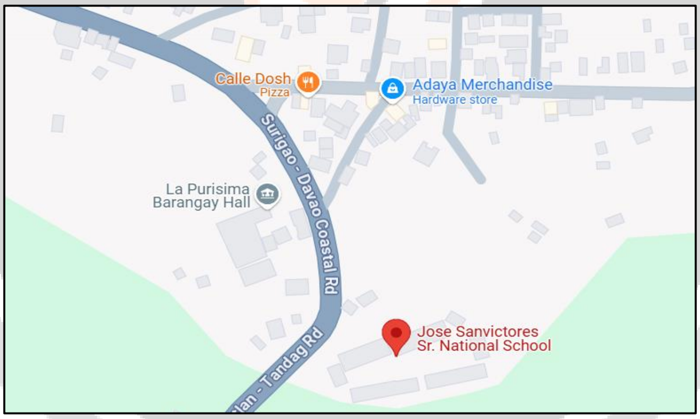

Fig -1: Map of Jose Sanvictores Sr. National School

3.3 RESEARCH PARTICIPANTS

The participants in this study included 60 Grade 9 students who were enrolled during the second semester of the 2024-2025 academic year. These students were selected to engage with the photosynthesis card game as part of their science curriculum, providing a diverse representation of learners within this grade level. Their involvement allowed for an in-depth examination of the game's impact on understanding photosynthesis concepts and overall engagement in science education.

RESEARCH INSTRUMENT

The researchers designed a set of research instruments to assess the engagement and understanding of students about photosynthesis concepts through a card game. A 50-item test was designed for both pretest and post-test to evaluate the students' knowledge. Experts in education and science pedagogy validated these instruments to ensure they are effective and accurate. The tests' reliability was thus confirmed, achieving a Cronbach's alpha score of 88%.

Data Gathering Procedure

The data collection follows these steps:

1. Conducting baseline tests to assess students' initial understanding.
2. Introducing and playing the photosynthesis card game in the classroom sessions.
3. Administering post-tests and conducting structured interviews to gather feedback.
4. Analyzing observation data to evaluate engagement and interaction.
5. Refining the game based on feedback from participants and educators.

The data-gathering procedure for studying the photosynthesis card game involves several key phases. The preparation phase involves finalizing the research instruments: a 50-item pretest and post-test to assess students' knowledge of photosynthesis, validated by experts in education and science pedagogy. The clarity of the study tool will be validated through a pilot test involving a smaller group of non-participants. Participant recruitment is providing informed consent to the participant and their guardians. It confirms 60 students from Grade 9 of Jose Sanvictores Sr. National School, the second-semester academic year 2024-2025. The pretest will be administered in a quiet classroom before introducing the card game, with clear instructions emphasizing honesty and effort. During the intervention phase, the card game will be implemented over several weeks, with observations on student interactions and engagement levels.

After this, a post-test will be administered under conditions similar to the pretest to measure knowledge changes. Focus group discussions (FGDs) and optional individual interviews will be conducted to collect qualitative data that will help understand students' experiences in the card game. All data will be recorded safely and anonymized to protect participants' identities. Quantitative analysis will be done using paired t-tests, while thematic analysis will be applied to qualitative data to identify common themes regarding engagement and learning experiences.

Ethical Considerations

In the study, ethical considerations were observed. Students and their guardians were informed of the study's goal to ensure that they understood the study's purpose before getting their consent and that they had the right to withdraw at any time. Participants' confidentiality and anonymity will be maintained by securely storing data and removing identifying information. The study will minimize potential harm by fostering a supportive learning environment. Participants will be treated equitably with respect for their dignity during the discussion. Transparency about the study's aims and any conflict of interest will also be a priority throughout the research process.

2. RESULTS AND DISCUSSION

Table 1. Mean Percentage Scores and Mastery Levels in Pretest.

Assessment	Percentage (%)	Mastery Level
Pretest	54. 67%	Near Mastery

The results from Table 1 indicate that the average pretest score of students was 54.67%, which classifies the mastery level as "Near Mastery." The result implies that while students have some basic knowledge about photosynthesis concepts, they still have much to learn. A score in the "Near Mastery" range typically indicates that students are starting to understand key ideas. However, they may struggle with more challenging applications or a more profound understanding of the content. Engaging educational tools, such as card games and interactive activities, has enhanced students' ability to understand and retain scientific concepts, thus making learning more fun and productive (Gutierrez, 2014).

Table 2. Mean Percentage Scores and Mastery Levels in Post-test.

Assessment	Percentage (%)	Mastery Level
Post-test	76.67%	Mastery

Table 2 shows the post-test, which indicates an average score of 76.67%, categorizing students' mastery level as "Mastery." This significant improvement from the pretest score of 55.31% suggests that implementing the photosynthesis card game as an instructional tool can effectively enhance students' understanding of photosynthesis concepts. Mastery level indicates that the students could understand the foundational knowledge and apply that knowledge to even more complex situations concerning photosynthesis. This aspect reflects the significance of interactivity and dynamism in the teaching materials to understand better and retain scientific concepts. The findings align with the literature emphasizing the benefits of game-based learning in terms of improved student engagement and outcome, which indicates that innovative methods like this can significantly contribute to better educational performances (Gee, 2003). The results showed a successful intervention; thus, it can be considered a potential for the card game educational tool in the science classroom.

Table 3. A significant difference between the Pretest and post-test Results

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference
Pretest	Post-test	Student's t	-11.5	29.0	<.001	-6.57	0.571

Note. H_a $\mu_{\text{Measure 1 - Measure 2}} \neq 0$

A significant difference was found between the pretest and the post-test scores: t=-11.5; df=29.0; p <.001. Thus, There is substantial statistical evidence for using the photosynthesis card game, which improves understanding of concepts for photosynthesis by students. The mean difference of -6.57 means that, on average, students gained 6.57 points from the pretest to the post-test, indicating a meaningful gain in knowledge. The standard error (SE) of the difference is 0.571, which estimates the variability in the mean difference; the smaller the SE, the greater the precision in the estimate. The low p-value also further confirms that the observed improvement is statistically significant and unlikely to have occurred by chance. These findings resonate with previous literature that shows how interactive educational tools promote student engagement and learning outcomes in science education (Gee, 2003). Overall, these results indicate the positive effects of the photosynthesis card game on students' learning.

Table 4. Thematic Analysis Based on Focus Group Discussions

Theme	Description	Key Findings
1. Student Engagement and Learning Outcomes	Encompasses participants' perceptions of their engagement levels and the impact of the photosynthesis card game on their learning outcomes.	This theme encompasses participants' perceptions of their engagement levels and the impact of the photosynthesis card game on their learning outcomes.
2. Perceived Challenges and Limitations	It reflects students' insights into difficulties encountered using the photosynthesis card game.	Some participants found out that some of the game mechanics and rules were not appropriately understood while playing at times. They clarified that adequate direction and ample support from instructors at the initiation level would increase the application of this game, therefore calling for implementing it in a planned manner with proper support for interactive learning materials.
3. Application of Knowledge	Focuses on how students perceive their ability to apply knowledge gained from the card game to real-world scenarios and scientific concepts.	Many respondents valued the card game because, for them, it had brought the theoretical knowledge of photosynthesis to real-world experience. Therefore, through this, many gained confidence during class discussions and applications of what they had learned to other related areas in biology.

The focus group discussions revealed three main themes related to using the photosynthesis card game to enhance student learning. First, participants noted that the game's interactive nature significantly boosted their motivation and interest in learning about photosynthesis, making complex concepts more understandable and enjoyable while fostering teamwork and communication skills. This game also supports earlier studies that have established the potential of game-based learning to foster engagement (Gee, 2003; Gutierrez, 2014). In contrast, a few students struggled to understand specific game mechanics. They would have required more explicit instructions and instructor support to fully appreciate the application of the game, thus calling for meticulous planning in implementing interactive learning tools (Baker et al., 2018).

Many participants indicated that the card game linked theoretical know-how to a practical scenario by building confidence in discussing topics concerning class presentations while pointing out experiential knowledge as the value and worth of gaining knowledge from contexts (Kolb, 1984). These results generally promise interactive educational tool approaches that create students' positive learning experiences. It points toward further improvements that require perfecting implementations of these technologies.

3. CONCLUSIONS

The study demonstrates the significant impact of the photosynthesis card game on enhancing students' understanding of photosynthesis concepts, as evidenced by a substantial increase in average post-test scores from 54.67% (Near Mastery) to 76.67% (Mastery). Statistical analysis confirmed this improvement with a t-statistic of -11.5 and a p-value of $< .001$, indicating that the gains in knowledge are statistically significant and unlikely to have occurred by chance. Thematic analysis from focus group discussions revealed that participants experienced increased motivation and engagement, finding the game both enjoyable and accessible while also improving their teamwork and communication skills. However, some students noted challenges with understanding game mechanics, suggesting a need for more precise instructions and teacher support during initial gameplay. Overall, the findings highlight the effectiveness of interactive educational tools in fostering deeper comprehension and practical application of scientific concepts, underscoring their potential to enhance learning outcomes in science education.

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