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Impact of Gamification and Collaborative Teaching Strategies on Students' Achievement in Periodic Table Concepts in Technical Secondary Schools in Akwa Ibom State, Nigeria

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ABSTRACT

Background: The increasing demand for quality science education in the 21st century has highlighted the need for effective instructional strategies that enhance students' understanding of abstract concepts in subjects like Chemistry. Despite the central role of Chemistry in scientific and technological advancement, students' achievement remains poor, particularly in abstract topics such as the periodic table. This has been largely attributed to the persistent use of conventional teaching methods that fail to actively engage learners and support conceptual understanding.
Objective: The study investigated the effect of gamification and collaborative teaching strategies on students' achievement in periodic table concepts in Technical Secondary Schools in Akwa Ibom State, Nigeria, as well as the influence of gender on students' achievement.
Method: The study adopted a quasi-experimental design, specifically a pretest–posttest non-equivalent group design. The population comprised 5,452 Senior Technical One (ST1) students in seven technical secondary schools, while a sample of 97 students from two randomly selected schools was used. Data were collected using the Periodic Table Achievement Test (PTAT), which had a reliability coefficient of 0.84 determined using Kuder-Richardson Formula 20 (KR-20). Mean and standard deviation were used to answer research questions, while Analysis of Covariance (ANCOVA) was used to test hypotheses at 0.05 level of significance.
Results: The findings revealed that there was a significant difference in students' achievement in the periodic table when taught using gamification and collaborative teaching strategies, with gamification producing higher mean gain scores than collaborative teaching strategy. The results further indicated that there was no significant difference in the achievement of male and female students when taught using either of the teaching strategies.
Conclusion: The study concluded that gamification teaching strategy is more effective than collaborative teaching strategy in enhancing students' achievement in periodic table concepts. It also established that both strategies provide equitable learning opportunities, as gender does not significantly influence students' achievement.
Unique Contribution: This study provides empirical evidence on the comparative effectiveness of gamification and collaborative teaching strategies in teaching abstract Chemistry concepts, particularly the periodic table. It contributes to existing literature by demonstrating how game-based instructional approaches can improve students' engagement, motivation, and achievement while minimizing gender disparities in learning outcomes.

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Key Recommendation: It was recommended that Chemistry teachers should adopt gamification strategies such as quizzes, challenges, simulations, point systems, and competitive group tasks when teaching periodic table concepts to enhance students' engagement and achievement.

Keywords: Gamification, Collaborative, Teaching Strategies, Academic Performance, Chemistry

INTRODUCTION

The 21st century has been marked by unprecedented advancements in science and technology, reshaping industries, economies, and societies globally. These rapid developments necessitate the cultivation of human resources equipped with high-level skills and strong ethical values to adapt to and thrive in this evolving landscape. As noted by UNESCO (2022), quality education is fundamental for fostering the competencies and character required to navigate complex challenges and seize opportunities in a knowledge-driven world. The emphasis on quality education is aligned with the United Nations Sustainable Development Goal 4 (United Nations, 2015), which advocates inclusive and equitable education that promotes lifelong learning opportunities for all. By ensuring that educational systems are robust, innovative, and accessible, societies can prepare individuals to contribute meaningfully to scientific, technological, and economic advancements (Ntegwung, 2025). The teaching of science and technology-related subjects such as Chemistry in secondary schools plays a pivotal role in equipping students with scientific knowledge and critical thinking skills required for national development (Ntegwung & Njoku, 2022).

Chemistry, a foundational science underpinning advancements in health, energy, and technology, aims to provide an understanding of the composition, structure, properties, and reactions of matter (Bobmanuel & Adolphus, 2025). Chemistry plays a vital role in achieving sustainable development, as it enables the development of environmentally friendly products and contributes to waste reduction and recycling, ultimately leading to a more sustainable future for the planet (Umanah, 2024; Sunday & Edet, 2024). Its objectives in education include fostering scientific literacy, critical thinking, and problem-solving skills necessary for participation in a technologically advanced society (Thote & Gowri, 2020). Despite its importance, students frequently perceive Chemistry as an abstract and difficult subject, which contributes to low interest and poor academic achievement (Umanah & Akpan, 2024).

A major challenge in learning Chemistry stems from the abstract nature of many of its core concepts such as atomic structure, periodic table, chemical bonding, and molecular geometry, which operate at the microscopic or symbolic level and cannot be directly observed (Sunday, Umanah & Udofia, 2025; Ramadhan et al., 2025). The periodic table, often described as the foundation of Chemistry, represents all known elements and their properties, and understanding its principles is essential for effective learning of other Chemistry concepts (Ullah et al., 2025). However, students often experience difficulty in understanding periodic trends and electron configurations due to the abstract and symbolic nature of the concept, particularly when taught using traditional expository approaches that rely heavily on verbal explanations and static representations (Umanah & Sunday, 2022; Umanah & Sunday, 2025; Ramadhan, Heliawati & Rubini, 2025; Rusek, Tóthová, Chytrý, & Říčan, 2024).

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Traditional teaching methods, which often rely on static representations and teacher-centered instruction, have been criticized for their limited ability to actively engage learners and support meaningful understanding of abstract scientific concepts (Elyasova, 2024; Nsabayezu et al., 2024; Sunday, Edet & Akpan, 2025). This limitation is reflected in the persistent poor performance of students in Chemistry examinations. Records of students' performance in the Senior School Certificate Examination (SSCE) conducted by the West African Examinations Council (WAEC) indicate that less than 40% of candidates obtain credit-level passes in Chemistry (WAEC Chief Examiner Report, 2022–2024). The reports further highlight students' inability to correctly interpret concepts, draw relevant diagrams, and solve problems effectively. These challenges have been attributed to factors such as teacher-centered instructional methods, inadequate instructional materials, and ineffective delivery of complex concepts.

To address these challenges, the use of innovative and learner-centered instructional strategies such as gamification and collaborative teaching has been advocated. Gamification teaching strategy (GTS) involves the use of game design elements such as points, rewards, badges, challenges, leaderboards, and feedback to enhance students' motivation, engagement, and achievement (Rao, 2022; Shamsuddin, Selman, Ismail, Amin & Raw, 2018). The application of game elements in teaching has been shown to arouse the interest of unmotivated learners and improve learning experiences (Zulkifli, Mat-Zin & Majid, 2019; Edet et al., 2025a). Gamified activities also promote the development of social skills such as teamwork, problem-solving, and decision-making while providing immediate feedback that enhances learning (Lebuna et al., 2022). Similarly, collaborative teaching strategy (CTS) involves students working in small groups to solve problems, complete tasks, and construct knowledge collectively (Achor, Aligba & Iloaksia, 2021; Abdulwahab, 2016). It emphasizes peer interaction, shared responsibility, and active participation, thereby shifting the role of the teacher from a knowledge transmitter to a facilitator of learning (Umoetuk et al., 2025; Sunday, Atabang & Ekon, 2025).

Another important variable in this study is gender, which refers to the socially constructed roles, behaviours, and characteristics associated with males and females (Achor & Abuh, 2021). The influence of gender on students' academic achievement in Chemistry has produced mixed findings, with some studies reporting differences while others report no significant influence (Umanah & Sunday, 2025; Sunday & Edet, 2024; Umanah & Akpan, 2024; Edet et al., 2025b). This inconsistency suggests that gender-related differences in achievement may depend on contextual and instructional factors, thereby necessitating further investigation.

Although previous studies have examined the effectiveness of gamification and collaborative teaching strategies in enhancing students' academic performance, many of these studies have focused on general science subjects, different educational contexts, or have examined each strategy independently. Few studies have specifically investigated the comparative effectiveness of gamification and collaborative teaching strategies on students' achievement in abstract Chemistry concepts such as the periodic table, particularly within technical secondary schools in Akwa Ibom State, Nigeria. In addition, limited attention has been given to how these strategies influence achievement across gender within this specific context.

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In the same vein, persistent reports of students' poor performance in Chemistry, especially in abstract topics like the periodic table as documented by WAEC Chief Examiner Reports (2022–2024), further underscore the need for more effective instructional approaches. This convergence of instructional challenges and limited context-specific empirical evidence highlights a gap in both practice and literature. Therefore, this study was undertaken to investigate the effect of gamification and collaborative teaching strategies on students' achievement in periodic table concepts in technical secondary schools in Akwa Ibom State, Nigeria.

RESEARCH QUESTIONS

1. What is the difference in mean performance scores of Chemistry students taught the concept of periodic table using gamification and collaborative teaching strategies?
2. What is the difference in mean performance scores of male and female Chemistry students taught the periodic table using gamification and collaborative teaching strategies?

HYPOTHESES

1. There is no significance difference in mean performance scores of Chemistry students taught the periodic table using gamification and collaborative teaching strategies.
2. There is no significance difference in mean performance scores of male and female Chemistry students taught the periodic table using gamification and collaborative teaching strategies.

METHODS

The study was conducted in public technical secondary schools in Akwa Ibom State, Nigeria, using a quasi-experimental pre-test–post-test non-equivalent group design with intact classes. The population comprised Senior Technical One (ST1) Chemistry students, and a total of 97 students from two randomly selected schools participated. The sample included all students in the selected classes, as random assignment of individuals was not feasible. Data were collected using a researcher-developed Chemistry Performance Test (CPT) consisting of two sections: Section A for demographic information and Section B with 20 multiple-choice items. The instrument was piloted, and reliability was confirmed with a Kuder–Richardson (K-20) coefficient of 0.84. Two instructional packages were developed to implement the gamification and collaborative teaching strategies.

Permission was obtained from school authorities, and a pre-test was administered to both groups to establish baseline equivalence. The gamification group received instruction on the periodic table incorporating game elements such as points, quizzes, badges, and leader board ranking, with immediate feedback provided. The collaborative teaching group worked in small heterogeneous groups on peer discussions, problem-solving tasks, and group presentations, emphasizing cooperation and shared responsibility. After the treatment, a post-test was administered. Data were analysed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) tested the hypotheses at a 0.05 significance level, controlling for pre-test scores.

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RESULTS

Research Question One: What is the difference in mean performance scores of Chemistry students taught the concept of periodic table using gamification and collaborative teaching strategies?

Table 1: Mean and standard deviation of performance scores of students on pre-test post-test based on teaching strategies

Teaching Strategies	N	Pre-test Mean	SD	Post-test Mean	SD	Mean Gain
GTS	50	35.54	10.20	75.52	14.11	40.00
CTS	47	35.62	12.07	60.17	21.82	24.55

The results in Table 1 show that students taught the periodic table using the gamification teaching strategy (GTS) had a pre-test mean score of 35.54 (SD = 10.20), which increased markedly to a post-test mean score of 75.52 (SD = 14.11), resulting in a mean gain of 40.00. Similarly, students taught using the collaborative teaching strategy (CTS) recorded a pre-test mean score of 35.62 (SD = 12.07) and a post-test mean score of 60.17 (SD = 21.82), with a mean gain of 24.55. Although both strategies improved students' performance in the periodic table, the mean gain of students in the GTS group (40.00) was higher than that of the CTS group (24.55). This indicates that while both gamification and collaborative teaching strategies were effective, gamification produced greater improvement in students' academic performance.

Research Question Two: What is the difference in mean performance scores of male and female Chemistry students taught the periodic table using gamification and collaborative teaching strategies?

Table 2: Mean and standard deviation of scores students in achievement test by gender and treatment

Teaching Strategies		N	Pre-test Mean	SD	Post-test Mean	SD	Mean Gain
GTS	Male	21	36.14	8.84	76.52	13.40	40.38
	Female	29	35.10	11.22	74.79	14.79	39.69
CTS	Male	15	35.33	8.44	59.87	23.37	24.53
	Female	32	35.75	13.57	60.31	21.44	24.56

Table 2 reveals that under the gamification teaching strategy (GTS), male students improved from a pre-test mean of 36.14 (SD = 8.84) to a post-test mean of 76.52 (SD = 13.40), yielding a mean gain of 40.38, while female students improved from 35.10 (SD = 11.22) to 74.79 (SD = 14.79), with a mean gain of 39.69. This suggests that both male and female students benefited substantially from gamification, with male students showing a slightly higher gain. Under the collaborative teaching strategy (CTS), male students increased from a pre-test mean of 35.33 (SD = 8.44) to a post-test mean of 59.87 (SD = 23.37), resulting in a mean gain of 24.53, while female students improved from 35.75 (SD = 13.57) to 60.31 (SD = 21.44), with a mean gain of 24.56. The gains for male and female students under CTS were nearly identical. Overall, both

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instructional strategies enhanced achievement for male and female students, with gamification yielding higher gains across both genders and no substantial gender disparity observed within each strategy.

Hypothesis One: There is no significance difference in mean performance scores of Chemistry students taught the periodic table using gamification and collaborative teaching strategies.

Table 3: Result of Analysis of Covariance (ANCOVA) on the difference in the mean achievement scores based on strategies

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6330.571[a]	2	3165.286	9.590	.000
Intercept	30308.294	1	30308.294	91.823	.000
Pretest	622.349	1	622.349	1.885	.173
Teaching Strategies	5721.310	1	5721.310	17.334	.000*
Error	31026.769	94	330.072		
Total	486974.000	97			
Corrected Total	37357.340	96			

a. R Squared = .169 (Adjusted R Squared = .152)
*Significant @0.05 level of significance

The ANCOVA result in Table 3 indicates that the effect of teaching strategies on students' mean achievement scores is statistically significant, $F(1,94) = 17.334$, $p = .000 < .05$. Since the probability value is less than the 0.05 level of significance, the null hypothesis is rejected. This implies that a significant difference exists in the mean performance scores of students taught the periodic table using gamification and collaborative teaching strategies. The difference favours the gamification teaching strategy (GTS), as students exposed to gamification recorded a higher mean gain (40.00) compared to those taught using the collaborative teaching strategy (24.55).

Hypothesis Two: There is no significance difference in mean performance scores of male and female Chemistry students taught the periodic table using gamification and collaborative teaching strategies.

Table 4: Result of Analysis of Covariance (ANCOVA) on the difference in the mean achievement scores based on learning approaches

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	729.488[a]	2	364.744	.936	.396
Intercept	30733.060	1	30733.060	78.872	.000
Pretest	600.537	1	600.537	1.541	.218
Gender	120.227	1	120.227	.309	.580
Error	36627.852	94	389.658		
Total	486974.000	97			
Corrected Total	37357.340	96			

a. R Squared = .020 (Adjusted R Squared = -.001)

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The ANCOVA result in Table 4 shows that the effect of gender on students' mean achievement scores is not statistically significant, $F(1,94) = 0.309$, $p = 0.580 > .05$. Since the p-value is greater than 0.05, the null hypothesis is retained. This indicates that there is no significant difference in the mean performance scores of male and female students taught the periodic table using gamification and collaborative teaching strategies when pre-test scores are controlled. Thus, gender did not significantly influence students' academic performance under the two instructional strategies.

DISCUSSION

The findings revealed that students taught the periodic table using the gamification teaching strategy performed significantly better than those taught using the collaborative strategy. Game-based elements such as competition, rewards, immediate feedback, and interactive challenges likely enhanced motivation, engagement, and active participation, improving understanding. The higher mean gain in the gamification group confirms its relative effectiveness. This aligns with Ochihu (2022), and Öztürk and Korkmaz (2019), who reported that gamified instruction enhances performance and learning outcomes. The study also found no significant gender differences in performance when pretest scores were controlled. Slight variations in mean gains were observed but were not statistically significant, suggesting both strategies offered equitable learning opportunities. The engaging nature of gamification and peer-supported collaborative learning may have minimised gender disparities. This supports Nwachukwu and Johnson (2020), Achor, Aligba, and Iloaksia (2021), and Niyonsaba, Nkurunziza, and Hakizimana (2022), who reported that collaborative and gamified instruction improves achievement irrespective of gender.

CONCLUSION

Based on the findings of this study, it was concluded that teaching the concept of periodic table in Chemistry using gamification strategy significantly enhances students' academic performance compared with collaborative teaching strategy. The study further established that gender does not significantly influence students' achievement when either gamification or collaborative teaching strategy is employed. Both male and female students benefited almost equally from the two instructional approaches. In general, the study confirms that learner-centred and interactive teaching strategies are effective for improving students' understanding of Chemistry concepts and promoting equitable learning outcomes. Gamification, in particular, emerged as a highly potent instructional strategy for enhancing achievement in the teaching of motion at the secondary school level.

RECOMMENDATIONS

Based on the findings and conclusions of the study, the following recommendations are made:

i. Chemistry teachers should adopt gamification strategies such as quizzes, challenges, simulations, point systems, and competitive group tasks when teaching topics like periodic table.
ii. Students should actively participate in gamified and collaborative learning activities during Chemistry lessons. They should engage in group discussions, problem-solving tasks, and educational games designed by their teachers, as these approaches enhance understanding and retention of scientific concepts.

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iii. Educational planners should integrate gamification-based instructional approaches into Chemistry curriculum guides and teaching manuals. They should design professional development frameworks that equip teachers with the skills required to employ innovative and technology-driven pedagogies in classroom instruction.
iv. The Federal Ministry of Education should support the integration of gamification and other interactive teaching strategies into national science education policies and curriculum revisions.

Ethical Clearance

Ethical consent was obtained from all participants involved in this study. Participants were fully informed that the study was purely for academic purposes and that their participation was entirely voluntary.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors' Contributions

George Johnson Ntegwung conceived the study and designed the research framework. Edima Sylvanus Sunday coordinated the data collection, handled the data analysis and interpretation. Owen Peter Ukafia reviewed the literature, contributed to the theoretical framework, and assisted in drafting the manuscript. Ataubong Edet Anthony drafted the initial manuscript. All authors critically reviewed and approved the final version of the manuscript. They collectively take responsibility for the content and the similarity index of the work.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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