Enhancing Understanding of Mendelian Genetics Using Collaborative Game-Based Learning

Gladys SJ. Olleres

Master Teacher I, Dalandanan National High School

Abstract
This study determined the effectiveness of the Collaborative Game-Based Learning on learners' academic performance in Mendelian genetics. Quasi-experimental research with pretest-post-test two-group design was utilized among eighty Grade 8 students at Dalandanan National High School in the Division of Valenzuela City. Descriptive statistics and Independent T-tests were used as the statistical tool in this study. Both groups were given the same pretest before the use of the intervention. The control group was taught using the traditional method of teaching while the experimental group was taught using collaborative-game based learning. Afterwards, the same post test was administered to both control and experimental groups. Based on the results of this study, the data showed that there is no significant difference between the pretest scores of control and experimental groups. The results showed that baseline values for both groups were similar prior to the new teaching approach being implemented. Moreover, it was found that there is a significant difference between the post-test mean scores of the control group and the experimental group. This suggests that Collaborative Game-Based Learning was more effective in teaching Mendelian genetics lesson than the use of the traditional teaching method It implied that collaborative game-based learning addressed most of the students' needs in learning Mendelian genetics because of the varied game activities and teaching strategies. The interests, collaborative skills, creative and critical thinking skills of the students were also considered that resulted to the success of the teaching and learning process.

Keywords: collaborative, game-based learning, Mendelian genetics

Introduction

Teaching and learning exist in a symbiotic relationship where the effectiveness of one directly influences the other. As teaching is designed to guide learners towards knowledge or skill acquisition, learning often relies on teaching to provide direction, structure, and motivation. Learning should always be an active process. While teaching provides information and instruction, learning requires students to engage actively—through questioning, practice, and reflection.

Science education has been part and parcel of the curricular programs of basic up to higher education. The science curriculum distinguishes the role of science and technology in daily human activities. Sunga and Hermosisima (2016) claimed that science education is an important key to succeed in today's global knowledge environment profoundly shaped by science and technology. Moreover, science education is vital in navigating the volatile, uncertain, complex, ambiguous, disruptive, and diverse world, which is considered a new normal in education (Sadera et al., 2020).

However, science education places a high cognitive and psychological demand on learners. This makes the effort involved in learning science much more significant than other academic subjects. Science often requires students to apply learned concepts in new, unfamiliar contexts. This shift from rote memorization to critical thinking and problem-solving can be challenging for some.

Science education in the Philippines is ailing. As mentioned by Sadera et al., (2020), the existing state of science education in the country, mostly in the basic education level, lags other countries in the world. International and local studies have revealed that Filipino students have low retention of concepts and inadequate reasoning and analytical skill. These serious problem in the field of science education were reflected in the latest result from Programme for International Student Assessment (PISA). From the given data of Organization for Economic Cooperation and Development (OECD), the latest PISA scores show the Philippines performed worse than the global average in math, reading, ad science. In science the average score decreased by one point, from 356 to 355. The mean score in science performance is one of the lowest among PISA-participating countries and economies (PISA 2022). Only 23% of Filipino students reached a basic proficiency in science which means that only one out of every four Filipino students in PISA 2022 can recognize the correct explanation for the familiar scientific phenomenon and validate conclusions (Chi, 2023). In addition to that, Lawsin and Garcia (2017) revealed that Mendelian and non-Mendelian genetics, mitosis and meiosis, and endocrine system are the top three topics where the students have low conceptual understanding and least mastered competencies as indicated by biology in-service teachers of National Capital Region.

Teaching Biology can present challenges mainly due to the complexity of the subject matter, the different scales of biological organization, and because it often includes challenging and counterintuitive concepts that may contradict students' preconceived notions. Integrating gaming into the high school Biology curriculum not only tackles the challenges of teaching complex concepts but can also promote student engagement. Customizing gaming experiences to Biology intricacies enhances critical thinking and creates a dynamic learning environment tailored to the demands of high school biological education (Lantzouni et al., 2024).

According to DOST–SEI (2011), the quality of science education in schools is greatly influenced by the quality of science teachers. Students' interest in science is directly linked to the quality of teaching as well as learning interactions provided by their science teachers. Interviews with students who excelled in science reveal that they were greatly inspired by science teachers who engaged them in tasks that enabled them to inquire and solve problems. Engaging students mean that the teacher must incorporate creative ways of delivering the lessons using teaching aids that hook the interest of the students thereby increasing their engagement with the lesson (Bien, 2023).

Learning through lectures and written assignments can be replaced with learning through games through the use of game-based learning (GBL), which has become an essential component of contemporary education. It enables students to learn fresh approaches to achieve their goals and objectives. Gamification has the potential to significantly improve learning and make it simpler for students to assimilate new material while receiving reinforcement in a fun and engaging fashion. (Bien, 2023)

In line with this, the researcher would like to use an effective teaching strategy that may improve the academic performance of students while learning Mendelian genetics. The integration of collaborative game-based learning (GBL) in the educational setting, particularly in the teaching of Mendelian genetics, addresses key challenges students face in learning science. This study aimed to determine the effectiveness of collaborative game-based learning in teaching Mendelian genetics to Grade 8 learners in Dalandanan National High School for School Year 2025-2026.

Specifically, the study sought answers to the following questions:

1. How may the pre-test results of the control group and experimental group be described?
2. How may the post-test results of the control group and experimental group be described?
3. Is there a significant difference between the pre-test results of the control group and the experimental group?
4. Is there a significant difference between the post-test results of the control group and the experimental group?

Related Literatures and Studies

Liu et.al (2021) found out that game-based learning can be effective in promoting student engagement, motivation, and learning outcomes in science education. They also found that game-based activities can be aligned with the curriculum by mapping game content to learning objectives and competencies. They suggest that game-based learning can be used as a complementary tool to traditional instruction and can be integrated into existing curricula across different subject areas. They note that game-based learning can be particularly effective in promoting 21st-century skills such as critical thinking, problem-solving, and collaboration. Furthermore, Lantzouni et al. (2024) emphasized that games, when applied to teaching, can be used as creative and interactive methods to capture students' interest and convey the relevance of Biology to their lives. While further research is needed to fully evaluate the effectiveness of specific games across diverse contexts and biological topics, the current body of evidence suggests that incorporating games into the curriculum can be a valuable tool in fostering student engagement, learning and achievement. Franco et al. (2023) stated that game-based learning (GBL) encourages students to learn the content of the course while playing and completing games included to promote learning. It is characterized by the exchange of knowledge in informal environments, participation in social activities, and the review of acquired knowledge, while participants play games. Consequently, teachers can see students' progress and make recommendations instantly. Hirsh-Pasek et al. (2020) mentioned that game-based learning involves designing and incorporating educational content within a game format, where players actively participate and interact with the game mechanics to acquire knowledge or develop skills. Many approaches tackle the umbrella of application of game-based learning in different educational fields. Different playful experiences can enable children to construct knowledge by playing and exploring a real-world problem often driven by students' interest in inquiry. Chen et al. (2018) cited that game-based learning is designed to balance theoretical content and learning with games. Game- based learning allows students to explore rigorous learning environments and concepts and targeted learning outcomes. Pho and Dinscore (2015) stated that game-based learning is not superior to other learning approaches in terms of educational potential, but that it has a greater potential to enhance motivation and increase student interest in the subject matter. Contrasting with this assertion, Kucher (2021) stated that other researchers have established that students are better able to retain knowledge learned through game-based approaches than that encountered through other learning approaches, but that this is dependent on the domain in question; interdisciplinary topics that require skills such as critical thinking, interpersonal communication, and debating are those that are associated with the greatest game-based learning advantage. Al-Amri et al. (2021) focused on the use of game-based strategies in teaching chemistry to students with learning disabilities. The authors analyzed six studies and found that game-based strategies were effective in promoting student engagement, improving motivation, and enhancing learning outcomes in chemistry for students with learning disabilities. The authors noted that game- based strategies allowed for differentiated instruction that catered to individual student needs.

The following research support the use of collaborative GBL as an effective pedagogical strategy that improves not only the academic performance but also nurtures key cognitive and social skills. It is especially beneficial in teaching complex science concepts, making it a valuable approach for enhancing both student engagement and long-term retention of knowledge. It also highlights the effectiveness of collaborative game-based learning (GBL) as a transformative educational tool that enhances student engagement, motivation, and academic performance. Key studies emphasize that GBL promotes cognitive development, critical thinking, and problem-solving skills by integrating interactive and competitive elements into the learning process.

Methodologies

Research Design

This study utilized quasi experimental research design to comprehensively explore the effectiveness of collaborative game-based learning on learners' academic performances. The research aims to capture a holistic view of the said intervention.

Respondents

The respondents of this study were eighty Grade 8 learners enrolled in Dalandanan National High School, School Year 2025-2026. The researcher purposively chose two sections from Grade 8 level that served as the control and experimental group. The section under experimental group was provided with the collaborative game-based learning strategy while the section under control group does not receive any treatment. These sections were chosen because the researcher had direct access to both groups. Both the control and experimental group was given pre-test and post-test.

Data Gathering Procedure

The researcher started with the seeking of permission from the School Principal of Dalandanan National High School before the collection of data. The researcher ensured the confidentiality of the data of the respondents and also provided consent forms both for the students and the parents. The researcher had a brief orientation regarding the objective of the said study, its duration, potential risks and benefits for the students and school community. All the data was secured and treated confidentially.

Pre-test was administered to both groups before the start of the lesson. Control group was taught using the traditional approach while the experimental group was taught using the collaborative game-based learning. Series of game-based activities was utilized to ensure the effectiveness of the research. The study took place for two weeks during the second quarter period. After that time frame of the lesson, both groups were given the same post-test. Statistical analyses were conducted to identify significant differences in outcomes between the two groups.

Instrumentation

The pre-test was used to determine the existing knowledge of both groups while the post-test was utilized to assess the result after applying collaborative game-based learning in lessons. By administering the same pre-test and post-test to both the experimental group (participants in collaborative game-based learning) and the control group (participants who will receive traditional instruction), the study had established whether the groups are equivalent in terms of their initial knowledge and abilities. This helped ensure that any differences observed in post-test scores can be attributed to the intervention used rather than pre-existing differences. The instrument that was utilized is a researcher-made test based on the Grade 8 Learning Competencies accompanied by a table of specification. The items in the pre-test and post-test focused on Mendelian genetics such as phenotypic and genotypic traits, monohybrid and dihybrid crossing of traits. The pre and post-test was utilized for both the experimental and control group. A total of 30 multiple choice items was used to measure the learner's academic performance in Mendelian genetics. In order to test the validity of the instrument, three master teachers in science were asked to validate the test questionnaire along with the lesson plan and table of specification.

Results and Discussion

This part presents the analysis and interpretation of data gathered by the researcher from the respondents. The data gathered was utilized to answer the specific problems in the study.

Pre – Test Results of the Control and Experimental Groups

The pre-test is an assessment that learners take to determine their baseline knowledge of the lesson, specifically in Mendelian genetics. The assessment was conducted on both the experimental and control group, and the outcomes are shown in Table 1.

Table 1.
Results of the Pre – Test of the Control and Experimental Groups

Groups	Number of Sample	Mean	SD	Interpretation
Control	40	8.47	1.70	Below Average
Experimental	40	8.41	1.59	Below Average

Table 1 shows the mean scores of the control group in the pre-test which is 8.47 interpreted as below average with standard deviation of 1.70 which indicates that the scores are more varied as it is father from the mean. The mean score of the experimental group in pre-test is 8.41 interpreted as below average with the standard deviation of 1.59. The variation in the experimental group is slightly smaller (SD = 1.59) compared to the control group (SD = 1.70), but the difference is minimal.

Samson (2017) mentioned that the group that has the higher mean with low standard deviation performs better. In this case, before the actual teaching of Mendelian genetics, the control group was perceived to be better than the experimental group. Based on the data, it shows that the mean scores of the control group is quite greater than the experimental group. It also depicts that the individual scores of the experimental group is more clustered than the control group.

The result of the pretest indicates that the baseline knowledge of both the control and experimental groups was below average before the intervention. This could be the outcome of the students' unfamiliarity with the topic and their lack of prior information about the lesson.

According to Dong et al. (2020), learning engagement is strongly influenced by prior knowledge. As Shapiro (2004) noted, prior knowledge interacts with other variables to influence learning outcomes. The relationship between prior knowledge and learning engagement can be further enhanced by self-regulated learning (Yang et al., 2018). It implies that prior knowledge can improve if applied to new learning experiences.

Post test Results of the Control and Experimental Groups

After the treatment, both groups underwent the same test but in a shuffled and paraphrased format and exhibited a different result, as indicated in Table 2.

Table 2.
Results of the Post – Test of the Control and Experimental Groups

Groups	Number of Sample	Mean	SD	Interpretation
Control	40	15.90	3.02	Average
Experimental	40	18.03	3.51	Average

Table 2 shows the mean scores of the control group in the post-test which is 15.90 interpreted as average with standard deviation of 3.02 which indicates that there is moderate variability among the scores. The mean score of the experimental group in the post-test is 18.03 interpreted as average with the standard deviation of 3.51. The experimental group has a bit more variation compared to the control group, with scores spread around the mean.

Findings revealed that after the conduct of instruction, the mean score obtained by the experimental group is greater than the mean score obtained by the control group. It also implies that the individual scores of the control group are more clustered or closer than the individual scores obtained by the experimental group. Likewise, it shows that the experimental group performed better after the instruction rather than the control group. In addition, the improvement of scores in the experimental group is greatly affected by collaborative game-based learning that was applied.

Through the use of collaborative game-based learning, where students' engagement, motivation, problem-solving and critical thinking skills in understanding Mendelian genetics were considered, the students increase their enthusiasm and academic performance in the said topic.

As an educational innovation, the game is a didactic resource for developing various topics in curricular content, promoting cognitive progression, and strengthening the relationship between students and teachers (Hierro et al., 2020). Hwang, et al. (2022) discusses the positive effects of digital game-based learning on students' achievement and learning attitudes in science education. The study demonstrates that GBL enhances students' critical thinking and problem-solving skills, which directly supports the findings about the experimental group outperforming the control group. The study also emphasizes the role of interactive learning environments in fostering better retention of scientific concepts.

Difference Between Control and Experimental Groups Pretest scores

Table 3.
Test of Significant Difference on Pretest scores between the Control and Experimental Group

	Mean	t-value	p-Value	Decision	Interpretation
Control Group	8.47	0.107	0.720	Accept H_o	There is no significant difference
Experimental Group	8.41				

Legend: < 0.01 = sig

Table 3 displays the test of significant differences in pretest scores between the control and experimental

groups. Since the p-value is 0.720 which is greater than at 0.01 level of significance, therefore, we accept the null hypothesis. Moreover, it indicates that there is no significant difference between the pretest scores of both groups of respondents.
This implies that the pretest scores of both groups seem to exhibit no significant variance. This means that both groups' baseline levels were comparable prior to the application of any intervention, such as the introduction of a new teaching strategy. This result is essential for ensuring the validity of any further comparisons between the groups that are conducted once the intervention has been implemented.
Talan et al. (2020) found that in most experiments, pre-test scores showed no significant difference between control and experimental groups, indicating similar starting points for both groups. This study reinforces the finding that pre-test results in both groups were below average and not statistically different, ensuring the comparability of the groups before the intervention.
Difference Between Control and Experimental Groups Pretest scores

Table 4
Test of Significant Difference on Change in Post-test scores between the Control and Experimental Groups

	Mean	t-value	p-Value	Decision	Interpretation
Control Group	15.90	-4.320	.000	Reject H_o	There is a significant difference
Experimental Group	18.03				

Legend: < 0.01 = sig

As shown in Table 4, the test of significant difference in change in posttest and pretest scores between the control and experimental groups rejects the null hypothesis because the p-value of 0.00 is less than 0.01 level of significance.
It indicates that there was a substantial difference in the academic performance of the learners in the experimental group based on the results of the tests administered before and after the intervention. This suggests that the experimental group outperformed the control group as a result of the intervention.
Furthermore, the collaborative game-based learning interactive and engaging elements probably play a major role in the difference in the outcomes that has been seen. By promoting active engagement, collaboration, and critical thinking, students in the experimental group have improved their comprehension of the topics in Mendelian genetics.
The findings of this study were aligned with the study conducted by Hartt et al (2020), game-based learning has emerged as an innovative learning technique that can increase student motivation, emotional involvement and enjoyment. Peer interaction and the ability to share ideas were reported as more effective in the gamified lecture. It also emphasizes the importance of peer interaction and collaboration in GBL environments, which is directly relevant to the findings about the collaborative aspect of this given intervention. The study found that students in GBL scenarios reported greater involvement and a deeper understanding of the material, which aligns with the results that show higher post-test scores in the experimental group.
This shows that students who were taught using the collaborative game-based learning performed better in academics than those who were taught using the usual teaching method. In summary, it implies that the collaborative game-based learning is successful in raising students' academic achievement in comparison

to conventional teaching techniques.

Conclusion

It was evidently shown in the data that the group where collaborative game-based learning was utilized performed better than the group where direct instruction or traditional methods were employed. It implied that collaborative game-based learning addressed most of the students' needs in learning Mendelian genetics because of the varied game activities and teaching strategies. The interests, collaborative skills, creative and critical thinking skills of the students were also considered that resulted in the success of the teaching and learning process. The result of the study implies that the use of this strategy in teaching Mendelian genetics promotes students' experiences and develops abilities relevant to 21st-century needs.

References

1. Adera, J.R.N., Torres, R.Y.S., & Rogayan, Jr. D.V. (2020). Challenges Encountered by Junior High School Students in Learning Science: Basis for Action Plan. Universal Journal of Educational Research, 8(12A), 7405 - 7414. DOI: 10.13189/ujer.2020.082524.
2. Al-Amri, M., Alqahtani, S., & Alamri, S. (2021). A systematic review of game-based learning for students with learning disabilities in chemistry education. Journal of Chemical Education, 98(2), 394-407. doi: 10.1021/acs.jchemed.0c01104.
3. Bien, L. (2023). Utilization of Mobile Game Application in Assessing Students' Learning in Biology. Psychology and Education: A Multidisciplinary Journal, 11(6), 1-11. http://doi.org/10.5281/zenodo.8205780
4. Chen, C., Liu, J., & Shou, W. (2018). How competition in a game-based science learning environment influences students' learning achievement, flow experience, and learning behavioral patterns. Journal of Educational Technology & Society, 21(2), 164-176. http://www.jstor.org/stable/26388392
5. Chi, C. (2023, December 6). Philippines still lags behind world in math, reading and science — PISA 2022. Philstar.com. Retrieved March 10, 2024, from https://www.philstar.com/headlines/2023/12/06/2316732/philippines-still-lags-behind-world-math-reading-and-science-pisa-2022.
6. Cruz, Z. (2023). Game-Based Activities as Teaching Strategy in Chemistry for Grade 9 Students. Psychology and Education: A Multidisciplinary Journal, 11(6), 1-9. http://doi.org/10.5281/zenodo.8203010
7. Dong, A., Jong, M., & King, R. B. (2020). How does prior knowledge influence learning engagement? The mediating roles of cognitive load and help-seeking. Frontiers in Psychology, 11, 591203. https://doi.org/10.3389/fpsyg.2020.591203
8. Franco, I.F., Caviedes,M., Chantre, Y. & Bernate,J.A (2023). Gamification and Game- Based Learning as Cooperative Learning Tools: A Systematic Review. International Journal of Emerging Technologies in Learning (iJET) 18(21):4-23 18(21):4-23 DOI:10.3991/ijet.v18i21.40035
9. Hartt, M., Hosseini, H., & Mostafapour, M. (2020). Game On: Exploring the Effectiveness of Game-based Learning. Planning Practice and Research, 35(5), 589 604. https://doi.org/10.1080/02697459.2020.1778859
10. Hierro, L. and Pastor, E. (2020) "Game-based learning as a social and educational tool in vulnerable community contexts" Revista Prisma Social, Vol. 30, pp. 88-114

11. Hirsh-Pasek, K.& Hadani, H. (2020)A new path to education reform: Playful learning promotes 21st-century skills in schools and beyond.Policy 2020 Brookings.
12. Wang, LH., Chen, B., Hwang, GJ. et al. Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. IJ STEM Ed **9**, 26 (2022). https://doi.org/10.1186/s40594-022-00344-0
13. Kucher, T. (2021). Principles and best practices of designing digital game-based learning environments. International Journal of Technology in Education and Science (IJTES), 5(2), 213-223. https://doi.org/10.46328/ijtes.190
14. Lantzouni, M., Poulopoulos, V., & Wallace, M. (2024) Gaming for the Education of Biology in High Schools. Encyclopedia 2024, 4(2), 672-681; https://doi.org/10.3390/encyclopedia4020041
15. Lawsin, N.L.P. & Garcia, G. (2017). Development of digital courseware in Transmission Genetics (Published Master's Thesis). Philippine Normal University, Manila. https://pnu-onlinecommons.org/omp/index.php/pnu-oc/catalog/book/369
16. Liu,J.H., Chen, C.H., & Shou,W.C. (2018) How competition in a game-based science learning environment influences students' learning achievement, flow experience, and learning behavioral patterns. Educational Technology & Society 21(2):164-176
17. OECD (2023), PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, OECD Publishing, Paris, https://doi.org/10.1787/53f23881-en
18. Pesare, E., Roselli, T.,& Corriero, N. (2016) Game-based learning and Gamification to promote engagement and motivation in medical learning contexts. Smart Learn. Environ. **3**, 5. https://doi.org/10.1186/s40561-016-0028-0.
19. Pho, A., & Dinscore, A. (2015). Game-based learning. Tips and trends.
20. Sadera, J. R. N., Torres, R. Y. S., & Rogayan, D. V., Jr. (2020). Challenges encountered by junior high school students in learning science: Basis for action plan. Universal Journal of Educational Research, 8(12A), 7405–7414. https://doi.org/10.13189/ujer.2020.082524
21. SEI-DOST & UP NISMED, (2011). Framework for philippine science teacher education.
22. Manila: SEI-DOST & UP NISMED
23. Shapiro, A. M. (2004). How Including Prior Knowledge As a Subject Variable May Change Outcomes of Learning Research. American Educational Research Journal, 41(1), 159-189. https://doi.org/10.3102/00028312041001159 (Original work published 2004)
24. Sunga, D. L., & Hermosisima, M. V. C. (2016). Fostering better learning of science concepts through creative visualization. The Normal Lights, (Special Issue), 50 – 63.
25. Talan T, Doğan Y & Batdı V. (2020). Efficiency of digital and non-digital educational games: A comparative meta-analysis and a meta-thematic analysis, Journal of Research on Technology in Education, 52:4, 474 514, DOI: 10.1080/15391523.2020.1743798
26. Yang, T.-C., Chen, M. C., & Chen, S. Y. (2018). The influences of self-regulated learning support and prior knowledge on improving learning performance. Computers & Education, 126, 37–52. https://doi.org/10.1016/j.compedu.2018.06.025