Sapientia Foundation Journal of Education, Sciences and Gender Studies (SFJESGS), Vol.7 No.4 December, 2025; pg. 19 – 28
ISSN: 2734-2522 (Print); ISSN: 2734-2514 (Online)

EFFECT OF GAMIFICATION ON SENIOR SECONDARY STUDENTS' ACADEMIC ACHIEVEMENT IN CHEMICAL REACTIONS IN ENUGU EDUCATION ZONE OF ENUGU STATE

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ABSTRACT

This study investigated the effect of gamification on senior secondary school students' academic achievement in chemical reactions in Enugu Education zone of Enugu State. Two research questions guided the study while three null hypotheses were tested at .05 level of significance. Quasi experimental research design was adopted for the study. The population for the study comprised 3,142 Senior Secondary School II (SS II) chemistry students. The sample size of 258 SS II students was drawn using purposive random sampling technique. The instrument for data collection was Chemical Reactions Achievement Test (CRAT) which was developed by the researcher and validated by three experts from Department of Science Education, Enugu State University of Science and Technology. Kuder-Richardson 20 (K-20) formula was used to estimate the reliability of the instrument and a reliability index of .80 was obtained. Mean and standard deviation were used for answering the research questions while Analysis of Covariance (ANCOVA) was used to test the null hypotheses. The findings of the study showed that students who were taught chemical reactions using gamification had improved academic achievement than their counterparts who were taught using lecture method. It was also found that male students had improved academic achievement than their female counterparts when exposed to gamification. In line with the findings, the study recommended that teachers should integrate gamification strategies, such as interactive quizzes, rewards, and problem-solving games, into teaching chemical reactions to enhance students' academic achievement.

Keywords: Gamification, Lecture Method, Academic Achievement, Chemical Reactions.

Introduction

Chemistry is a fundamental science that explains the composition and behavior of matter, influencing various fields such as medicine, engineering, and environmental science. It is a subject that focuses on understanding the structure, characteristics, creation, and applications of substances. Chemistry is a branch of science that deals with the properties, composition, formation, and product of matter. Aniodoh and Egbo (2013) defined chemistry as a branch of science concerned with studying the structure, composition, properties, and reactions of matter in various states. It explores how various materials interact and the optimal environments for these interactions. Chemistry also focuses on examining the atomic and molecular makeup of matter to discern its properties both in terms of quantity and quality (Ababio in Usang & Okoli, 2021). Chemistry at the secondary education level serves as a foundation for understanding the subject and prepares students who intend to pursue chemistry at higher levels in the future.

However, despite its significance, students' academic achievement, particularly in external examinations such as the Senior School Certificate Examination (SSCE) conducted by the West African Examination Council (WAEC), has been consistently low (West African Examination Council (WAEC) Chief Examiner, 2018). This issue is a matter of concern for science educators, researchers, and chemistry teachers because inadequate foundational knowledge may hinder students' future studies in chemistry (Adekunle, 2015). Acid-base reactions play a fundamental role in chemistry, serving as a cornerstone for understanding various chemical processes and reactions. Additionally, chemistry contributes to technological advancements by developing new materials, pharmaceuticals, and sustainable energy solutions. Chemistry provides the fundamental principles that explain how substances interact, transform, and produce new materials through various chemical reactions.

Chemical reactions involve the transformation of one or more substances into different substances through the breaking and forming of chemical bonds (Brown, LeMay & Bursten, 2014). According to Atkins and de Paula (2018), a chemical reaction is a process in which reactants undergo a chemical change to form products with different compositions and properties. Kotz, Treichel, and Townsend (2019) defined chemical reactions as processes that involve the rearrangement of atoms in reactant molecules to create new substances with distinct physical and chemical characteristics. Despite various efforts to improve students' performance in chemistry, their academic achievement in the subject remains consistently low. Several factors have been identified as contributing to this poor performance, with the instructional methods used by chemistry teachers being a major concern (Rasha, 2017 ; Usman, 2015).

The instructional approach chosen by teachers plays a crucial role in shaping students' academic performance in chemistry, with teacher-centered methods being widely used by educators. Research suggests that many chemistry teachers rely heavily on lecture-based instruction, which, while effective for delivering large amounts of information, often fails to actively engage students in the learning process (Anih & Ukeh, 2023). Additionally, limited access to well-equipped laboratories and inadequate teaching resources in many Nigerian secondary schools further impede students' ability to fully grasp chemistry concepts (Sulaiman & Shahrill, 2015). The absence of hands-on experiments and interactive learning experiences reduces students' interest and retention of scientific principles. Lecture methods, though useful for handling large classes, do not foster creativity, inquiry, or scientific reasoning among students. Instead, they promote rote memorization, leading to a shallow understanding of concepts that are easily forgotten (Ogbu, 2018). Furthermore, studies have shown that students often perceive lecture-based teaching as ineffective, particularly in science-related subjects that require practical engagement (Eze et al., 2020 ; Ukeh et al., 2020; Omeje, 2023; Ukeh & Nwankwo, 2023). Implementing student-centered teaching strategies, such as inquiry-based learning and problem-solving approaches, could enhance students' understanding and interest in chemistry. Therefore, addressing these instructional challenges is essential for improving students' academic achievement in chemistry, and one effective strategy to achieve this is through gamification.

Gamification is the use of game design principles in non-game settings to boost engagement, motivation, and learning. Bayat et al. (2014) described gamification as an enjoyable teaching method that encourages repetition in a fun environment for students. Dichev and Dicheva

(2017) defined gamification as an approach that enhances engagement by incorporating game elements into educational activities. By integrating aspects of video games, gamification helps to make learning experiences more interactive and engaging. It fosters student participation by introducing competition, rewards, and challenges that stimulate interest in the subject matter. According to Flores et al. (2022), gamification applies game mechanics to education, creating an environment that supports motivation and enthusiasm. When effectively implemented, gamification can complement teaching strategies to improve knowledge retention and comprehension. It transforms passive learning into an active process, where students take ownership of their learning journey. The use of gamification in education has been shown to increase collaboration, problem-solving skills, and critical thinking. Ultimately, these benefits contribute to improved student performance and higher academic achievement.

Academic achievement refers to the extent to which a student has attained their educational goals, measured through grades, test scores, and overall performance in academic activities. Academic achievement refers to the extent to which a student has attained their educational goals, often measured through standardized tests, grades, and completion of educational milestones. According to Borman et al. (2019), interventions that address academic and social challenges can lead to improvements in students' academic performance, behavior, and well-being. Similarly, Wößmann (2016) emphasizes that educational institutions and systems play a significant role in influencing student achievement, highlighting the impact of school accountability, autonomy, and choice on learning outcomes. Therefore, academic achievement serves as a critical indicator of a student's learning progress and overall educational development. Gibson et al. (2015) , Zainuddin, Chu, Shujahat, and Perera (2020), Nwankwo and Ukeh (2023) and Bushra, Yousuf, and Parveen (2023) reported that students who were taught using gamification had improved academic achievement than their counterparts who were taught with lecture method. Academic achievement is influenced by various factors, including cognitive abilities, learning opportunities, and societal expectations, which can differ based on gender.

Gender encompasses the roles, behaviors, activities, and characteristics that a society deems suitable for men, women, and individuals with diverse identities. According to Suzanne (2010), gender is defined as the state of being male or female. Teaching methods can either acknowledge gender differences or reflect biases based on gender. Research has shown that some instructional strategies favor one gender over the other. A study by Gibson et al. (2015) indicated that male students tend to outperform female students in science subjects. It is based on the above background that this study investigated the effect of gamification on senior secondary students' academic achievement in chemical reactions in Enugu Education zone of Enugu State.

Statement of the Problem

Academic achievement in Chemistry, particularly in chemical reactions, has remained a challenge for many senior secondary students in Nigeria. Traditional lecture-based teaching methods often fail to engage students actively, leading to poor understanding and low performance in Chemistry. Research has shown that students struggle with abstract concepts in chemical reactions, which require interactive and practical learning approaches for better comprehension. In Enugu Education Zone, reports from examination bodies indicate a consistent decline in students' performance in Chemistry, raising concerns among educators

and policymakers. Gamification, which integrates game-like elements into learning, has been suggested as a potential strategy to enhance students' motivation, engagement, and academic performance.

However, its application in Chemistry education, particularly in Enugu Education Zone, remains largely unexplored. Furthermore, gender differences in academic achievement have been widely debated, yet little is known about how male and female students respond differently to gamified learning in Chemistry. Existing studies on gamification have focused on other subjects, leaving a gap in its effectiveness in teaching chemical reactions at the senior secondary level. Given the persistent low achievement in Chemistry and the need for innovative teaching strategies, it is crucial to investigate the effect of gamification on the academic achievement of senior secondary students in chemical reactions, considering gender differences in the Enugu Education Zone of Enugu State.

Purpose of the Study

The purpose of the study was to investigate the effect of gamification on senior secondary students' academic achievement in chemical reactions in Enugu Education zone of Enugu State. Specifically, the study investigated the:

1. effect of gamification on SS II Chemistry students' academic achievement when taught chemical reactions and those taught the same topic using lecture method;
2. influence of gender (male and female) on Chemistry students' academic achievement when taught chemical reactions using gamification.

Research Questions

The following research questions guided the study:

1. What are the mean achievement scores and standard deviations of SS II Chemistry students taught chemical reactions with gamification and those taught the same topic using lecture method?
2. What are the mean achievement scores and standard deviations of male and female SS II Chemistry students taught chemical reactions with gamification?

Hypotheses

The following hypotheses were tested at .05 level of significance:

Ho_1: There is no significant difference between the mean achievement scores and standard deviations of SS II Chemistry students taught chemical reactions using gamification and those taught the same topic using lecture method in both pre-test and post-test.

Ho_2: There is no significant difference between the mean achievement scores and standard deviations of male and female SS II Chemistry students taught chemical reactions with gamification.

Ho_3: There is no significant interaction effect of gender and method (gamification) on students' academic achievement in chemical reactions.

Research Method

Quasi experimental research design was adopted for the study. Nworgu (2015) described a quasi-experimental research design as one where it's not feasible to randomly allocate participants to both experimental and control groups. The population for the study comprised 3,142 Senior Secondary School II (SS II) chemistry students. The sample size of 258 (133 for

experimental group (72 for male and 61 for female) and 125 for control group) SS II students was drawn using purposive random sampling technique. The instrument for data collection was Chemical Reactions Achievement Test (CRAT) which was developed by the researcher and validated by three experts from Department of Science Education, Enugu State University of Science and Technology. Kuder-Richardson 20 (K-20) formula was used to estimate the reliability of the instrument and a reliability index of .80 was obtained.

Chemistry teachers assigned to the experimental group received training on using the gamification to teach chemical reaction topics. A detailed lesson plan was developed to guide the lessons. On the other hand, teachers in the control group received no formal training and continued with their usual lecture method. The intervention lasted four (4) weeks, following the regular school timetable. Chemistry classes were scheduled for one (1) double period (80 minutes) and one (1) single period (40 minutes) each week. Each topic was covered in one (1) week across the four-week period. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) tested the null hypotheses. ANCOVA was chosen because intact classes were used, making it difficult to ensure equal initial abilities. The null hypothesis was rejected if the probability value was less than or equal to 0.05 ($P \leq 0.05$); otherwise, it was not rejected.

Results Presentation

Research Question 1: What are the mean achievement scores and standard deviations of SS II Chemistry students taught chemical reactions with gamification and those taught the same topic using lecture method?

Table 1: Mean achievement scores and standard deviations of students taught chemical reactions with gamification and those taught using lecture method

Groups	Number	Pre-test		Post-test		Mean Gain
		Mean ($\bar{x}$)	Standard Deviation (s)	Mean ($\bar{x}$)	Standard Deviation (s)	
Experimental	133	34.89	5.03	37.09	5.13	2.20
Control	125	32.44	4.86	33.99	5.01	1.55
Mean Diff.						**0.65**

Table 1 presents the mean achievement scores and standard deviations of SS II Chemistry students taught chemical reactions using gamification (experimental group) and the lecture method (control group). The pre-test mean scores for the experimental and control groups were 34.89 and 32.44, respectively, with standard deviations of 5.03 and 4.86, indicating similar initial performance. After the intervention, the post-test mean scores increased to 37.09 for the experimental group and 33.99 for the control group, with mean gains of 2.20 and 1.55 , respectively. The mean difference of 0.65 suggests that students taught with gamification achieved slightly higher gains than those taught using the lecture method.

Research Question 2: What are the mean achievement scores and standard deviations of male and female SS II Chemistry students taught chemical reactions with gamification?

Table 2: Mean achievement scores and standard deviations of male and female students taught chemical reactions using gamification

Gender	Number	Pre-test Mean ($\bar{x}$)	Pre-test Standard Deviation (s)	Post-test Mean ($\bar{x}$)	Post-test Standard Deviation (s)	Mean Gain
Male	72	33.87	4.89	36.91	5.05	3.04
Female	61	31.65	4.03	33.56	4.83	1.91
Mean Diff.						**1.13**

The results in Table 2 show that both male and female SS II Chemistry students improved in their achievement scores after being taught chemical reactions using gamification. The mean achievement score for male students increased from 33.87 in the pre-test to 36.91 in the post-test, with a mean gain of 3.04, while female students' scores rose from 31.65 to 33.56, with a mean gain of 1.91. The standard deviations for both genders indicate slight variations in performance, with male students having a higher posttest standard deviation (5.05) compared to females (4.83). The mean difference of 1.13 suggests that male students performed slightly better than female students after the intervention.

Hypotheses

H_{O1}: There is no significant difference between the mean achievement scores and standard deviations of SS II Chemistry students taught chemical reactions using gamification and those taught the same topic using lecture method in both pre-test and post-test.

Table 3: Analysis of Covariance on the mean achievement scores of Chemistry students taught chemical reactions using gamification and those taught using lecture method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision
Corrected Model	202.22	2	101.11	3.91	.000	Rejected
Intercept	129.03	1	129.03	9.58	.000	
Pretest	211.45	1	211.45			
Group	370.81	1	370.81	11.01	.000	
Error	107.26	256	.419	8.54	.030	
Total	1020.77	258				
Corrected Total	1011.41	257				

The Analysis of Covariance (ANCOVA) in Table 3 shows a statistically significant difference between the mean achievement scores of SS II Chemistry students taught chemical reactions using gamification and those taught with the lecture method. The significance value (Sig. = .000) for the group effect is less than 0.05, leading to the rejection of the null hypothesis (Ho1). This indicates that gamification had a significant positive impact on students' achievement compared to the lecture method. The F-value of 11.01 further supports this finding, suggesting that the teaching method played a crucial role in influencing students' learning outcomes.

Ho_2: There is no significant difference between the mean achievement scores and standard deviations of male and female SS II Chemistry students taught chemical reactions with gamification.

Table 4: Analysis of Covariance on the mean achievement scores of male and female Chemistry students taught chemical reactions using gamification

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision
Corrected Model	153.08	2	76.54	4.19	.00	Rejected
Intercept	81.36	1	81.36	2.09	.00	
Pretest	304.42	1	101.42			
Gender	96.55	1	96.55	6.11	.00	
Error	52.14	131	.398	4.56	.01	
Total	687.55	133				
Corrected Total	671.50	132				

The Analysis of Covariance (ANCOVA) in Table 4 reveals a statistically significant difference between the mean achievement scores of male and female SS II Chemistry students taught chemical reactions using gamification. The significance value (Sig. = .00) for gender is less than 0.05, leading to the rejection of the null hypothesis (Ho2). This suggests that male and female students performed differently after the intervention, with gender playing a role in their achievement scores. The F-value of 6.11 further supports this conclusion, indicating that gamification had a varying impact on male and female students' learning outcomes.

Ho_3: There is no interaction effect of gender and method (gamification) on students' academic achievement in chemical reactions.

Table 5: Analysis of Covariance on the interaction effect of gender and method (gamification) on Chemistry students' achievement in chemical reaction

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision
Corrected Model	74.18	2	37.09	3.54	.00	
Intercept	59.68	1	59.68	10.09	.00	
Method*Gender	100.44	1	100.44	8.38	.01	Rejected
Error	217.86	256	.851			
Total	452.16	258				
Corrected Total	411.86	257				

The Analysis of Covariance (ANCOVA) in Table 5 shows a statistically significant interaction effect between gender and the teaching method (gamification) on students' academic achievement in chemical reactions. The significance value (Sig. = .01) for the interaction term (Method*Gender) is less than 0.05, leading to the rejection of the null hypothesis (Ho3). This indicates that the impact of gamification on students' achievement varied based on gender, meaning male and female students responded differently to the instructional method. The F-

value of 8.38 further confirms this interaction effect, highlighting the need to consider gender differences when implementing gamification in Chemistry instruction.

Discussion of Findings

The findings of the study revealed that students who were taught chemical reactions using gamification achieved higher academic performance compared to those taught using the traditional lecture method. This suggests that gamification enhances students' engagement, motivation, and understanding of complex Chemistry concepts, leading to better learning outcomes. The significant difference in achievement scores between the two groups indicates that interactive and game-based learning approaches can be more effective than passive instructional methods in improving students' academic success.

This finding aligns with the work of Gibson et al. (2015), who highlighted that gamification enhances student engagement and motivation, leading to improved academic performance. Similarly, Zainuddin, Chu, Shujahat, and Perera (2020) found that integrating game-based elements in learning environments fosters active participation and deeper understanding, which positively impacts students' achievement. Bushra, Yousuf, and Parveen (2023), Nwankwo and Ukeh (2023) further reinforced this by emphasizing that gamification improves knowledge retention and critical thinking, making learning more effective and enjoyable.

The study also found that male students showed greater academic improvement than their female counterparts when taught chemical reactions using gamification. This suggests that male students may have responded more positively to the interactive and competitive elements of gamification, leading to higher achievement gains. The difference in performance highlights the need for further research on how gamification can be tailored to support both male and female students equally in Chemistry education.

The finding agrees with Gibson et al. (2015), who asserted that male students outperformed their female counterparts when taught using gamification methodology due to their higher engagement with competitive and reward-based learning environments. This suggests that game-based elements such as leaderboards and challenges may align more with male students' learning preferences, leading to increased motivation and participation. However, while gamification benefits all learners, Gibson et al. (2015) noted that gender differences in response to game mechanics should be considered when designing educational interventions to ensure inclusivity and effectiveness.

Conclusion

The study concluded that gamification is an effective instructional strategy for enhancing students' academic achievement in chemical reactions. Students taught using gamification outperformed those taught using the lecture method, indicating its potential to improve learning outcomes. Additionally, male students demonstrated greater academic improvement than their female counterparts when exposed to gamified instruction. The findings suggest that gender differences should be considered when implementing gamification in Chemistry education. Furthermore, the significant interaction effect between gender and gamification highlights the need for differentiated instructional approaches. Based on these results, educators and policymakers should incorporate gamification strategies while addressing gender-related learning needs to maximize student achievement.

Recommendations

Based on the findings, the following recommendations were proffered:

1. Teachers should integrate gamification strategies, such as interactive quizzes, rewards, and problem-solving games, into teaching chemical reactions to enhance students' academic achievement.
2. Teachers should design gamified learning activities that accommodate the learning preferences of both male and female students.
3. The Ministry of Education should review the chemistry curriculum to encourage the use of innovative teaching methods like gamification.

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