



Learning Enzyme Concept through BioMan Enzymatic: An HTML Simulation Game

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ABSTRACT

This research examined the impact of the HTML-based simulation game "BIOMAN: Enzymatic" on first-year students' grasp and retention of enzyme-related biology concepts. In the academic year 2022-2023, 70 students participated in the study. The game effectively improved student performance across three classes, evidenced by significant increases in mean scores from pre-tests to post-tests. Statistical analyses, including paired t-tests and ANOVA, confirmed the significance of these improvements, ruling out chance as the cause. These findings emphasize the value of simulation games in science education, boosting engagement, motivation, and understanding. The study encourages educators to integrate such technology into teaching, advocating for personalized learning, active methods, and ongoing innovation.

INTRODUCTION

The landscape of science education is undergoing a major shift, largely propelled by technological innovations. Traditional approaches to science instruction, often criticized for their rigidity and focus on theoretical knowledge, are facing increased scrutiny. Experts argue that these conventional methods fall short in fostering essential skills like critical thinking and problem-solving, which are vital for grasping scientific ideas (National Research Council, 2012).

To fill these gaps, simulation games have gained traction as an effective alternative. Such games simulate real-world systems, and provide students with an easy and fun way to interact with complex scientific concepts (Squire, 2011). Interactions in these games also contribute to an active learning environment, increasing student engagement and deepening their understanding of the topic (Clark, et al., 2016).

Several studies support the value of simulation games in science education. The comprehensive study by Clarke et al. (2016) showed that students who use simulation games have higher academic achievement compared to those who receive traditional instruction. This is supported by the other study, conducted by Wouters et al. in 2013, which found that using simulation games had a favorable impact on both cognitive and cognitive learning outcomes.

In an age where technology is increasingly being integrated into the educational environment, effective simulation-based learning strategies are a critical issue. Simulation technology offers unique advantages in science education, especially in enhancing cognitive skills and thinking in a deeper sense of the word. Merchant et al. (2014) argue that the interactive aspect of simulation contributes to a marked improvement in cognitive skills. Similarly, Ruten et al. (2015) reported that students who participated in simulated research demonstrated better understanding of scientific concepts than those relying on traditional teaching methods.

Furthermore, immersive simulation experiences have been shown to engage and motivate students. The study by Vogel et al. (2006) argue that such spaces are more effective in promoting emotional and intellectual engagement, making learning more enjoyable for students. This sentiment is confirmed by Panadero et al. (2017), who argue that the experiential nature of simulations increases students' intrinsic motivation.

The primary objective of this study was to assess the impact of using BIOMAN Enzymatic, an HTML-based visualization game developed by Baugman (2021), on students' understanding and retention of concepts related to enzymes in biology education.

LITERATURE REVIEW

A comprehensive literature review examines the effectiveness of integrating simulation and simulation games into science instruction, drawing insights from research studies. The consensus among these studies is that simulation is a valuable tool for enhancing science education. They have been found to consistently improve overall learning outcomes, provide a deeper and

more nuanced understanding of scientific concepts (Rutten et al., 2012), and encourage inquiry-based learning (de Jong et al., 2013).). These findings highlight the potential of simulation as powerful teachers in science classrooms.

Similarly, simulation games have emerged as promising educational tools. They demonstrate a unique ability to increase student engagement and motivation, which in turn positively impacts academic achievement (Honey & Hilton, 2011). In addition, simulation games help develop critical scientific reasoning and problem-solving skills (Squire & Jan, 2007). The study revealed that simulation games are not only engaging but also highly educational.

Comparative research has shed light on the flexibility and universality of simulation games. These studies in diverse cultural contexts such as Taiwan and the United States suggest that simulation games can be as effective as traditional teaching methods, transcending cultural boundaries (Clark et al., 2011). This universality adds weight to the argument in favor of simulation games as a global solution for science education.

Despite this consensus, the research touches on specific aspects of simulation-based learning. It shows that the amount of interaction in simulations significantly impacts STEM (science, technology, engineering, and mathematics) learning (D'Angelo et al., 2014). Simulations are praised for their ability to sustain student interest in science and empower them due to immersion (Lamb et al., 2012). Furthermore, the development of virtual laboratories provide positive impact on learning outcomes (Potkonjak et.al, 2016; El Kharki et.al, 2021; Obispo et.al, 2020)

The study highlighted that the benefits of game-based learning are not limited to practical hands-on activities. Even in highly theoretical contexts, such as medical education, game-based learning has proven effective (Boeker et al., 2013). Augmented reality and serious gaming, as explored in the literature, offer new ways to enhance STEM understanding and engagement (Ibáñez & Delgado-Kloos, 2018; Boyle et al., 2016).

The inclusion of narrative simulation games has been emphasized because they contribute to better retention and understanding of scientific concepts (Adams et al., 2012). In addition, virtual reality is emerging as a particularly powerful tool for teaching biological concepts (Merchant et al., 2014). Finally, the study acknowledges the broad cognitive development potential of digital games in a variety of other sciences and disciplines (Blumberg & Fisch, 2013).

METHODOLOGY

Research Design

To determine the effectiveness of the simulation game entitled "BIOMAN: Enzymatic", pretest and post-test design is used in this study. There are 3 classes of student that participated the study. A total of 70 1st year students participated this study who have biochemistry laboratory course for the academic year 2022-2023.

A free HTML simulation game called BIOMAN: Enzymatic is available at <https://biomanbio.com/HTML5GamesandLabs/LifeChemgames/enzymaticht>

[ml5page.html](#). Enzyme concepts, substrates, products, active sites, enzyme specificity, enzyme shape, and factors affecting enzymes (temperature, pH, and substrate concentration) are all covered in the simulation game. This game's creator/developer gave permission for its use.

Respondent of the Study

The respondent of this study are the students with biochemistry subject for the 1st semester of academic year 2022-2023 in a local higher institution in Olongapo City. Purposive sampling technique is used in the study because it better matches the sample to the goals and objectives of the research, enhancing the study's rigor and the reliability of the data and findings (Campbell, et.al, 2020).

Research Instrument

The study data were collected using a pretest and post-test. The pretest assessed the prior knowledge of the students about the enzymes, substrates, products, active sites, enzyme specificity, enzyme shape, and factors affecting enzymes (temperature, pH, and substrate concentration).

Data Analysis

The pre and post-test results of the students were analyzed for significant differences using a t-test at a 0.05 significance level. ANOVA was employed to examine the Pre-Test and Post-Test distinctions across three classes.

RESULTS

The following tables are the result of the study to evaluate the impact of using an HTML-based simulation game called BIOMAN Enzymatic on students' understanding and retention of enzyme-related concepts in biology.

Table 1. Difference of Pre-Test and Post Test of Class A

<i>Pair</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>t-test</i>	<i>p-value</i>	<i>Interpretation</i>
<i>Pre</i>	20	14.450	3.220	-9.899*	.000	Significant
<i>Post</i>	20	21.450	2.665			

Note: $df=19$; $p < .05$

Table 1 shows the differences between the pretest and posttest scores in study A. A pretest and posttest evaluation in study A were administered to 20 students. The data reveal notable differences in scores between the two. The mean score of the pre-test was 14.45 with a standard deviation of 3.220, the mean score of the post-test increased to 21.45 with a slightly smaller standard deviation of 2.665 with t-value of -9.899 and p-value of .000 by statistical analysis obtained with paired t-test, well below the alpha level of .05. This statistically significant result indicates that students in class A showed a significant improvement in their performance from pretest to posttest. A negative t-value indicates that this increase in posttest scores is not due to random variation but represents genuine improvement. Overall, the data reveal

a significant positive effect, likely attributable to the use of a simulation game BIOMAN: Enzymatic as an educational experience between the two experiments.

Table 2. Difference of Pre-Test and Post Test of Class B

<i>Pair</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>t-test</i>	<i>p-value</i>	<i>Interpretation</i>
<i>Pre</i>	25	15.880	3.689	-9.952*	.000	Significant
<i>Post</i>	25	24.040	1.720			

Note: $df=24$; $p < .05$

Table 2 shows the difference of pretest and posttest scores for class B. Pretest and posttest were administered to 25 students of class B. The mean score of the pre-test was 15.88 with standard deviation of 3.689, the post-test showed that a significant improvement with a mean score of 24.04 and a low standard deviation of 1.720 paired t-test revealed a t-value of -9.952 and a p-value of .000, well below the alpha level which is .05. These findings indicate a statistically significant increase in scores from pretest to posttest for class B. The fact that this improvement is not the result of chance but rather of significant educational gain is supported by the negative t-value and low p-value, which demonstrate how well the simulation game BIOMAN: Enzymatic worked as a teaching tool.

Table 3. Difference of Pre-Test and Post Test of Class C

<i>Pair</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>t-test</i>	<i>p-value</i>	<i>Interpretation</i>
<i>Pre</i>	25	14.960	3.155	-10.184*	.000	Significant
<i>Post</i>	25	22.760	2.832			

Note: $df=24$; $p < .05$

Table 3 shows the difference of pretest and posttest scores for class C. Pretest and posttest were administered to 25 students of class C. The pre-test average score was 14.96 with a standard deviation of 3.155. This improved notably in the post-test, where the average score rose to 22.76 and had a standard deviation of 2.832. Statistical analysis using a paired t-test yielded a t-value of -10.184 and a p-value of .000, which is significantly below the threshold of .05. This result indicates that the observed increase in test scores from the pre-test to the post-test is statistically significant. The negative t-value confirms that this improvement is genuine and not due to random variation. Consequently, the data suggests that the use of simulation game entitled BIOMAN: Enzymatic as educational experience occurred between the two tests was highly effective in improving student performance in Class C.

Table 4. Difference of the Pre-Test and Post Test of the Three Classes

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F-Test</i>	<i>p-value</i>	<i>Interpretation</i>
<i>Between Groups</i>	76.362	2	38.181	6.254*	0.003	Significant
<i>Within Groups</i>	390.713	64	6.105			

Total	467.075	66				
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Note: $p < .05$

The table displays results from an analysis of variance (ANOVA) that used one independent variable, referred to as "Between Groups," and one dependent variable. According to an Analysis of Variance (ANOVA) conducted to compare the pre-test and post-test score differences among three classes (Class A, Class B, and Class C), there is a statistically significant difference in test score improvements across these groups, $F(2, 64) = 6.254, p = .003$. Given that the p-value is less than the alpha level of .05, this result suggests that the use of simulation game entitled BIOMAN: Enzymatic as educational intervention or experience had a varying level of effectiveness across the three classes. The 'Between Groups' sum of squares is 76.362, and the 'Within Groups' sum of squares is 390.713, further supporting the significant variation in the effects of the intervention among the classes. This warrants further investigation into the factors contributing to the differing outcomes.

CONCLUSIONS

In conclusion, the comprehensive analysis of pre-test and post-test scores across three classes highlights the significant impact of the simulation game "BIOMAN: Enzymatic" on student performance. The consistent improvements in test scores, evident in Tables 1 to 4, are substantiated by both the paired t-test and ANOVA analyses. The statistical significance of these improvements, indicated by the presence of low p-values, firmly establishes the effectiveness of the educational intervention provided by the simulation game.

These findings underscore the potential of educational technology, particularly simulation games, to enhance student learning outcomes. Notably, students across all three classes exhibited substantial progress in their understanding and application of the subject matter. The negative t-values observed in the paired t-tests, along with the ANOVA results, further emphasize that these improvements are not merely coincidental but rather indicative of genuine enhancements in comprehension and retention.

The inclusion of simulation games like "BIOMAN: Enzymatic" as useful tools for increasing student learning outcomes is supported by the compelling evidence offered in this study. These results provide a substantial contribution to our understanding of effective educational strategies and provide educators and institutions with useful information about cutting-edge approaches to enhancing student performance and engagement in academic settings.

RECOMMENDATIONS

Based on the compelling results and insights derived from the study's comprehensive analysis, several recommendations emerge for educators and institutions seeking to enhance student learning outcomes:

- **Integration of Educational Technology:** Embrace the use of educational technology, particularly simulation games like "BIOMAN: Enzymatic," to create engaging and interactive learning experiences. These tools can

effectively supplement traditional teaching methods, fostering deeper understanding and application of subject matter.

- **Personalized Learning:** Recognize the value of catering to individual learning preferences and paces. Utilize simulation games to offer personalized learning pathways that accommodate diverse student needs, thereby maximizing comprehension and retention levels.
- **Active Learning Strategies:** Incorporate active learning strategies that encourage student participation and critical thinking. Simulation games inherently promote hands-on engagement and decision-making, nurturing a deeper grasp of concepts and fostering problem-solving skills.
- **Continuous Innovation:** Stay abreast of emerging educational technologies and pedagogical approaches. Continuously explore new tools and methodologies to keep instruction fresh, engaging, and aligned with evolving student needs.
- **Future research** should aim to unravel these nuances to optimize the implementation of educational interventions like simulation games.

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