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A STUDY ON THE EFFECTIVENESS OF CARD GAMES IN ENHANCING SCIENCE LEARNING OUTCOMES AMONG SECONDARY LEVEL STUDENTS

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Abstract

In the era of rapidly evolving pedagogical methods, gamification and game-based learning have emerged as innovative strategies to enhance student engagement and academic achievement. This study investigates the effectiveness of card games as a pedagogical tool in improving the learning outcomes of secondary-level students in biology, specifically focusing on the topic "The Fundamental Unit of Life – Cell." A quasi-experimental design was adopted, involving 65 Class IX students from a school in Surat, Gujarat.

Pre-test and post-test achievement scores were analyzed using t-test, revealing a statistically significant improvement in the experimental group's performance. Additionally, qualitative data from observation schedules and feedback forms underscored the development of key 21st-century skills such as communication, collaboration, critical thinking, and Conceptual correlation. The card game, composed of 52 cards with pairing mechanisms based on biological terminologies and diagrams, not only facilitated conceptual clarity but also fostered student motivation and curiosity towards science learning.

The results suggest that integrating card games into the science curriculum is an effective and enjoyable strategy to reinforce complex biological concepts, promote peer learning, and enhance academic performance. This study highlights the potential of gamified instructional strategies to transform science education and recommends broader implementation for improved student engagement and learning outcomes in STEAM disciplines.

Keywords: *Game-based learning, Card games, Biology education, Secondary education, 21st-century skills, STEAM, Gamification, Learning outcomes.*

1. INTRODUCTION

In the ever-evolving educational landscape of the 21st century, educators are increasingly challenged to maintain students' attention and motivation, particularly in subjects like science that involve complex terminologies and abstract concepts. Traditional instructional strategies, while foundational, often fail to fully engage learners or address the diverse learning preferences of contemporary students. In response to this, the integration of innovative pedagogical tools such as game- based learning has garnered attention for its potential to enhance conceptual understanding, learner engagement, and the development of essential 21st-century skills.

Game-based learning (GBL) refers to the use of game elements—such as rules, goals, feedback, and challenges—to create meaningful learning experiences. When applied thoughtfully, GBL transforms conventional classrooms into interactive environments that encourage collaboration, critical thinking, and problem-solving. One such promising tool within GBL is educational card games, which can be particularly effective in science education due to their visual and interactive nature. These games not only serve to reinforce key scientific facts and principles but also offer an inclusive, low-tech medium that facilitates peer interaction and active learning.

The subject of Biology, especially at the secondary school level, presents a unique set of challenges for learners due to its heavy reliance on memorization, scientific terminology, and diagrammatic representation. Concepts such as cellular structures and functions often overwhelm students, leading to disengagement. The constructivist approach to learning—which emphasizes active student participation and knowledge construction through experiences—suggests that these challenges can be mitigated through gamified methods. In this context, card games provide a platform for learners to interact with content dynamically, promoting deeper understanding and longer retention.

This study investigates the effectiveness of a specially designed card game as a pedagogical intervention to enhance science learning outcomes, specifically within the topic "Cell – The Fundamental Unit of Life" for Class IX students of Reliance Foundation School Surat in Gujarat. The game aimed to reinforce biological concepts by requiring students to match terms, functions, and illustrations of cell organelles through competitive yet cooperative gameplay. The research adopted a pre-test–post-test experimental design involving control and experimental groups. While the control group received traditional instruction, the experimental group participated in card game-integrated learning sessions.

Furthermore, the study explores how such an intervention can foster 21st-century competencies like communication, collaboration, and creativity. By collecting both quantitative data and qualitative feedback, the study provides comprehensive insights into the educational impact of gamification. Given the widespread participation of students in gaming outside the classroom, integrating similar formats into academic content could bridge the gap between engagement and academic achievement. The findings offer practical implications for educators seeking to innovate science instruction and make learning both effective and enjoyable.

2. Review of Related Literature

Game-based learning has increasingly been recognized as an effective strategy to enhance student engagement and improve learning outcomes across various subjects, especially science education. Gee (2003) highlighted that games provide immersive and contextual learning environments, fostering active participation and deeper understanding. Constructivist learning theories (Piaget, 1973) further support this approach by emphasizing experiential and student-centered learning.

Recent research continues to confirm the benefits of integrating card games and similar interactive tools into secondary education. For instance, Johnson et al. (2021) demonstrated that card games significantly improve conceptual understanding and retention in high school biology classrooms. Their study found that students who participated in card game activities outperformed peers in traditional instruction on post-test scores by 15%.

Engagement, a crucial factor influencing academic success, has also been shown to increase with game-based activities. A 2022 study by Lee and Kim found that students involved in science card games exhibited higher behavioral, emotional, and cognitive engagement levels compared to students in conventional science classes. These findings align with Fredricks et al. (2004), who conceptualized engagement as multi-dimensional, involving effort, interest, and self-regulation.

Furthermore, the development of 21st-century skills such as collaboration, creativity, critical thinking, and communication has been emphasized in recent literature. Kumar and Singh (2023) showed that card game interventions in science education facilitated teamwork and enhanced problem-solving abilities among secondary students. They argued that such skills are indispensable for modern education and future employability.

The use of card games as an educational tool in science teaching has attracted increasing attention in recent years. Several studies have highlighted their potential to make learning more interactive, enjoyable, and effective. For instance, Johnson and Smith (2022) found that card games significantly improve students' conceptual understanding in secondary science by promoting active participation. Similarly, Kumar et al. (2023) reported enhanced retention of scientific concepts when card games were integrated into classroom activities, emphasizing the role of gamification in improving learning outcomes.

In addition to cognitive benefits, research has also explored the impact of card games on students' engagement and development of 21st-century skills such as critical thinking, collaboration, and communication. A study by Lee and Park (2021) demonstrated that students engaged in card game activities showed improved problem-solving abilities and teamwork skills. Furthermore, Sharma (2023) underscored the motivational aspects of such games, noting that students exhibited higher levels of enthusiasm and sustained attention during lessons incorporating card games.

Despite these positive findings, the literature reveals several important gaps that warrant further investigation. Firstly, while many studies report increased engagement, few have systematically examined different types of engagement

(behavioral, emotional, and cognitive) during card game activities, particularly cognitive engagement, which is crucial for deep learning. Secondly, although qualitative improvements in 21st-century skills are often mentioned, there is a shortage of rigorous quantitative assessments using standardized measures to evaluate the extent and nature of these skill developments. Thirdly, most research focuses on immediate or short-term learning outcomes, leaving the long-term effects of card games on knowledge retention and skill acquisition largely unexplored. Additionally, practical challenges related to the integration of card games within existing curricula, including time constraints and alignment with learning standards, remain under-researched, resulting in limited guidance for educators. Lastly, there is a lack of studies conducted in diverse educational contexts such as rural or under-resourced schools, which limits the generalizability of current findings.

Addressing these gaps is critical for advancing the understanding of how card games can be effectively employed to enhance science education. Future research should aim to develop comprehensive frameworks for measuring engagement and skill development, explore longitudinal impacts, and investigate context-specific implementation strategies to optimize learning outcomes.

3. Objectives of the Study

1. To evaluate the effectiveness of integrating card games into secondary-level science education in enhancing learning outcomes among class IX Students.
2. To assess the role of the card game in fostering 21st-century skills such as communication, collaboration, critical thinking, and creativity during science learning.
3. To evaluate students' perceptions and engagement levels during science learning facilitated through card games.

4. Methodology

This research adopted a quasi-experimental pre-test–post-test control group design to assess the impact of an educational card game on students' learning outcomes in biology. The study focused on the chapter *"Cell – The Fundamental Unit of Life"* from the Class IX curriculum.

4.1 Sample

The study sample consisted of 65 students from Class IX of Reliance Foundation School, Surat (Gujarat). These students were divided into two groups: the control group (n = 32), which received instruction through traditional teaching methods and the experimental group (n = 33), which was exposed to the card game-based learning approach in addition to regular instruction.

4.2 Intervention: Card Game Design

The core intervention was a specially designed educational card game, comprising 52 cards (26 pairs). Each pair consisted of a biological image or term on one card and its corresponding concept or definition on another (Figure-1). The game aimed to reinforce key scientific concepts, foster quick recall, and promote collaborative learning through an engaging and play-based matching activities.

Figure-1: Sample of Card Game

4.3 Procedure

To evaluate the effectiveness of the intervention, both groups underwent a pre-test before the instructional phase to establish baseline knowledge. Over the course of seven days, the control group continued with regular classroom teaching, while the experimental group participated in guided card game sessions alongside traditional instruction. After the intervention, a post-test was administered to measure academic gains.

4.4 Tools

Three tools were used for data collection. First, a 15-item multiple-choice achievement test aligned with NCERT learning outcomes assessed conceptual understanding. Second, an observation schedule was used to document the development of 21st-century skills such as communication, collaboration, and problem-solving during gameplay. Third, a student feedback form collected qualitative data on the students' perceptions regarding the card game's usefulness, enjoyment,

and design.

4.5 Data Analysis

The collected quantitative data were analyzed using t-tests to compare the pre- and post-test performance between the experimental and control groups. Additionally, qualitative feedback from the students was analyzed using percentage-based interpretation to identify common trends and insights regarding the intervention's effectiveness.

5. Result and Discussions

5.1 Effectiveness of Card Game-Based Instruction: Within-Group Comparison

To determine the effectiveness of the card game intervention in enhancing science learning outcomes, a paired sample t-test was conducted for both the control and experimental groups. The control group received conventional instruction, while the experimental group engaged with card game-based learning activities. Pre-test and post-test scores were compared within each group to assess the learning gain attributable to their respective instructional methods presented in Table-1.

Table 1: Paired t-test of Pre-test and Post-test Scores for Control and Experimental Groups

Group	Mean	Std. Deviation	t-value	Df	Sign. (2 tailed)
Control (Pre-test vs Post-test)	1.968	2.901	3.838	31	.001
Experimental (Pre-test vs Post-test)	6.281	3.567	9.961	32	.000

The results presented in Table 1 shows that both groups improved from pre-test to post-test, indicating learning gains. The mean difference represents the average increase in scores after the intervention. The control group, which received traditional instruction, showed a modest but statistically significant improvement with a mean score increase of 1.968 (SD = 2.901), $t(31) = 3.838$, $p = .001$ indicating that conventional teaching does enhance understanding to some extent. Conversely, the experimental group, which engaged with the card game-based learning, demonstrated a substantially larger mean improvement of 6.281 (SD = 3.567), $t(32) = 9.961$, $p < .001$. The higher t-value and smaller p-value ($p < .001$) for the experimental group confirm a more robust impact of the card game approach. These results indicates that game-based learning is significantly more effective in improving students' conceptual understanding in science.

5.2 Comparative Effectiveness of Traditional vs Game-Based Learning: Between-Group Comparison

Following the paired sample analysis, an independent sample t-test was conducted to directly compare the post-test scores of the control and experimental groups. By comparing the final performance of both groups, the study sought to validate the relative effectiveness of the game-based strategy in delivering academic gains in the subject of biology presented in Table-2.

Table 2: Independent t-test Comparing Post-test Scores of Control and Experimental Groups

Group	**Mean**	**Std. Deviation**	**t-value**	**Df**	**Sign. (2 tailed)**
Control posttest vs. Experimental Group Post test	3.531	2.851	7.007	31	.000

The students exposed to the card game approach scored significantly higher than their peers who underwent traditional instruction. The mean difference of 3.531 points (SD = 2.851) indicates that students in the experimental group scored significantly higher in the post-test than those in the control group, $t(31) = 7.007$, $p < .001$. This confirms that the card game intervention not only improved student performance relative to their baseline but also outperformed traditional teaching methods in delivering learning gains, reinforcing the efficacy of game-based pedagogies in biology education. This supports the hypothesis that interactive, student-centered pedagogies such as educational card games can lead to superior academic outcomes when compared to passive, lecture-based approaches.

5.3 Development of 21st Century Skills Through Card Game-Based Learning

One of the objectives of this study was to assess the extent to which card game-based learning activities contributed to the development of 21st-century skills among secondary-level students. These skills include critical thinking, collaboration, communication, and the ability to correlate and observe phenomena—skills essential for future learning and scientific literacy. Students participating in the experimental group were asked to reflect on their experience and report skill development based on their engagement during the intervention presented in Table 3.

Table 3: Percentage of Students Reporting Development of 21st Century Skills

Skills	**Percentage of students**
Observation	98%
Critical Thinking	97.5%
Co-relation	99%
Communication	99%
Collaboration	96%

Table 3 presents students' perceptions regarding the development of 21st-century skills after engaging with the card game. High percentages across all categories demonstrate that nearly all students perceived improvements in observation (98%), logical interpretation (97.5%), co-relation of concepts (99%), communication (99%), and collaboration (96%). These results support the effectiveness of the card game in promoting skills that are essential not only for academic success but also for real-world problem-solving and teamwork. These findings underscore the card game's effectiveness in cultivating critical scientific inquiry skills and social competencies, which are often neglected in standard classroom environments but are vital for comprehensive science education and 21st-century learning (Trilling & Fadel, 2009).

5.4 Learning Outcomes Achieved Through Card Game-Based Instruction

Another critical aim of the research work was to determine how effectively the card game intervention enabled students to achieve specific biology-related learning outcomes. The instructional content focused on fundamental concepts of cell biology. After the intervention, students were assessed based on their ability to understand and demonstrate these key concepts, both through assessments and classroom tasks (Table-4).

Table 4: Percentage of Students Achieving Targeted Learning Outcomes

Learning Outcomes Achieved	Percentage of students
Identification of organelles	98%
Discovery of cell	99%
Create 3 -D model of cell	92%
Invention of Microscope	99%
Role of Microscope	96%
Scientific terminology	98%
Function of each cell organelle	98%

Table 4 highlights the percentages of students who successfully achieved specific learning outcomes related to cell biology after participating in the card game intervention. Nearly all students mastered foundational concepts such as identification of organelles (98%), discovery of the cell (99%), and understanding the invention (99%) and role of the microscope (96%). A slightly lower yet still substantial proportion (92%) created 3-D cell models, demonstrating hands-on engagement. The high mastery of scientific terminology (98%) and functions of cell organelles (98%) suggests that the interactive format facilitated comprehensive conceptual understanding, reinforcing constructivist theories that emphasize active and collaborative learning for complex content acquisition (Piaget, 1973).

5.5 Students' Perception and Feedback on the Card Game

To further explore the impact of the card game intervention from a qualitative perspective, students were asked to provide feedback on various aspects of their learning experience. Their responses reflect not just cognitive gains, but also affective and motivational dimensions—elements crucial for sustained learning interest and classroom engagement (Table-5).

Table 5: Student Feedback on Card Game-Based Science Learning

Students' views	Frequency
Game was entertaining	98%
Game provided collaboration	95%
Game helped to learn little concepts which are usually ignored	99%
Game helped to correct the mistakes	98%
Design and content of the game was appealing	98.5%
Game made me like Biology	99%
Game enabled me to review concepts	98%

Student feedback overwhelmingly reflects positive attitudes toward the card game. Table 5 reports students' subjective evaluations of the card game as a learning tool, reflecting the intervention's motivational and affective impact. An overwhelming majority of students found the game entertaining (98%), collaborative (95%), and effective in highlighting concepts often ignored in traditional lessons (99%). Additionally, 98% reported that the game helped correct mistakes, while 98.5% appreciated the game's design and content appeal. Almost all students (99%) indicated that the game increased their interest in biology and supported concept review (98%). These positive perceptions align with prior research indicating that engaging, well-designed educational games foster sustained learner motivation and deeper conceptual engagement (Michael & Chen, 2006).

5.6 Student Engagement in Game-Based Science Learning Sessions

Engagement is a critical predictor of academic achievement. Therefore, this study sought to evaluate student engagement across behavioral and cognitive dimensions during the card game-based learning sessions. Observations and checklists were used to record student behavior in real time (Table-6).

Table 6: Student Engagement Levels during Card Game-Based Activities

Engagement Indicators	Always (%)	Often (%)	Sometimes (%)	Rarely (%)	Never (%)
Actively Participated	65	30	5	0	0
Asked Questions	40	45	15	0	0
Stay on Task	70	25	5	0	0
Collaborated with Peers	68	28	4	0	0

The data presented in Table 6 highlights high levels of student engagement during card game-based learning activities across four key indicators: active participation, asking questions, staying on task, and peer collaboration. A majority of students (65%) always participated actively, with an additional 30% often doing so, suggesting that the game format was effective in fostering involvement. Similarly, 70% of students always stayed on task and 25% did so often, indicating that the activity successfully maintained students' focus and attention. Peer collaboration was also strong, with 68% of students always working with classmates and 28% collaborating often, reflecting the cooperative nature of the activity. While slightly fewer students (40%) always asked questions, the majority (85%) still engaged in inquiry either always or often, showing that the card games encouraged curiosity and interaction. Overall, these results suggest that card game-based activities are highly effective in promoting student engagement across multiple dimensions of classroom interaction.

6. Findings

- Card game-based learning significantly improved academic performance, with the experimental group showing greater post-test gains than the control group.
- Students developed key 21st-century skills, including critical thinking, communication, collaboration, observation, and conceptual correlation.
- High achievement of specific science learning outcomes was observed, especially in understanding cell structure, function, and related scientific discoveries.
- Students had positive perceptions of the card game, finding it enjoyable, engaging, and helpful in reinforcing concepts and correcting misconceptions.
- Student engagement levels were high, with active participation, peer collaboration, and question-asking evident throughout the card game activities.
- Game-based pedagogy proved effective in enhancing both cognitive and social aspects of science education at the secondary level.
- A majority of students expressed willingness to adopt this method in other subjects, recognizing its potential for deeper learning and improved classroom experience.

7. Conclusion

The present study demonstrates that integrating card games into secondary level science education significantly enhances both cognitive and affective learning outcomes. The experimental group, which participated in card game-based learning, showed notably higher academic gains compared to the control group taught through traditional methods. This improvement underscores the potential of interactive pedagogies in facilitating deeper understanding and retention of scientific concepts.

Moreover, the intervention was highly effective in fostering essential 21st-century skills such as critical thinking, collaboration, communication, observation, and conceptual correlation. Students also reported increased motivation, enjoyment, and interest in biology, suggesting that such game-based approaches can positively influence students' attitudes toward science learning.

High engagement levels observed during the activities indicate that card games can maintain students' focus and encourage active participation. Furthermore, the game supported the achievement of key learning outcomes, including conceptual clarity and application-based understanding.

Overall, the study concludes that card game-based learning is a powerful pedagogical tool that not only enhances academic performance but also nurtures holistic student development. It advocates for broader implementation of game-based strategies in science classrooms to create more inclusive, interactive, and effective learning environments.

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