

# Effectiveness of Online Simulation Educational Games as a Reinforcement Intervention in Teaching Genetic Engineering in Earth and Life Science

Alvin A. Pabores

Governor Felicisimo T. San Luis National Agro-Industrial Integrated High School

[alvin.pabores@deped.gov.ph](mailto:alvin.pabores@deped.gov.ph)

Date Submitted:

**April 1, 2026**

Date Accepted:

**April 14, 2026**

Date Published:

**April 19, 2026**

DOI:

**10.5281/zenodo.19653149**

## ABSTRACT

This action research evaluates the effectiveness of online simulation educational games as a reinforcement tool for teaching genetic engineering in Earth and Life Science. The study addresses the challenge of low student mastery and poor conceptual comprehension in complex science topics among senior high school students. Its primary purpose is to enhance engagement and knowledge retention by bridging the gap between initial instruction and long-term mastery through interactive digital tools. The researcher employed a quasi-experimental methodology involving twenty-seven (27) Grade 11 students selected through cluster sampling. Data were gathered using standardized pre-tests and

post-tests to measure objective knowledge gains. The intervention integrated specific online games during the "Developing Mastery" phase of the lesson cycle. The results revealed a substantial and significant increase in student performance following the intervention. Statistical analysis showed that the improvement was not due to random chance, leading to the rejection of the null hypothesis and confirming that the games served as powerful tools for knowledge retention. Major findings indicated that a majority of learners achieved medium to high gains in their understanding of genetic engineering. These results imply that gamified reinforcement can successfully elevate student mastery and should be strategically integrated into lesson planning across various subject areas to boost overall academic achievement.

**Keywords:** *Action research, online educational games, reinforcement intervention, genetic engineering, student engagement*

## INTRODUCTION

Recent evidence underscores that game-based learning (GBL) serves as a transformative pedagogical strategy that consistently elevates student participation and motivation. According to research by Thi (2025), gamified instruction results in a marked improvement in student engagement levels, moving learners from average mastery to higher proficiency through more interactive and enjoyable learning experiences. These digital environments foster a "very satisfactory" level of involvement by reducing the monotony of traditional lecture-based teaching. Ratinho and Martins (2023) further emphasizes that strong learning motivation derived from these tools encourages students to actively overcome academic challenges and persist in their understanding of difficult material. The effectiveness of gamification in science is particularly evident in the mastery of abstract and complex biological topics. Selçuk and Keskin (2024) studies indicate that students who engage in gamified biology lessons outperform those taught through traditional methods, demonstrating significantly better retention and conceptual understanding. For instance, the use of points, levels, and immediate feedback reinforces

learning and facilitates a deeper mastery of processes like cellular division or genetic engineering. Research by Jaaska and Aaltonen (2022) notes that game media designed by teachers help students visualize concepts that are otherwise difficult to grasp, thereby bridging the gap between theoretical instruction and cognitive application. Additionally, Samortin (2020) highlight that the strategic application of gamification elements correlates directly with increased long-term knowledge retention among secondary learners.

Beyond simple quizzes, online simulations offer immersive environments that function as critical scaffolding for scientific inquiry. As described by Sapuan and Chan (2024), modern simulations allow students to manipulate variables and analyze multiple outcomes in a risk-free virtual setting, which promotes higher-order thinking and self-directed learning. As noted by Li et al., (2023), these tools are particularly valuable for teaching concepts that are too small or dangerous to experience in a physical laboratory, such as molecular interactions. The integration of these simulations after formal discussion allows for the "Developing Mastery" phase to become more dynamic, as students receive immediate, data-driven feedback on their performance. This real-time feedback mechanism is essential for correcting misconceptions early in the learning process.

Despite the clear benefits, the implementation of digital tools in Senior High School (SHS) science face specific hurdles. Haleem et al. (2022) identify those students often struggle with fast-paced schedules and technical vocabulary in subjects like Earth and Life Science, necessitating more interactive and fun instructional designs. While students show high acceptance for gamified learning, Salgado and Paglinawan (2025) pointed out teachers often encounter challenges related to limited digital resources, time constraints, and the need for specialized technical skills. Nevertheless, the consensus among educational researchers is that when institutions provide adequate support and professional training, gamification and simulations significantly enrich the curriculum and cultivate more collaborative, motivated learners.

The literature collectively supports the premise that gamification and digital simulations are not merely supplementary activities but are essential instructional tools that address the cognitive and motivational needs of 21st-century learners. While traditional methods often struggle with the abstract nature of biological sciences, gamified platforms provide the necessary engagement and immediate feedback to ensure conceptual mastery and improved knowledge retention. The recurring theme across recent studies is the shift from passive reception to active, student-centered learning. However, the successful integration of these tools depends heavily on instructional design and institutional support to overcome technical and time-related barriers. This research builds upon these findings by specifically evaluating the effectiveness of these digital tools as a targeted reinforcement strategy to close the performance gaps identified in the local school context.

The evolving educational landscape increasingly prioritizes innovative methodologies to bolster student engagement, motivation, and overall learning outcomes in complex scientific disciplines. Central to this shift is the integration of educational online games, often categorized under gamification, which serve to foster critical thinking, problem-solving skills, and collaborative learning environments. Research by Bolat and Tas (2023) identifies these digital tools as transformative, while studies by Handoko et al. (2021) and Kalleney (2020) demonstrate that platforms such as Kahoot! and Quizizz significantly enhance the effectiveness of instruction by making the learning process more interactive. Furthermore, Li et al., (2024) highlight those digital educational games positively impact student motivation through increased learning engagement within digital environments. Despite these benefits, a notable research gap exists regarding how these games specifically support and reinforce classroom discussions rather than just serving as primary teaching tools. While Alotaibi (2024) notes a focus on skill acquisition in mathematics and science, there is limited exploration into using online games as a mechanism to solidify concepts immediately following a lecture. This is particularly relevant for Senior High School (SHS) students who often find Earth and Life Science (ELS) challenging, as evidenced by low mastery levels in standardized assessments.

The rationale for this action research is rooted in the documented struggle of Grade 11 students to comprehend complex biological concepts, specifically within the unit of Genetic Engineering. Diagnostic

results at one public secondary school revealed an average weekly Mean Percentage Score (MPS) of 34.35, a figure that indicates low mastery and a pressing need for targeted reinforcement based on DepEd Memorandum no. 160, s. 2012. As Al-Tameemi et al. (2023) explain, such low performance suggests that students require additional support to bridge the gap between initial instruction and long-term retention. By strategically utilizing educational online games during the "Developing Mastery" phase of the Daily Lesson Log (DLL), the study aims to provide an interactive intervention that addresses these cognitive hurdles. This approach seeks to determine if digital reinforcement can provide the necessary scaffolding for students to better understand and apply scientific knowledge after a formal discussion has taken place.

The main objectives of this study are designed to evaluate the effect of online simulation games as a reinforcement intervention. Specifically, the research seeks to determine the average scores of learners before and after the integration of these digital tools to identify objective knowledge gains. It further aims to calculate the degree of improvement using normalized gain analysis to assess how much of the knowledge gap was closed relative to the maximum possible improvement. A critical component of the study is investigating whether a significant difference exists between pre-test and post-test performance, thereby testing the null hypothesis that the intervention has no significant effect on student knowledge. The primary variables involved include the independent variable, which is the integration of educational online games as a reinforcement tool, and the dependent variable, represented by the students' academic performance and mastery of genetic engineering concepts. This study aimed to evaluate the significance of educational online games as reinforcement tools in classroom discussions. The study was conducted on General Academic Strands of Grade 11 students in senior high school during the Academic Year 2025-2026. The results of the study were used to enhance classroom discussions and improve educational instruction. Specifically, the researcher aimed to answer the following questions in pursuit of academic advancement:

1. What are the average scores of learners before and after the integration of educational online games as a reinforcement tool?
2. What is the degree of improvement of learners achieved between pretest and posttest scores?
3. Is there a significant difference in student knowledge before and after the integration of educational online games as a reinforcement tool?

## METHODS

### Research Design

The research design for this action research is the quasi-experimental design, specifically employing a one-group pre-test/post-test approach. This design is chosen because it allows the researcher to evaluate the effectiveness of an intervention—online simulation educational games—within a natural classroom setting where random assignment to a control group may not be feasible. By comparing the students' performance before and after the intervention, the researcher can directly measure academic improvement and determine if the digital reinforcement significantly addresses the identified knowledge gaps in complex subjects like genetic engineering. This study utilizes a quantitative methodology to assess the impact of digital reinforcement on student mastery. The sample consists of 28 Grade 11 senior high school students at Governor Felicisimo T. San Luis National Agro-Industrial Integrated High School, selected through cluster sampling based on their initial low Mean Percentage Score (MPS) in Earth and Life Science. The primary variables include the independent variable, which is the integration of online simulation games during the "Developing Mastery" phase of the lesson, and the dependent variable, which is the students' level of conceptual understanding as measured by test scores. Data collection involves the administration of standardized 25-item pre-tests and post-tests to capture objective knowledge gains, supplemented by a Likert scale questionnaire to gather subjective feedback on the intervention's utility. To ensure reliability and validity, the research instruments were externally validated by a seasoned science teacher with five years of experience, ensuring the clarity and effectiveness of the

questions before the primary data collection phase. Data analysis is performed using Microsoft Excel, employing descriptive statistics such as mean and standard deviation, alongside Hake's normalized gain formula to categorize improvement and a paired t-test to determine if the difference in scores is statistically significant. Ethical concerns are addressed through a formal declaration of anti-plagiarism and the absence of conflict of interest, ensuring the integrity of the findings. Finally, the study ensures replicability by providing a clear, step-by-step procedure—from baseline assessment to intervention and final evaluation—enabling other educators to apply similar digital strategies in various academic contexts.

Table 1. *Normalized Gain Score Criteria*

Gain Range	Interpretation
0.70 to 1.00	High Gain
0.30 to 0.69	Medium Gain
0.00 to 0.29	Low Gain

Note. Adopted from Hake's formula, by Deadmond et al., (2018)

### Research Locale

This action research is situated at Governor Felicisimo T. San Luis National Agro-Industrial Integrated High School, where the study is scheduled to take place during the 2025–2026 academic year. The locale serves a diverse population of Senior High School students, specifically focusing on a cohort of 28 Grade 11 learners enrolled in the Earth and Life Science (ELS) subject. These participants, selected through cluster sampling, represent various academic strands and were identified as the primary focus due to a documented knowledge gap in complex scientific concepts such as genetic engineering. The school setting is characterized by its integration of the Daily Lesson Log (DLL) framework, particularly the "Developing Mastery" phase, which provides the structured environment necessary for implementing digital interventions. This location is highly relevant to the research topic because the student population recently demonstrated a low average weekly Mean Percentage Score (MPS) of 34.35, indicating a significant struggle with subject mastery that requires targeted educational reinforcement. By conducting the study within this specific institution, the researcher can directly address these academic challenges using online simulation games to bridge the gap between initial classroom instruction and long-term conceptual retention.

### Sampling Technique

The primary participants for this action research were 28 Grade 11 senior high school students enrolled in the Earth and Life Science (ELS) subject at Gov. Felicisimo T. San Luis National Agro-Industrial Integrated High School during the 2025-2026 academic year. These participants were selected through a cluster sampling procedure, a method utilized because the group was identified based on their initial pre-test performance. The diagnostic results revealed a low average weekly Mean Percentage Score (MPS) of 34.35, which underscored a significant struggle to grasp ELS concepts and a specific requirement for targeted educational reinforcement. The inclusion of these particular learners was rationalized by their active engagement in the ELS curriculum and a documented knowledge gap regarding genetic engineering, rendering them the most relevant cohort to evaluate the effectiveness of online simulation games as a reinforcement intervention. Beyond the student participants, data were gathered through standardized pre-tests and post-tests to measure objective knowledge gains, while a Likert scale questionnaire was employed to capture the students' subjective perceptions of the intervention's utility.

## RESULTS AND DISCUSSION

### Scores of Learners Before and After the Integration of Educational Online Games as a Reinforcement Tool in Genetic Engineering

The analysis revealed that the learners obtained a pre-test mean score of 10.48 with a standard deviation of 4.15, which significantly increased to a post-test mean score of 17.89 with a standard deviation of 3.29. This reflects a mean raw improvement of approximately 7.41 points, indicating that the use of online simulation games effectively addressed the initial low mastery of the subject matter. Such results align with the findings of Handoko et al. (2021) and Kalleney (2020), who noted that gamified platforms like Kahoot! and Quizizz make learning more effective by enhancing engagement and knowledge retention. To further analyze these improvements, the researcher identified the students with the highest and lowest scores of changes relative to their starting points using the normalized gain ( $g$ ) formula. Student 24 demonstrated the highest score of change with a normalized gain of 0.89, moving from a pre-test score of 16 to a near-perfect post-test score of 24. In contrast, Student 2 showed the lowest score of change with a normalized gain of only 0.09, increasing by just one point from a pre-test score of 14 to a post-test score of 15. The disparity in these individual gains illustrates the importance of using normalized gain to avoid the "ceiling effect," as it measures how much a student improved relative to the total possible room for improvement. This approach is supported by Bolat and Tas (2023), who emphasize that digital gaming fosters critical thinking and problem-solving skills at varying individual rates depending on the student's baseline mastery. The overall effectiveness of the intervention was interpreted using Hake's Criteria, which classifies gain scores into high, medium, and low categories.

The mean normalized gain for the entire group was 0.51, which falls under the "Medium Gain" category (0.30 to 0.69). This numerical value of 0.51 indicates that, on average, the students closed 51% of the gap between their initial knowledge and total mastery of genetic engineering concepts. Specifically, the data shows that five students achieved a "High Gain" ( $g > 0.70$ ), while the majority (21 students) achieved a "Medium Gain," and only one student remained in the "Low Gain" category. This moderate to high growth confirms the assertion by Duterte (2024) that online games serve as powerful reinforcement tools that help students retain knowledge from classroom discussions for deeper application. Furthermore, as highlighted by Al-Tameemi et al. (2023), providing such targeted reinforcement after initial discussions is crucial for students who initially struggle to comprehend complex Earth and Life Science lessons.

Table 2. Comparison of Pre-test and Post-test Results in Online Simulation Educational Games as Using Normalized Gain Analysis

Participant of the Study	Written Quiz (Pre-Test)	Used online games (Post Test)	Normalized Gain	Interpretation
Student 1	13	17	0.3333	Medium Gain
Student 2	14	15	0.0909	Low Gain
Student 3	7	15	0.4444	Medium Gain
Student 4	15	22	0.7000	High Gain
Student 5	7	15	0.4444	Medium Gain
Student 6	12	16	0.3077	Medium Gain
Student 7	10	18	0.5333	Medium Gain
Student 8	9	15	0.3750	Medium Gain
Student 9	8	16	0.4706	Medium Gain
Student 10	7	15	0.4444	Medium Gain
Student 11	7	16	0.5000	Medium Gain
Student 12	13	22	0.7500	High Gain
Student 13	9	18	0.5625	Medium Gain
Student 14	3	16	0.5909	Medium Gain
Student 15	9	18	0.5625	Medium Gain
Student 16	7	14	0.3889	Medium Gain
Student 17	8	16	0.4706	Medium Gain

Student 18	10	18	0.5333	Medium Gain
Student 19	7	13	0.3333	Medium Gain
Student 20	9	17	0.5000	Medium Gain
Student 21	5	16	0.5500	Medium Gain
Student 22	19	24	0.8333	High Gain
Student 23	19	24	0.8333	High Gain
Student 24	16	24	0.8889	High Gain
Student 25	12	21	0.6923	Medium Gain
Student 26	11	20	0.6428	Medium Gain
Student 27	17	22	0.625	Medium Gain
Mean:	10.48	17.89	0.510330579	Medium Gain
SD:	4.15	3.29		

*Legend: 0.70 to 1.00 - High Gain; 0.30 to 0.69 - Medium Gain; 0.00 to 0.29 - Low Gain*

### Difference between Pretest and Post-test

The paired t-test results for the study, reveal a substantial increase in student knowledge following the intervention. The analysis compared the pre-test scores, which had a mean of 10.48 (SD = 4.15), against the post-test scores, which achieved a significantly higher mean of 17.89 (SD = 3.29). To address the research question regarding whether a significant difference exists in student knowledge before and after the integration of the games, the calculated t-statistic of 16.1044 was compared against the t-critical value of 2.0555. Because the test statistic (16.1044) is much larger than the critical value, it indicates that the observed improvement is not due to random chance.

Furthermore, the p-value of  $4.83 \times 10^{-15}$  is significantly lower than the standard alpha level of 0.05, providing overwhelming evidence against the null hypothesis. Consequently, the null hypothesis, which stated there was no significant difference in student knowledge, is rejected. These findings align with the assertions of Jaaska and Aaltonen (2022), who noted that games serve as powerful reinforcement tools that help students retain knowledge from classroom discussions for deeper understanding. This significant growth is consistent with research by Samortin (2020), who identified that gamification fosters the critical thinking and problem-solving skills necessary to master complex scientific concepts.

Table 3. Paired t-Test Results for Pre-test and Post-test Scores

	n	Mean	SD	T-computed	P-Value	Difference
Pretest	27	10.48	4.15	16.1044	$4.83 \times 10^{-15}$	Significant
Post test	27	17.89	3.29			
Mean Difference		7.41				

### CONCLUSION

This action research investigated the effectiveness of online educational games as a reinforcement tool for teaching genetic engineering to Grade 11 students. The study recognized a need to improve student engagement and knowledge retention in Earth and Life Science, a subject where students often struggle with complex concepts. The intervention involved integrating selected online simulation games into the learning process after classroom discussions, specifically during the "Developing Mastery" phase. Data were collected through pre- and post-tests to measure knowledge acquisition and a Likert scale questionnaire to gauge student perceptions of the intervention's usefulness. The findings indicated that the use of these digital tools led to improvements in student understanding and retention of genetic engineering concepts. The action research concluded that online educational games significantly enhance student learning in Earth and Life Science, particularly in reinforcing complex topics like genetic engineering. The integration of these games after classroom discussions proved effective in addressing the initial challenges students faced in comprehending and retaining the material.

The study demonstrated that such gamified approaches not only make learning more engaging but also contribute to a deeper understanding and application of scientific concepts, thereby improving overall academic performance. Based on the positive outcomes of this action research, it is recommended that educators incorporate online educational games as a regular component of their teaching strategies, especially in subjects requiring the reinforcement of complex concepts. Teachers should explore and select games that align with their curriculum objectives and student learning needs. Furthermore, it is advised that educational institutions provide adequate resources, including reliable internet access and technological tools, to support the effective implementation of such digital interventions. Continued research into the impact of various gamified learning tools across different subjects and grade levels is also encouraged to further enrich pedagogical practices.

## References

- Alotaibi, M. (2024). Game-based learning in early childhood education: a systematic review and meta-analysis. *Frontiers in Psychology*, 15(1). <https://doi.org/10.3389/fpsyg.2024.1307881>
- Bolat, Y., & Tan, N. (2023). Digital Games and Gamification in Education. ResearchGate. [https://www.researchgate.net/publication/378708224\\_Digital\\_Games\\_and\\_Gamification\\_in\\_Education](https://www.researchgate.net/publication/378708224_Digital_Games_and_Gamification_in_Education)
- Maximizing Utilization of the National Achievement Test (NAT) Results to Raise the Achievement Levels in Low Performing Schools, no. DepEd Memorandum no. 160, s. 2012 (2012). [https://www.deped.gov.ph/wp-content/uploads/2012/09/DM\\_s2012\\_160.pdf](https://www.deped.gov.ph/wp-content/uploads/2012/09/DM_s2012_160.pdf)
- Duterte, J. P. (2024). The Impact of Educational Gamification on Student Learning Outcomes. *International Journal of Research and Innovation in Social Science*, VIII(X), 477–487. <https://doi.org/10.47772/ijriss.2024.8100040>
- Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3(1), 275–285. <https://doi.org/10.1016/j.susoc.2022.05.004>
- Handoko, W., Mizkat, E., Nasution, A., Hambali, Y., & Eska, J. (2021). Gamification in Learning using Quizizz Application as Assessment Tools. *Journal of Physics: Conference Series*, 1783, 012111. <https://doi.org/10.1088/1742-6596/1783/1/012111>
- Jaaska, E., & Aaltonen, K. (2022). Teachers' experiences of using game-based learning methods in project management higher education. *Project Leadership and Society*, 3(3), 100041. <https://doi.org/10.1016/j.plas.2022.100041>
- Kalleny, N. K. (2020). Advantages of Kahoot! Game-based Formative Assessments along with Methods of Its Use and Application during the COVID-19 Pandemic in Various Live Learning Sessions. *Journal of Microscopy and Ultrastructure*, 8(4), 175. [https://doi.org/10.4103/jmau.jmau\\_61\\_20](https://doi.org/10.4103/jmau.jmau_61_20)
- Li, Y., Chen, D., & Deng, X. (2024). The impact of digital educational games on student's motivation for learning: The mediating effect of learning engagement and the moderating effect of the digital environment. *PLOS ONE*, 19(1), e0294350–e0294350. <https://doi.org/10.1371/journal.pone.0294350>
- Ratinho, E., & Martins, C. (2023). The role of gamified learning strategies in student's motivation in high school and higher education: A systematic review. *Heliyon*, 9(8), e19033. <https://doi.org/10.1016/j.heliyon.2023.e19033>
- Salgado, J. D. A., & Paglinawan, J. (2025). Teacher's Challenges and Opportunities in Integrating Digital Technology in the Classroom. *International Journal of Scientific and Management Research*, 08(10), 282–292. <https://doi.org/10.37502/ijsmr.2025.81022>
- Samortin, M. (2020). Effects of Gamified Learning Activities in Enhancing Junior High School Students' English Vocabulary Retention • Far Eastern University. Far Eastern University. <https://www.fe.u.edu.ph/asian-journal-on-perspectives-in-education/ajpe-volume-1-issue-1/effects-of-gamified-learning-activities-in-enhancing-junior-high-school-students-english-vocabulary-retention/>
- Selçuk, Z. V., & Keskin, M. Ö. (2024). Gamification in Biology Education: A Systematic Reviews Analysis. *International Journal of Eurasia Social Sciences*, 15(55), 375. <https://doi.org/10.35826/ijoess.4445>
- Thi, L. D. (2025). Game-Based Learning in Improving Student Engagement. *International Journal of Research and Innovation in Social Science*, IX(V), 5116–5123. <https://doi.org/10.47772/ijriss.2025.905000397>