International Journal of Formal Sciences: Current and Future Research Trends (IJFSCFRT)
ISSN: 2790-7945

https://ijfscfrtjournal.isrra.org/index.php/Formal_Sciences_Journal/index

PhET Interactive Simulations: A Tool in Improving Academic Performance of Grade 10 Students in Balancing Chemical Equations

Evangeline Q. Omoy*

Department of Education, Ormoc City 6541, Philippines
Email: evangeline.omoy@deped.gov.ph

Abstract

The study assessed the effectiveness of PhET interactive simulation as a tool in improving the academic performance of students on balancing chemical equations, which is the least mastered skill in the 4th quarter of grade 10 Science. The subjects of the study are 8 males and 12 females Grade 10 students who were purposely selected for the study. The instruments used in the study were the validated 15-item pretest and the posttest from the Regional Test Item Bank. The items of the test were purely balancing of chemical equations aligned with the learning competency on how to apply the mass conservation principles to chemical reactions, particularly the skills of balancing chemical equations of (in) Grade 10 Science K-12 curriculum. Moreover, the researcher utilized appropriate statistical tools such as the frequency distribution, mean, percentage, and t-test. The paired sample t-test revealed that there is a significant difference between the students' performance before and after the implementation of the PhET interactive simulation. This is established through the t-value of 15.28, which is greater than the t-critical value of 1.729 (15.28>1.729), and a probability value (p value) of .001, which is less than the 0.05 level of significance (.001<0.05). Based on the data presented, it was evident that the use of PhET interactive simulations is an effective tool in improving the academic performance of the student. It is an effective intervention or remediation tool in assisting learners to develop mastery skills in balancing equations. This implies that PhET interactive simulation is an effective tool in improving the mastery level of students in balancing chemical equations, thus increasing academic performance.

Keywords: PhET Simulation; Academic Performance; Balancing Equations.

---

* Corresponding author.

1. Context and Rationale

In this new normal, teachers are especially important in addressing issues with learning challenges such as self-management, personality, intelligence, moral values, and the skills that both students and society need. Therefore, in order for the students to attain their full potential and improve their learning performance, the teacher must make an effort to connect with them. During this pandemic, the new normal in education has existed and it was noted that the performance of Grade 10 Science students at Valencia National High School has been declining. One of the least learned competencies of grade 10 students in Science 10 is on how to apply the mass conservation principles to chemical reactions, particularly in balancing chemical equations. This is evidenced by the data from SMEA Quarter 4 for School Year 2021–2022 with 33% MPS in the item analysis, which is considered the least learned skills in the quarterly test. This learning competency is consistently one of the least learned skills of grade 10 students and was aggravated by the school closure during the worldwide health crisis – the COVID-19 Pandemic.

Studies reveal that due to invisible concepts' lack of models or representations, students struggle to comprehend complex ideas. The author in, [1] noted that simulations can successfully improve conventional training. Students' ability to visualize science concepts can be improved by the use of Physics Education Technology (PhET) interactive simulation-based activities. Effective science instruction requires the kind of learning that leads to conceptual understanding. As a result, science teachers should use inquiry-and discovery-based approaches, demonstrations and simulations, laboratory-based learning, and other hands-on activities to teach their subjects. Despite the fact that some science topics are theoretical in nature, models and practical representations are nevertheless necessary in order to comprehend the concepts. The balancing of chemical equations carries many concepts which need to be well understood by the learners. Since it is the cornerstone of learning chemistry, they must understand how to balance chemical equations.

Chemical equations haven't been balanced appropriately by the students. The performance of grade 10 learners in balancing chemical equations has been low, hence the need to find better ways of improving the learners' performance. PhET, short for Physics Education Technology, is a group of interactive computer simulations for teaching and studying the STEM (Science, Technology, Engineering, and Mathematics) fields that are based on research. In order to change the way science is taught and learned, Nobel Laureate Carl Wieman founded PhET simulations in 2002 [2]. Approaches used in PhET Interactive Simulation replicate a real-world occurrence. PhET offers enjoyable, no-cost, interactive simulations of science and mathematics that are based on research. The interactive simulation in PHET enables students to fully engage in the teachings, just like they would when playing a video game. In line with constructivism learning theory, which holds that students actively create meaning, the PHET interactive simulation is a student-centered teaching strategy [3, 4]. It is based on socio-constructivist and constructivist learning theories with the intention of promoting and assisting active knowledge production through dialogue between students and content [5].

In this study, the PhET Interactive Simulation is used as a tool in improving students' mastery of balancing chemical equations, a least learned skill in the 4th quarter of Science 10.

2. Innovation, Intervention and Strategy

Recent studies have examined the effectiveness of interactive simulations in science education [5, 6, 7]. These interactive simulations hold a distinctive place in science teaching and learning because they provide fresh learning settings that aim to improve teachers' capacity for instruction and encourage students' active participation [8]. Along with technological advancements, the availability of computers, mobile phones, and related devices like LCD projectors and SMART televisions has expanded. This has led to an increase in the use of simulation-based software physics programs. Through the Google Play Store, the students downloaded the PhET Simulations Android app, which includes all HTML simulations and their translations for offline use on Android smartphones and tablets. PhET simulation is a software app that is freely downloadable and usable offline.

Levels in the software allow users to go from more straightforward chemical equations to more challenging ones. As they go from one level to another, the students' ability to control the balancing of chemical equations gets better. The coefficients and subscripts in a chemical equation are seen using this simulation. Constructivism theory, advocated by PhET Interactive Simulation, boosts students' attitudes toward academic success and encourages them to learn scientific knowledge and abilities. The students' enthusiasm for learning increases.

During the intervention. The students collaborated in groups. Each student opens the app on their devices or loads the simulation at http://phet.colorado.edu/en/simulation/ balancing-chemical-equations. To start the simulation, click the triangle-shaped "play" button. They can choose between the introductory and game simulations (re-selectable at the bottom of the window once they are in one). Before they start the exercise, it is advised that they experiment with the various buttons and functions. The "Game" simulation would be used to test and refine students' understanding of and aptitude for balancing equations, it was explained to the class.

In this interactive simulation, users can change an equation's coefficients while viewing molecules in a box above the equation. Users may now understand what the symbols in the chemical equation actually signify thanks to this. They are able to count the quantity and type of each atom as well as how the count of each atom changes when the coefficient varies. Once the equation is balanced, a broad smiley face emerges to show that the reactants and products both contain the same amount and kind of atoms. Users can access a toolbox in the introduction section to display a bar chart of each type of atom present in the reactants and products to help them understand what a balanced equation is. They can also see a scale for each type of atom that is present and balances when the same number of each is present on both the reactant and product sides. The user has the option to play one of three games with increasing levels of difficulty to further establish the principles after solving the three introduction equations.

When working in a group, they alternately use the Level 1 tactics they learned to balance the equations in the simulation in level 2, adding new ones as necessary. Each person should be in charge of solving at least one equation even when working in a group, seeking assistance from the others as necessary. They recorded the equations as they were solved collectively. The students balance the equations that were embedded in the interactive simulation program for PhET.

The software contains levels where users can move from simpler chemical equations to more difficult ones. The capacity of the learners to balance chemical equations improves as they move from one level to another. After completing the simulation, the students' respondents presented their findings to the class.

3. Action Research Questions

The purpose of the study is to determine how PhET interactive simulation can help students master the skills in balancing chemical equations thus increasing academic performance. Specifically, it sought to answer the following questions:

What is the level of performance of students in balancing chemical equations

1. before the use of PhET Interactive Simulation?
2. after the use of PhET Interactive Simulation?

Is there a significant difference in the mean scores of students' before and after using PhET interactive simulation in balancing chemical equations?

Null hypothesis:

There is no significant difference in the mean scores of students' before and after using PhET interactive simulation in balancing chemical equations

4. Action Research Methods

A. Participants and/or Other Sources of Data and Information

A.1 Research Design

Due to one group of students receiving remedial instruction in balancing chemical equations using the "PhET Interactive Simulation," the researchers utilized a quasi-experimental one group Pre-Test-Post-Test approach. To determine the effect of the intervention, pre-test and post-test were conducted and compared.

$O1\ x\ O2$

Where:

$O1$ – test before the treatment

x – treatment (PhET simulation))

$O2$ – test after the treatment

Due to the nature of the problem at hand, the researcher chose to employ this design. Only selected learners who require remediation have been chosen for the "PhET Simulation," which is intended to be used as a re-teaching tool (Bugan, 2016). Only the data collected from the experimental group were used in this investigation.

A.2 Research Respondent

The subjects for the study were chosen from a group of Grade 10 students who performed poorly on a periodic test and failed the quiz on balancing chemical equations. Students were chosen using basic random sampling (Fishbowl method). This sample method involved selecting a name at random from a list of the pooled students' names on a piece of paper. Twenty sheets have been drawn to form the 8 males and 12 female Grade 10 students.

A.3 Research Instruments

The researcher used the following tools and instruments in conducting this study. The "PhET Interactive Simulation" in balancing chemical equations which the students downloaded/accessed in PhET Colorado website http://phet.colorado.edu/en/simulation/balancing-chemical-equations, and the Students' Pre-Test and Post Test in balancing chemical equations.

PhET offers enjoyable, cost-free, interactive simulations of science and math based on research, PhET simulations are particularly excellent for providing visual representations of challenging scientific ideas while engaging learners through manipulation. This is an effective teaching tool that influences students' understanding (Taneo, 2021). Anyone with a device and an Internet connection can easily access and use PhET simulations.

The 15-item Pretest and Post-Test questions in balancing chemical equations were taken from the Regional test item bank since it was already validated. Balancing chemical equations was the sole focus of the test's questions, which were matched with the learning competency on applying the principles of conservation of mass to chemical reactions focused on balancing chemical equations (S10MT-IVe-g-23) of the Grade 10 Science K–12 curriculum.

B. Data Gathering Methods

In order to address the stated concerns, this study conducted quantitative research. Several statistical tools were utilized to assess or evaluate the data acquired.

B.1 Pre-implementation

The 15-item Student's Pretest was given to 20 students to gauge their degree of prior knowledge. The frequency distribution of the scores for each item, the mean, and the standard deviation were used to analyze the Pretest in order to visualize and illustrate the data gathered, define the distribution, and assess the level of score dispersion.

B.2 Implementation

The learners used the interactive PhET simulation on balancing chemical equations following the pretest. To gauge the students' progress, the researcher examined students' responses to the simulation. The task is repeated until the learner is able to respond to the interactive simulation activities/questions in the PhET.

B.3 Post implementation

Next, the post-test will be finished by the students. There was data encoding, analysis, and verification. It was assessed how much the scores from the Pre- and Post-Test differed. A significant increase in the post-test score indicates that the student has learned the simulation. Additionally, the significance of the difference between the pre-test and post-test data was determined using a two-tailed paired-sample t-test of means. With 19 degrees of freedom, the test analysis is set at a 95% confidence level.

5. Discussion of Results and Reflection

Based on the gathered data the researcher found the following:

A. Prior to Intervention

What is the level of performance of the students in balancing chemical equations before the use of PhET Interactive Simulation?

Table 1: Pretest result.

Score Range (15 item test)	Pretest		
	Scores Frequency	Percentage	Performance Level
14-15	0	0	Very Good
9-13	0	0	Good
5-8	6	30%	Average
0-4	14	70%	Low
Total	20	100%	**Low**
Mean	**3.6**		

Table 1 shows the level of performance of students based on the results of the 15-item pretest in balancing chemical equations. The results showed that the students had a "low" performance in the pre-test with a mean score of 3.6. Pre-test results show that not a single student scored 14-15 and 9-13 with "Very good" and "Good" performance levels; 6 out of 20 or 30% performed in the "Average" level; and 70%, or 14 out of 20, scored 0-4, which is considered low performing.

This data indicates that students require intervention to increase their level of performance. According to one of the most difficult concepts for teachers to teach and tough for students to understand in chemistry is balancing equations (Aplaon, 2019).

B. After the Intervention

After implementing the PhET Interactive Simulation activities on balancing chemical equations, students were given a post-test. The results were tallied and analyzed.

What is the level of performance of the students in balancing chemical equations after the use of PhET Interactive Simulation?

Table 2: Post-test Result.

Score Range (15 item test)	Post Test		
	Scores Frequency	Percentage	Performance Level
14-15	5	25%	Very Good
9-13	14	70%	Good
5-8	1	5%	Average
0-4	0	0	Low
Total	20	100%	**Good**
Mean	**12**		

On the other hand, the post-test revealed that 5 out of 20 respondents, or 25% of the group, performed very well, while more than half, or 70% of the population, scored between 9 and 13, and performed well, and 1 out of 20 subjects, or 5% of the group, had an average performance, and not a single student scored 0-4, which is in the low level of performance. It was very evident that there was an increase in students' scores. One study found that, PhET interactive simulation proved a more effective way to cultivate positive attitudes and attain academic excellence. (Bhatti & Teevno, 2021).

Table 3: Mean of Pretest and Post-Test Scores.

No. Of Items	df	Pre-Test Mean	Post-Test Mean	Difference
15	19	3.6	12	8.4

The table displays the results of the pretest and post-test in the 15-item test that the researcher administered before and after using the PhET Interactive Simulation. It was found that the pretest mean score was 3.6, and its mean score of 12 supported the post-test result.

The data unmistakably shows that the mean of the respondents' pretest significantly increased after they used the interactive simulations from PhET for balancing chemical equations This is an apparent indication that the utilization of PhET Interactive Simulation is effective and powerful method in improving learners' performance and mastering the skills of balancing chemical equations, which is one of the least learned skills in the fourth quarter of Grade 10 Science .

Is there a significant difference in the mean scores of students' before and after using PhET interactive simulation in balancing chemical equations?

Table 4: Finding the Significant Difference in the means Before and After the Utilization of PhET.

Compared Variables	*df*	*Means*	*SD*	*t-value*	*Critical t-value*	*P-value*	*Decision*	*Impression 0.05 Level*
Pretest	*19*	*3.6*	*1.31*	15.28	*1.729*	*<.001*	*Reject Ho*	*Significant*
Posttest		*12*	*2.15*					

Table 3 shows the result of the t-test on finding the significant difference between the pre-test and post-test. Following data computation, it became apparent that the t-value, 15.28, exceeded the t-critical value, 1.729, at the degree of freedom, 19. Additionally, it demonstrates that the p-value is <.001, indicating that the result is significant at p 0.05. As a result, the null hypothesis is rejected. There is a significant difference in the mean scores of students before and after the utilization of PhET Interactive Simulation in balancing chemical equations. PhET Interactive Simulation is a learner-centered approach supported by constructivism learning theory that says learners construct knowledge rather than just passively take in information. It is an effective and successful instrument for raising students' academic performance in their least mastered areas the balancing of chemical equations because learners are actively engaged in the learning process and acquire knowledge and skills even when attempting new approaches.

6. Conclusion

Based on the data presented, the researcher concludes that the use of PhET interactive simulations is an effective tool in improving the academic performance of the student. It is an effective intervention or remediation tool in assisting learners to develop mastery skills in balancing equations. When PhET interactive simulations are properly implemented in lessons where students are struggling to comprehend scientific ideas, such as how to balance chemical equations, they are far more likely to become engaged in the lesson, which in turn boosts their academic performance. Therefore, the use of PhET simulations can be seen as an effective solution that can improve the learners' poor performance and mastery of least learned skills.

7. Recommendations

1. Conduct further research on students' attitudes and perceptions in the use of PhET Interactive Simulation.
2. Research the application of PhET in different scientific fields, such as Biology, Earth Science, and Chemistry lessons.

Acknowledgement

I would like to express my great appreciation to Abel M. Dayandayan for his valuable and constructive suggestions during the planning and development of this research work. His willingness to give his time generously has been very much appreciated. I would also like to thank Lengie Dalupan-Gabi for her advice, enthusiastic encouragement, and useful critiques of this research work. Special thanks should be given to my husband, for his love, support, and encouragement throughout, in making this study a success.

Above all, I would like to acknowledge the help, mercy, and guidance of our almighty God, who made this study possible. All honor and glory to GOD.

References

[1]. N. Rutten."The Learning Effects of Computer Simulations in Science Education". Computer and Education Journal, vol.58, pp.136-153, Jan.2012.

[2]. Q. Jia. "A brief study on the implications of constructivism teaching theory on classroom teaching reform in basic education". International Education Studies, vol. 2, pp. 2-4, 2010.

[3]. M. Saudell,R.Klelv,J.Davies."PhET Simulations in Undergraduate Physics: Constructivist Learning Theory in Practice". A Journal of Educational Research and Practice. vol.31,pp.52-69.2021

[4]. KKPerkins, Loeblein PJ, Dessau KL. "SIMS for science: Powerful Tools to Support Inquiry Based Teaching". The Science Teacher. 2010;77(7):46-71.

[5]. A. Jimoyiannis, V. Komis. "Computer simulations in chemistry teaching and learning: A case study on students' understanding of preparing soluble salts". Computer & Education, vol.36, pp.183-204,2001

[6]. A.Bhatti, R.Teevno,S.Devi."Teaching Balancing Of Chemical Equations Through Phet Interactive Simulations and Powerpoint Presentation SlideShow Visualisation". Elementary Education Online. Journal, Vol 20 (Issue 1): pp. 4298-4317,2021. http://ilkogretim-online.org

[7]. J.Erlin Eveline, ,I.Wilujeng,& H.Kuswanto."The Effect of scaffolding approach assisted by phet simulation on students' conceptual understanding and students' learning independence in physics". Journal of Physics:Conference Series, vol.1233, pp.12-36. https://doi.org/10.1088/1742- 6596/1233/1/012036

[8]. J. Potane, R. Bayeta."Virtual Learning Through PhET Interactive Simulation: A Proactive Approach in Improving Students Academic Achievement in Science" 2018 https://www.researchgate.net/publication/324673528_

[9]. E.Taneo, E. Liberty , Moleño, E.Ruth."Students' Performance Using Physics Education Technology (PhET) Interactive Simulation Strategy"at https://jespnet.com/journals/Vol_8_No_2_June_2021/8.pdf

[10]. J.Chamberlain,M., Lancaster, K. Parson, & K.Perkins. (2017). How guidance affects student engagement with an interactive simulation. Chemistry Education Research and Practice, 15(4), 628-638. https://doi.org/10.1039/c4rp00009a. 2017

Appendix

Action Plan and Timelines

Table 5

OBJECTIVE	STRATEGIES	PERSONS INVOLVED	TIME FRAME	EXPECTED OUTPUT
Pre-Implementation Phase				
Developed a Research Proposal	Drafted Context & Rationale, Research Questions and Methods	Researcher	April 2022	Research proposal completed
Submitted Research Proposal	E-mailed a hard copy to the DO's research coordinator.	Researcher Research Coordinator for District VI School Principal	May 2022	Completed research proposal
Created pre- and post-test questionnaires that were validated	Constructed Pretest and Post-test Questionnaire. For validation, I showed the constructed Pretest and Post-test to the Grade 10 teacher and Master Teacher. Production of test papers for Pretest	Researcher Grade 10 Teachers Master teacher	May 2022	Printed Pretest and Posttest questionnaire
Downloaded PhET Interactive Simulation activity on balancing chemical equations	Check Internet Connectivity in the classroom and download PhET simulation. Check materials and gadgets for students use	Researcher Students/Respondents	June 2022	PhET Interactive Software downloaded in student's gadgets and teacher's laptop
Implementation Phase				
Application of the PhET interactive simulation	Student's gadgets connected to the internet and access PhET Colorado site for the simulation on balancing chemical equations	Researcher Students/Respondents	June 2022	Students' scores during the simulation
. Post-test results compilation	Let the respondents answer the post-test Checking of answer sheets	Researcher Respondents	June 2022	Students raw score recorded
Analyzed Data	Collected, Calculated,		July 2022-	Data Analysis and

	tabulated and analyze results Discussion of results based on tabulation Data Interpretation	Researcher Statistician	September 2022	Interpretation stated in the research paper
Completed action research	Go over different parts of the research and complete all research output Final revision of output	Researcher	October 2022	Complete action research
Post Implementation Phase				
Presentation of Complete Action Research	Presentation of results	Researcher School principal	October 2022	Hard Copy of complete action research
Publication of Research Findings	Share the results of research during the Learning Action Cell session.	Researcher School Principal Teachers	December 2022-January 2022	LAC Plan Activity Completion Report