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EFFECT OF PERIODIC TABLE PUZZLE GAME ON SENIOR SCHOOL CHEMISTRY STUDENT ACADEMIC PERFORMANCE

UTICAJ IGRE SLAGALICE PERIODNOG SISTEMA NA AKADEMSKI USPJEH UČENIKA SREDNJIH ŠKOLA IZ HEMIJE

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ABSTRACT

This study investigated the effects of periodic table puzzle game on secondary school students' academic performance in Chemistry, focusing on the topic of the periodic table. A quasi-experimental 2x2x3 factorial design involving pre-test and post-test control groups was employed. A total of 105 SS2 students from co-educational public schools in Ilorin, Kwara State, were selected using purposive and stratified sampling techniques. The experimental group was taught using a periodic table puzzle game, while the control group received conventional instruction. Data were collected using a validated 50-item Chemistry Achievement Test (CAPT), with a reliability coefficient of 0.81 using Kuder-Richardson Formula 20 (KR-20). Pre-test and post-test scores were analysed using descriptive statistics for research questions and ANCOVA for hypotheses testing. The findings revealed that students taught using periodic table puzzle game learning performed significantly better than those taught with traditional methods ($F(1,102) = 18.497$, $p < .05$). There was no significant gender difference in performance, but a significant difference was observed among high, medium, and low scorers ($F(2,102) = 5.767$, $p < .05$). No significant interaction effect was found between gender and achievement level. The study concluded that periodic table puzzle game is effective in enhancing students' academic performance in Chemistry across varying ability levels.

Key words: Academic performance**,** Effect, Periodic table puzzle game

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SAŽETAK

Ova studija ispitivala je efekte igre slagalice periodnog sistema na akademski uspjeh učenika srednjih škola iz hemije, s posebnim fokusom na nastavnu temu periodnog sistema elemenata. Korišten je kvazieksperimentalni faktorski dizajn 2×2×3 koji je uključivao eksperimentalnu i kontrolnu grupu s predtestom i posttestom. Ukupno 105 učenika drugog razreda srednje škole (SS2) iz mješovitih javnih škola u Ilorinu, savezna država Kwara, odabrano je primjenom namjernog i stratificiranog uzorkovanja. Eksperimentalna grupa poučavana je korištenjem igre slagalice periodnog sistema, dok je kontrolna grupa realizirala nastavu primjenom tradicionalnih metoda poučavanja. Podaci su prikupljeni pomoću validiranog testa postignuća iz hemije od 50 zadataka (Chemistry Achievement Test – CAPT), s koeficijentom pouzdanosti od 0,81, izračunatim primjenom Kuder–Richardsonove formule 20 (KR-20). Rezultati predtesta i posttesta analizirani su deskriptivnom statistikom za istraživačka pitanja, dok je analiza kovarijanse (ANCOVA) korištena za testiranje hipoteza. Nalazi istraživanja pokazali su da su učenici poučavani pomoću igre slagalice periodnog sistema postigli statistički značajno bolje rezultate u odnosu na učenike poučavane tradicionalnim metodama ($F(1,102) = 18,497$; $p < 0,05$). Nije utvrđena statistički značajna razlika u postignuću s obzirom na spol, ali je utvrđena značajna razlika među učenicima s visokim, srednjim i niskim nivoom postignuća ($F(2,102) = 5,767$; $p < 0,05$). Također, nije utvrđen značajan interakcijski efekat između spola i nivoa postignuća. Studija zaključuje da je igra slagalice periodnog sistema efikasna u unapređenju akademskog uspjeha učenika iz hemije, bez obzira na različite nivoe sposobnosti.

INTRODUCTION

Education is the process of imparting valuable knowledge that brings a positive change in the behaviour of human beings. It can also be defined as the process of acquiring knowledge through teaching and learning. Moreover, education plays a significant role in the development of any nation. Quality education lays the foundation for sustainable development by fostering innovation, equity, and lifelong learning (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020).

Within the broader framework of education, science education holds a particularly vital place, science education remains a cornerstone for national development and global competitiveness in the 21st century**.** Science education is an integrated and interdisciplinary field that encompasses not only the content knowledge of core science subjects such as Biology, Physics, Chemistry, and Agricultural Science, but also the instructional methods, learning processes, and sociocultural contexts that shape students' understanding of science. It aims to develop scientific literacy, inquiry skills, and problem-solving abilities that are essential for individuals to participate meaningfully in a scientifically and technologically driven society (Lederman & Lederman, 2023; National Research Council, 2019).

Chemistry is essential for comprehending the natural world, as its principles govern phenomena ranging from biological processes within the human body to environmental transformations such as climate change and pollution control (Organisation for Economic Co-operation and Development [OECD], 2023). Its applications span diverse fields such as

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medicine, agriculture, food technology, and environmental management, making chemistry education vital for developing a scientifically literate and innovative population (American Chemical Society, 2021). Through the study of chemistry concepts, students not only gain theoretical knowledge but also develop transferable skills such as critical thinking, problem-solving, and communication attributes that are valuable in any career path (University Career Center, 2021).

One such foundational concept in chemistry is the periodic table of Elements a critical organisational tool that helps learners predict chemical properties and understand atomic behaviour. The periodic table serves as a central framework for understanding the behaviour of matter and predicting the properties of elements (Scerri, 2007). Yet, its structure and the trends it reveals (e.g., atomic radius, ionisation energy, electronegativity) can be abstract and intimidating for students (Taber, 2009). However, research indicates that many students struggle to understand these trends and their scientific basis, especially when instruction focuses solely on memorisation rather than conceptual understanding (Nieminen & Aksela, 2019; Lilik & Effendy, 2020). Furthermore, visual and spatial challenges related to interpreting the structure of the table, the relationships between groups and periods, and abstract representations of atomic number and configuration make it difficult for students to make meaningful connections (King, 2012; Seery, 2020). Studies show that traditional teaching methods often fail to actively engage learners or provide the interactivity needed to master this complex tool (Ozmen et al., 2022).

As such, new pedagogical approaches are needed ones that contextualise and visualise the periodic table in a more interactive and student-centred way. Instructional strategies like simulations, animations, and game-based learning; periodic table puzzle game have been found to enhance students' conceptual grasp and motivation (Pérez et al., 2023). Without such innovative approaches, students may continue to view the Periodic Table as a static chart to be memorised rather than a dynamic tool for reasoning and problem-solving in chemistry.

One increasingly pedagogical approach for enhancing student motivation and engagement is game-based learning. Game-based leaning in education refers to the integration of game design elements such as points, levels, badges, and leaderboards into non-game learning environments to stimulate interest and participation (Deterding et al., 2011). By tapping into students’ natural desires for achievement, competition, and social interaction, game-based learning offers a fun and immersive way to approach complex academic content (Hussain et al., 2014). It has been shown to increase student motivation, improve academic performance, and foster collaboration (Seaborn et al., 2015; Koivisto & Hamari, 2019). In chemistry education, game-based learning helps students engage with difficult concepts in a more accessible and interactive manner (Liberatore, 2011; Revell et al., 2014).

Studies have shown that integrating games into chemistry lessons boosts students’ motivation and learning outcomes (Stringfield & Kramer, 2014). Game-based learning strategies built on psychological theories such as goal-setting and flow can create immersive learning experiences that hold students' attention and support information retention. Beyond academic benefits, gamified environments have been found to foster social support and a sense of belonging among learners, especially in situations where students may feel isolated or overwhelmed (Morschheuser et al., 2017; Nieto-Escamez et al., 2021).

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Academic performance remains a central concern in educational research and practice, as it reflects the extent to which students have achieved intended learning outcomes. Students' performance levels are categorised into high, medium, and low score levels, offering a practical framework for identifying individual learning needs and informing differentiated instruction. Score levels provide insight not only into learners' mastery of content but also into how they respond to various teaching methods, learning environments, and assessment strategies (Zhu, *et al*., 2021).

Despite its critical role in equipping students with scientific knowledge and analytical skills, Chemistry continues to pose significant learning challenges to many secondary school students in Nigeria. This is evident in the recurring low performance of candidates in national examinations. The West African Examinations Council (WAEC, 2023) reports a decline in students' performance in Chemistry, with many candidates showing persistent weaknesses in applying theoretical concepts to practical contexts, especially in physical and organic chemistry, stoichiometry, and electrolysis. These challenges are often linked to conventional teacher-centred instructional methods that fail to actively engage learners or promote meaningful learning experiences.

Studies by Iji et al. (2020), Yusuf and Afolabi (2021) Anyaegbu and Eze (2022) have shown that integrating gamified instructional strategies can enhance motivation, engagement, and academic achievement among students. While these studies demonstrate the potential of game-based learning across subjects, empirical research specifically focused on mathematics, biology and computer science remains limited especially within the Nigerian context. It is against this that the study investigated effect of periodic table puzzle game on the academic performance of secondary school chemistry students in Ilorin, Kwara State, Nigeria. Specifically, the study investigated

1. the performance of senior school students taught periodic table system using periodic table puzzle game and those taught not using periodic table puzzle game;
2. the difference in the performance of male and female senior school students taught periodic table using periodic table puzzle game and those taught not periodic table puzzle game;
3. the performance of high, medium, and low scoring senior school students taught periodic table using periodic table puzzle game and those taught not using periodic table puzzle game; and
4. the interaction effects of gender and scoring level on senior school students' academic performance chemistry when taught periodic table with periodic table puzzle game.

The following null hypotheses were postulated to guide the study.

HO_1. There is no significant difference in the performance of senior school students taught periodic table using periodic table puzzle game and those taught not using periodic table puzzle game.

HO_2. There is no significant difference in the performance of male and female senior school student taught periodic table using periodic table puzzle game and those taught not using periodic table puzzle game

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HO_3. There is no significant difference in the performance of high, medium and low scoring senior school student taught periodic table system using periodic table puzzle game and those taught not using periodic table puzzle game

HO_4. There is no significant difference in the interaction effects of gender and scoring level on senior school students' academic performance in chemistry when taught periodic table with periodic table puzzle game

MATERIAL AND METHODS

Sample of participant

The population for the study consisted of all Senior Secondary School II (SS2) Chemistry students in public co-educational secondary schools in Ilorin South Local Government Area of Kwara State, Nigeria. A combination of purposive and stratified sampling techniques was employed to ensure balanced representation of gender and ability levels. A total of 105 students participated in the study, drawn from intact classes to preserve the natural classroom setting. The experimental group, which was exposed to periodic table puzzle game instruction, comprised 54 students (28 male and 26 female), while the control group, which received conventional teaching, consisted of 51 students (25 male and 26 female). This selection strategy allowed for meaningful comparison across instructional methods and student characteristics.

Method of conducting research

The study adopted a 2x2x3 quasi-experimental pre-test, post-test control group design to investigate the effects of the periodic table puzzle game on senior secondary school students' academic performance in Chemistry, with a particular focus on the topic of the periodic table. The factorial design enabled the examination of the main effects of instructional strategy (periodic table puzzle game vs. conventional), gender (male vs. female), and score levels (high, medium, low), as well as the interaction effects among these variables.

The intervention spanned four weeks and was implemented in three distinct phases:

- Pre-test Phase: Both the experimental and control groups were administered the same 50-item Chemistry Achievement Test on the periodic table to establish baseline performance.
- Treatment Phase: The experimental group received instruction through a periodic table puzzle game designed to promote critical thinking, collaboration, and problem-solving. The activity increased in difficulty as students progressed, encouraging deeper cognitive engagement. The control group, however, was taught the same content using conventional methods such as lectures, textbook references, and oral questioning. The same teacher (the researcher) delivered instruction to both groups, and the duration, content, and teaching time were kept constant.
- Post-test Phase: Students in both groups completed the same test administered during the pre-test to determine learning gains attributable to the instructional strategies.

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Measuring instruments

The primary instrument for data collection was the Chemistry Achievement Test on the Periodic Table (CAPT), developed by the researcher in line with the NERDC Chemistry curriculum and standard SSCE/WAEC textbooks. The instrument consisted of 50 multiple-choice questions, each carrying two marks, making a total score of 100. Items were designed to assess different cognitive levels of Bloom's Taxonomy: knowledge, comprehension, application, and analysis.

To ensure content and construct validity, the instrument was reviewed by two experienced Chemistry teachers, two university Chemistry education lecturers, and one expert in test and measurement. A trial test with 23 students from a nearby school not included in the study produced a KR-20 reliability coefficient of 0.81, indicating high internal consistency and reliability for the study.

Data processing methods

Data from the pre-test and post-test were analysed using descriptive and inferential statistics. Descriptive statistics such as mean and standard deviation were computed to describe student performance across groups. Analysis of Covariance (ANCOVA) was employed to examine the main and interaction effects of instructional strategy, gender, and score levels while controlling for initial group differences. All statistical analyses were conducted using SPSS version 23. Ethical considerations were also strictly observed, including obtaining informed consent from school authorities and participants, ensuring confidentiality, and providing equitable learning opportunities to all students regardless of their group assignment.

RESULTS AND DISCUSSION

The null hypotheses were tested using Analysis of Covariance (ANCOVA) at a 0.05 alpha level.

HO_1. There is no significant difference in the performance of senior school students taught periodic table using periodic table puzzle game and those taught not using periodic table puzzle game.

Table 1 indicated that there is a statistically significant difference in the post-test performance of students based on instructional strategy after controlling for the pre-test score ($F(1,102) = 18.497$, $p < .05$). This means that students taught using periodic table puzzle game performed significantly better than those taught with the conventional method. The null hypothesis is therefore rejected. The findings revealed that students taught using the periodic table puzzle game significantly outperformed those taught using the conventional method. This is because students exposed to periodic table puzzle game performed significantly better than their counterparts who were taught using conventional methods. This finding is consistent with the results of Kayode et al. (2023**)** who observed influence of periodic table puzzle game on biology students' engagement and knowledge retention in reported that students exposed to digital games showed superior performance compared to their peers in conventional settings. Similarly**,** Pedersen et al. (2016) studies on game-based mathematics learning for physics

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reported that the use of "DiffGame," a math and physics game, significantly improved conceptual understanding and problem-solving skills.

Table 1. ANCOVA of the Effect of Instructional Strategy on Students' Post-Test Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2748.699	2	1374.350	12.429	.000	.196
Intercept	426.591	1	426.591	3.857	.052	.037
Pre-test Score (Covariate)	563.243	1	563.243	5.090	.031	.048
Instructional Strategy	2185.456	1	2185.456	18.497	.000	.154
Error	11285.641	102	110.643			
Total	548762.000	105				
Corrected Total	14034.340	104				

HO_2. There is no significant difference in the performance of male and female senior school student taught periodic table using periodic table puzzle game.

Table 2 indicated that gender does not have a statistically significant effect on post-test performance after controlling for pre-test scores ($F(1,102) = 2.514$, $p > .05$, $\eta^2 = .024$). The null hypothesis is therefore not rejected, indicating that both male and female students benefited equally from the instructional approaches. The findings showed that there was no statistically significant main effect of gender on students' academic performance. This could be that gender alone did not significantly affect achievement in the topic of acid, base and salt. The higher performance among female students may be attributed to the collaborative and structured nature of the game used in this study, which may align better with female learners' preferences for social interaction and narrative learning. This is not in agreement with Sung et al. (2015) who observed gender differences in science game-based learning which reported that female middle school students showed higher post-test gains in a science game context. Furthermore, the study carried out by Yang and Quadir (2018) on effects of gender differences on learning performance in digital game-based science learning found that female chemistry students benefited significantly from scaffolded game features.

Table 2. ANCOVA of the Effect of Gender on Students' Post-Test Scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared

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Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1745.413	2	872.707	7.888	.001	.134
Intercept	502.261	1	502.261	4.538	.035	.043
Pre-test Score (Covariate)	488.769	1	488.769	4.152	.044	.039
Gender	296.017	1	296.017	2.514	.116	.024
Error	11285.641	102	110.643			
Total	548762.000	105				
Corrected Total	13031.054	104				

HO_3. There is no significant difference in the performance of high, medium and low scoring senior school student taught periodic table system using periodic table puzzle game.

Table 3a indicated that there is a significant main effect of achievement level was found on students' post-test performance ($F(2,102) = 5.767$, $p < .05$, $\eta^2 = .102$). This shows that students' academic standing (high, medium, low) significantly influenced their post-test scores. The null hypothesis is rejected.

Table 3a. ANCOVA of the Effect of Achievement Levels on Students' Post-Test Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1873.451	3	624.484	5.644	.001	.142
Intercept	453.829	1	453.829	4.102	.046	.039
Pre-test Score (Covariate)	509.773	1	509.773	4.435	.038	.042
Score Level	1276.225	2	638.113	5.767	.004	.102
Error	11285.641	102	110.643			
Total	548762.000	105				
Corrected Total	13159.092	104				

Table 3b indicated post hoc analysis using Bonferroni correction showed significant differences among the achievement levels. High scorers performed significantly better than

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both medium (p = .014) and low scorers (p = .000), while medium scorers also outperformed low scorers (p = .001). This confirms that the periodic table puzzle game had varying effects across score levels, with high achievers benefiting the most. Hence, HO_3 is rejected. The study also revealed a significant difference in the academic performance of students based on their scoring levels. High-scoring students significantly outperformed their medium- and low-scoring counterparts, as confirmed by post hoc analysis. Indicating that students' prior academic background may affect how well they benefit from game-based strategies. This outcome is supported by the findings of Ibitomi et al. (2023) who investigated effect of computer simulations on chemistry achievement, reported that high-ability students benefited more from interactive digital tools. However, contrary evidence was found in Anyanwu et al. (2023) who investigated the effect of multimedia instruction on high, medium and low ability students in solid geometry reported that the multimedia package helped to bridge the performance gap, with no significant difference in the post-test scores across ability levels, highlighting that well-structured multimedia instruction could support equity among learners.

Table 3b. Bonferroni Post Hoc Pairwise Comparisons of Students' Post-Test Scores

Achievement Level (I)	(J)	Mean Difference (I–J)	Std. Error	Sig.	95% CI Lower Bound	Upper Bound
High	Medium	7.28	2.51	.014	1.30	13.26
High	Low	16.78	2.64	.000	10.21	23.35
Medium	Low	9.50	2.53	.001	3.45	15.55

HO_4. There is no significant difference in the interaction effects of gender and scoring level on senior school students' academic performance in chemistry when taught periodic table with periodic table puzzle game.

Table 4 indicated that the interaction effect between gender and score level on students' post-test scores was not statistically significant**:** $F(2, 48) = 2.513$**,** $p > .05$**,** partial $\eta^2 = .047$. This means the null hypothesis is not rejected, indicating that the combined effect of gender and score level does not significantly influence the academic performance of students taught using periodic table puzzle game in the topic of the periodic table. Furthermore, the study found no significant interaction between gender and scoring level, suggesting that gender did not moderate the influence of scoring level on academic performance. In other words, the effectiveness of the periodic table puzzle game was consistent across male and female students irrespective of whether they were high, medium, or low scorers. This is in agreement with Barab et al. (2005) who investigated transformational play: using games to position person, content, and contex reported that inclusive game design can neutralize gender-based learning differences, allowing all learners to achieve similarly high outcomes.

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Table 4. ANCOVA of the Interaction Effect of Gender and Achievement Level

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1945.231	5	389.046	3.517	.006	.147
Intercept	427.236	1	427.236	3.862	.052	.037
Pre-test Score (Covariate)	496.276	1	496.276	4.489	.037	.042
Gender	312.115	1	312.115	2.821	.096	.027
Score Level	905.310	2	452.655	4.086	.020	.074
Gender * Score Level	180.943	2	90.472	2.513	.086	.047
Error	5139.641	48	107.076			
Total	274762.000	54				
Corrected Total	7084.872	53				

CONCLUSION

The findings of this study demonstrate that periodic table puzzle game has a significant positive effect on students' academic performance in Chemistry, particularly when teaching complex topics such as acids, bases, and salts. Students exposed to periodic table puzzle game instructional strategies performed better than those taught using conventional methods, highlighting the transformative potential of interactive and student-centred learning approaches. While gender did not emerge as a significant factor, the study found that students' prior achievement levels whether high, medium, or low did influence learning outcomes, suggesting that differentiated support is necessary to address individual learning needs.

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