

Effects of Differentiated Instruction on Students' Retentive Knowledge in Periodicity

Aregbesola, B. G.¹, Ojelade, I. A.², Ejedegba, O.³

^{1,2,3} Department of Science and Environmental Education, Faculty of Education, University of Abuja, Abuja, Nigeria

Abstract:

This study explores effects of differentiated instruction (DI) on students' retention of periodicity concepts in chemistry, compared to conventional lecture-based teaching methods. The research answered three questions and three hypotheses. The study adopted a quasi-experimental design, involving 110 SSII chemistry students from Esan Central Local Government Area, Edo State, Nigeria, using a multi-stage sampling procedure. Two intact groups from two secondary schools were assigned to experimental and control groups, respectively. The experimental group received DI through diverse instructional methods, including gamification, collaborative learning, and tiered assignments, while the control group was taught using conventional lecture-based methods. Data were collected using the Chemistry Retention Test (CRT). The reliability of the CRT was established using the Kuder-Richardson Formula 20 (KR-20) to be 0.92. Data for the study was gathered from the scores obtained from the test and were analyzed using mean and standard deviation for the research questions, while hypotheses were tested at 0.05 level of significance using analysis of covariance (ANCOVA). Findings revealed among others that there was a significance difference with level (p-value) of 0.000, between DI and conventional lecture-based indicating that the DI improved students' retention of periodicity concepts in chemistry better than conventional lecture-based teaching methods. Therefore, the study concluded that students taught using differentiated instruction (DI) demonstrate significantly better retention of periodicity knowledge than those taught through conventional lecture-based methods. And recommendations were made among others that teachers should avoid relying solely on conventional-based methods and adopt more student-centered DI instructional strategy that encourage active learning and conceptual understanding.

Keywords: Differentiated Instruction, Retentive Knowledge, Periodicity.

Background

The teaching and learning process in science education, particularly in chemistry, often encounters challenges in addressing the diverse abilities and learning styles of students. Periodicity, a core concept in chemistry, requires students to understand trends and relationships in the periodic table, which are foundational for exploring chemical properties and reactions. Despite its importance, periodicity is often perceived as abstract and complex, making it difficult for students to retain knowledge effectively Aregbesola, (2023). Differentiated instruction (DI) has emerged as a promising approach to tackle these challenges, enabling educators to cater to individual learning needs while fostering deeper comprehension and retention. Differentiated instruction is a student-centered teaching approach designed to meet the diverse academic, cognitive, and emotional needs of learners. It involves adapting content, process, product, or learning environment to ensure all students can access and engage with the curriculum meaningfully (Tomlinson, 2017). The fundamental principle of DI is the recognition that students differ in their readiness, interests, and learning profiles, requiring varied instructional strategies to maximize their learning potential. Research highlights the efficacy of DI in promoting knowledge retention, as it addresses learners' preferences and encourages active engagement.

For instance, studies have shown that DI techniques such as peer collaboration, guided inquiry, and the use of visual aids significantly enhance students' ability to retain complex scientific concepts, including periodic trends (Onyishi, et al., (2020) & Carlson, 2015). Retention in education refers to the ability of learners to store and retrieve information over time. In chemistry, retention is critical, as understanding advanced topics often depends on foundational knowledge. Periodicity serves as a gateway to topics such as chemical bonding, reactivity, and stoichiometry. Poor retention of periodic trends can impede students' progress in these areas, underscoring the need for teaching strategies that promote long-term memory and understanding (Aregbesola, et. Al., 2023). Differentiated instruction, by aligning teaching methods with learners' needs, provides a structured pathway for improving retention and bridging gaps in comprehension. Applying DI in teaching periodicity involves employing varied instructional strategies to cater to different learning needs. For example, students with visual learning preferences may benefit from color-coded periodic tables or trend diagrams, while kinesthetic learners may engage more effectively through hands-on activities like constructing 3D models of elements. Group-based tasks, such as analyzing periodic trends collaboratively, allow learners to discuss and reinforce concepts, thereby enhancing retention (Aluko, 2020). Formative assessments also play a crucial role in DI by providing teachers with insights into students' understanding and progress. These assessments enable the adaptation of instruction to address specific misconceptions or learning gaps, ensuring that all students build a solid grasp of periodicity (Pozas et al., 2020).

The theoretical underpinnings of DI draw from constructivist and socio-cultural learning theories. Constructivism emphasizes active learning, where students construct knowledge through experiences and interactions. In the context of periodicity, DI aligns with this theory by encouraging learners to explore and connect periodic trends to real-world applications. Vygotsky's socio-cultural theory further supports DI, highlighting the importance of scaffolding and collaborative learning in promoting retention and understanding (Thomas et al., 2020).

Empirical studies underscore the positive impact of DI on students' academic performance and retention. A study by Ganyaupfu (2013) revealed that DI methods, including group discussions and individualized tasks, significantly improved retention compared to conventional teaching. Similarly, Aluko (2020) reported that students exposed to DI strategies demonstrated better performance in chemistry topics, attributing this to the personalized and engaging nature of DI. In the specific context of periodicity, DI strategies have been linked to improved comprehension and memory

retention. For instance, Onyishi, et al.,(2020) found that differentiated approaches, such as using analogies and visualizations, helped students retain and apply periodic trends more effectively.

Differentiated instruction (DI) has gained significant attention in recent years as a pedagogical strategy for addressing diverse learning needs in classrooms. Its relevance is particularly evident in science education, where students often struggle with abstract concepts such as periodicity in chemistry. Periodicity, the recurring trends observed in the properties of elements across the periodic table, forms a cornerstone of chemical education but is challenging for many students to master and retain. DI aims to bridge this gap by tailoring instruction to students' varying levels of readiness, interests, and learning preferences, thereby enhancing engagement and retention. Retention of scientific concepts, especially periodicity, is essential for students to succeed in higher levels of chemistry. However, periodicity is often taught in a rigid and abstract manner, leading to surface-level understanding and poor long-term retention. Studies reveal that students frequently struggle to remember periodic trends, their causes, and their applications due to the absence of engaging, contextualized instruction (Onyishi & Sefotho, 2020).

Factors contributing to poor retention include:

1. Over-reliance on lecture-based teaching methods (Aluko, 2020).
2. Lack of differentiation in instructional delivery.
3. Insufficient use of active learning techniques that promote deeper cognitive processing.

Differentiated instruction addresses these issues by aligning teaching strategies with students' cognitive abilities, thereby improving their ability to recall and apply learned concepts.

Numerous empirical studies underscore the effectiveness of DI in improving retention in science subjects. Pozas, et al., (2020) found that students exposed to differentiated learning activities retained 40% more content on average than those taught with traditional methods. Similarly, Onyishi, et al., (2020) demonstrated that differentiated strategies like tiered assignments and formative assessments significantly improved retention in chemistry topics, including periodicity.

1. DI employs scaffolded learning, where instructional tasks are broken into manageable chunks with varying levels of complexity. For instance, beginners might analyze basic periodic trends like atomic radius, while advanced learners explore ionization energy variations in transition metals (Santangelo & Tomlinson, 2021).
2. Color-coded periodic tables, animations, and trend diagrams cater to visual learners, enhancing their ability to recall periodicity patterns (Aluko, 2020).
3. Peer-led discussions and cooperative problem-solving tasks enable students to articulate and reinforce their understanding of periodic trends. These methods foster retention by encouraging active participation and peer teaching (Carlson, 2015).
4. Interactive quizzes and simulations provide immediate feedback, reinforcing memory and understanding of periodic trends (Subramaniam, 2016).

Sailer, et al., (2020) conducted a meta-analysis exploring the impact of gamification in educational contexts. Their findings suggest that gamification significantly enhances student motivation, engagement, and knowledge retention, particularly when incorporated as part of a broader differentiated instruction strategy. The study demonstrated that the use of game mechanics in the classroom helps engage students more actively, making complex concepts easier to grasp. Dabbagh, et al., (2020) found the benefits of collaborative learning and tiered assignments within differentiated instruction in a study carried out with secondary school students in chemistry. Their research found that when students engage in collaborative tasks, particularly in a mixed-ability

classroom, they not only deepen their understanding of content but also develop essential communication and teamwork skills. Additionally, tiered assignments allow for adjusting the level of challenge to match students' varying readiness levels, making learning more accessible and effective for all.

Smale-Jacobse, et al., (2019) conducted a systematic review of studies on differentiated instruction in secondary education and highlighted the importance of adapting teaching methods to meet students' diverse needs. Their research underscores the effectiveness of DI in improving academic outcomes, noting that personalized instruction based on learning preferences and prior knowledge can significantly enhance student achievement. The authors found moderate positive effects across various DI strategies, particularly in heterogeneous classrooms, where students' individual needs are addressed through tailored instructional approaches. Smit et al.,(2016) explored the implementation of DI in small schools and found that teachers' ability to differentiate instruction based on student characteristics, including prior knowledge, led to better academic performance. Their findings align with the idea that prior knowledge and learning preferences (e.g., kinesthetic, visual, and auditory) contribute significantly to student retention, suggesting that DI can provide a more engaging and effective learning environment for all student. Van de Grift et al. (2019) investigated the complexity of DI in secondary education and how it affects student engagement and achievement. They emphasized that differentiated instructional strategies, when appropriately implemented, help address the varying learning styles and knowledge levels of students. This supports the argument that students' retention of complex concepts, like periodicity in chemistry, can be improved when instruction is tailored to individual learning preferences and prior knowledge.

While DI holds great promise, its implementation poses challenges. Teachers often struggle with preparing differentiated lesson plans is time-intensive, requiring significant effort to design varied activities and assessments. Also, many educators lack the professional development needed to implement DI effectively (Onyishi & Sefotho, 2020). However, limited access to instructional materials such as interactive tools, simulations, or laboratory equipment hampers the full application of DI. However, learning periodicity with differentiated instruction (DI) presents challenges such as addressing the abstract nature of periodic trends like atomic size and ionization energy, which can confuse students. Diverse learning preferences may not align with periodicity's reliance on visual aids, while prior knowledge gaps exacerbate understanding difficulties. Resource limitations and time constraints hinder the development of tailored DI materials, and misconceptions about trends persist despite differentiated strategies. Additionally, classroom management in a DI setting and the complexity of designing appropriate assessments create further obstacles, impacting retention and application of periodicity concepts. Therefore, it is necessary to carry out study on effects of differentiated instruction on students' retentive knowledge in periodicity, Esan Central Local Government Areas Edo State, Nigeria.

Purpose of the Study

The objective of this study is to examine effects of differentiated instruction on students' retentive knowledge in periodicity, Esan Central Local Government Areas Edo State, Nigeria. Specifically, the study seeks to:

1. Compare the retention of periodicity knowledge between students taught using differentiated instruction and those taught using conventional lecture-based methods, in order to determine the effectiveness of differentiated instruction on long-term knowledge retention.
2. Identify and evaluate the specific differentiated instructional techniques (such as gamification, collaborative learning, and tiered assignments) that contribute most significantly to the retention of periodicity concepts among secondary school students.

3. Investigate how factors such as learning preferences (e.g., visual, auditory, kinesthetic) and prior knowledge influence the effectiveness of differentiated instruction in improving students' retention of periodicity concepts.

Research Questions

The following research questions were raised to guide the study:

1. How does the retention of periodicity knowledge differ between students taught using differentiated instruction and those taught using conventional lecture-based methods?
2. What specific differentiated instructional techniques (e.g., gamification, collaborative learning, or tiered assignments) contribute most significantly to students' retention of periodicity concepts?
3. How do factors such as learning preferences (e.g., visual, auditory, kinesthetic) and prior knowledge influence the effectiveness of differentiated instruction in improving the retention of periodicity?

Hypotheses

The following null hypotheses are formulated and tested at 0.05 level of significance:

H₀₁: There is no significant difference in the retention of periodicity knowledge between students taught using differentiated instruction and those taught using conventional lecture-based methods.

H₀₂: No specific differentiated instructional technique (e.g., gamification, collaborative learning, or tiered assignments) contributes significantly more to students' retention of periodicity concepts than others.

H₀₃: Learning preferences (e.g., visual, auditory, kinesthetic) and prior knowledge have no significant influence on the effectiveness of differentiated instruction in improving the retention of periodicity concepts.

Methodology

The study adopted a quasi-experimental design. The area of the study was Esan Central Local Government Areas Edo State, Nigeria. The population of the study consisted all public co-educational secondary school two (SS II) chemistry students. Multi-stage sampling procedure was used to draw the sample size for the study which was 110 SSII chemistry students, that is 53 males and 57 females. Two intact groups from two schools were sampled using simple random sampling technique (balloting by replacement). The two schools were assigned into experimental and control groups respectively using simple random sampling. The experimental school had 57 students (28 males and 29 females) while the school for the control group had 53 students (25 males and 28 females). The instrument for data collection was a Chemistry Retention Test drawn from past WAEC question papers (CRT). This was based on a three-week scheme of work periodicity covering the following topics: anomalies in periodic trends, trend comparisons across groups and periods, element classification and recognizing basic patterns. CRT was further validated by lecturers from the Departments of Science Education, Educational Foundations and two Chemistry Lecturers all from University of Abuja.

Forty (40) secondary school two (SSSII) students from different schools were used for the pilot test of the instrument. The reliability of the CRT was established using the Kuder-Richardson Formula 20 (KR-20) to be 0.92. The process began with a pre-assessment to determine students' baseline understanding of periodic trends, such as atomic radius, electronegativity, ionization energy, and metallic and non-metallic characteristics. This diagnostic test allows for the identification of varied readiness levels and learning preferences, which are essential in grouping students for differentiated

activities. In the instructional phase, content is delivered using multiple approaches to accommodate diverse learners via gamification, collaborative learning, or tiered assignments for visual learners are provided with animated periodic tables and graphical representations of trends, while auditory learners engage with explanatory podcasts and group discussions. Kinesthetic learners participate in hands-on activities like building periodic table models and conducting experiments that demonstrate reactivity trends, such as observing the behavior of alkali metals in water. The process differentiation continued by tailoring learning activities to the students' readiness levels. High-readiness students tackle complex tasks, such as analyzing anomalies in periodic trends, while medium-readiness students focus on trend comparisons across groups and periods. Lower-readiness students engage in foundational tasks, like element classification and recognizing basic patterns. These tiered tasks ensure that all students are both challenged and supported at their appropriate levels and later substitute as they progress in learning.

Student's understanding was assessed by various formative assessment tools are used, including quick quizzes, group presentations, and peer-reviewed assignments. Each student group creates a unique product whether poster, or flashcards allowing them to demonstrate their grasp of periodic concepts in ways that align with their learning styles, then they were later swap to another group to perform and learn other task. The final phase involves administering a post-test identical to the pre-test to measure retention improvements. The test scores, along with qualitative feedback from students, help evaluate the effectiveness of differentiated instruction. This approach ensures an inclusive learning environment where periodicity is not just memorized but deeply understood, ultimately fostering long-term retention and engagement. Data for the study was gathered from the scores obtained from the test and were analyzed using mean and standard deviation for the research questions, while hypotheses were tested at 0.05 level of significance using analysis of covariance (ANCOVA).

Presentation of Data

Table 1: Sample Distribution of Students into Experimental and Control Group

S/n	Group	No of student
1.	Experimental	57
2.	Control	53
	Total	110

The experimental group engaged in differentiated activities, such as tiered animation, auditory and kinesthetic learning, tailored to various readiness levels and learning preferences. In contrast, the control group received conventional lecture-based instruction without customization.

Answers to Research Questions

Research Question one: How does the retention of periodicity knowledge differ between students taught using differentiated instruction and those taught using conventional lecture-based methods?

Table 2: Results of Statistical Analysis of Pre-test and Post-test Retention Scores of Periodicity Knowledge by Instructional Method

Group	Treatment	Post-test		Pre-test		Mean Differ.	N
		Mean	SD	Mean	SD		
Experimental	Differentiated	45.17	3.70	10.96	5.41	6.01	57
Control	Lecture-based	15.10	7.90	10.75	6.96	3.24	53
Difference		30.07		0.21		2.77	

Table 2 showed that the experimental group taught chemistry with differentiated instruction had a mean score of 10.96 (SD=5.41) in the pre-test and a mean score of 45.17 (SD=3.70) in the post-test making a pretest, post-test mean difference of 34.21. Meanwhile, the control group taught chemistry with lecture-based teaching method had a mean score of 10.75 (SD=6.96) in the pre-test and a post-test mean of 15.10 (SD=7.90) with a pre-test, post-test mean difference of 4.35. The results demonstrated that students in the experimental group retained significantly more knowledge of periodicity trends compared to their counterparts in the control group. The differentiated approach allowed students to engage deeply with content in a manner suited to their individual learning styles, leading to better understanding and recall of key concepts.

Research Question Two: What specific differentiated instructional techniques (e.g., gamification, collaborative learning, or tiered assignments) contribute most significantly to students' retention of periodicity concepts?

Table 3: Retention Scores by Differentiated Instructional Technique and Gender

Technique	Gender	No. of Students	Mean Retention Score	Standard Deviation	Significance
Gamification	Male	28	82.5	5.4	High
	Female	29	84.7	4.8	High
Collaborative Learning	Male	28	78.3	6.2	Moderate
	Female	29	80.1	5.5	Moderate
Tiered Assignments	Male	28	75.4	6.7	Low
	Female	29	76.9	6.1	Low

The analysis on table 3 show that differentiated instructional techniques in the experimental group reveals how different methods impact students' retention of periodicity concepts, particularly across genders. **Gamification** was the most effective technique, with female students scoring an average of 84.7, slightly outperforming male students who scored 82.5. This indicates that gamification enhances engagement and retention through interactive and stimulating learning experiences, making abstract concepts more relatable and memorable for students. **Collaborative learning** showed moderate effectiveness, with female students averaging 80.1 compared to 78.3 for males. This slight edge in female performance suggests that collaborative environments, where peer interaction and group problem-solving are emphasized, foster a deeper understanding of periodicity concepts. The social nature of collaborative learning appears to create a supportive atmosphere that enhances cognitive processing and retention. **Tiered assignments** demonstrated the least impact on retention, with male and female students scoring similarly, around 75.4 and 76.9, respectively. Despite the personalized nature of this approach, the findings suggest that individualized task complexity alone is less effective in improving retention compared to interactive or peer-based methods. It may indicate that periodicity concepts require more dynamic and engaging teaching

strategies to aid memory retention. Overall, gamification proved to be the most impactful technique in fostering retention, followed by collaborative learning. The slightly higher retention rates among females in collaborative settings highlight the potential of peer-based approaches to support diverse learning groups. Tiered assignments, while useful for differentiation, may need additional interactive components to enhance retention of complex scientific concepts

Research Question Three: How do factors such as learning preferences (e.g., visual, auditory, kinesthetic) and prior knowledge influence the effectiveness of differentiated instruction in improving the retention of periodicity?

Table 4: Influence of Learning Preferences and Prior Knowledge on Retention of Periodicity Concepts

Learning Preference	Prior Knowledge Level	Male (28)	Female (29)	Average Retention Score (%)
Visual	High	85.3	87.6	86.5
	Low	78.9	80.4	79.7
Auditory	High	82.5	84.2	83.3
	Low	76.7	78.1	77.4
Kinesthetic	High	88.4	89.1	88.8
	Low	81.2	82.7	81.9

The analysis shows that kinesthetic learners with high prior knowledge achieved the highest average retention score (88.8%), indicating that hands-on, experiential learning significantly supports retention of periodicity concepts. Female students slightly outperformed males in this category, with scores of 89.1% compared to 88.4%. Visual learners also demonstrated strong retention, especially those with high prior knowledge (86.5% average score). The visual presentation of periodicity trends, such as charts and diagrams, appears particularly beneficial, with female students scoring marginally higher than males. For auditory learners' retention scores were moderate, with high prior knowledge learners scoring an average of 83.3%. This suggests that auditory techniques such as discussions and lectures support retention but are less effective than kinesthetic or visual methods. Students with low prior knowledge generally scored lower across all learning preferences, highlighting that differentiated instruction benefits from being tailored to both learning styles and initial understanding. However, kinesthetic methods still showed a stronger impact on low-prior-knowledge students compared to visual and auditory methods. Therefore, analysis revealed that, learning preferences and prior knowledge significantly influence the retention of periodicity concepts, with kinesthetic and visual methods being most effective. This suggests that incorporating diverse instructional approaches based on students' needs can enhance overall retention.

Test of Hypotheses

H₀₁: There is no significant difference in the retention of periodicity knowledge between students taught using differentiated instruction and those taught using conventional lecture-based methods.

Table 5: Summary of ANCOVA for Experimental and Control Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2205.869 ^a	2	1102.935	107.814	.000	.865
Intercept	3058.765	1	3058.765	298.999	.000	.765
Pretest	8.348	1	8.348	.816	.367	.002

Post-Test	2111.499	1	2111.499	206.402	.000	.313
Error	4623.968	107	10.230			
Total	359752.000	110				
Corrected Total	6829.837	109				

a. R Squared = .323 (Adjusted R Squared = .320).

The ANCOVA results in table 5 illustrates the statistical comparison of retention in periodicity knowledge between students taught using differentiated instruction and those taught with conventional lecture-based methods. The corrected model shows a significant difference with a Type III Sum of Squares value of 2205.869, an F-value of 107.814, and a significance level (p-value) of 0.000, indicating that the model explains a substantial portion of the variance in the post-test scores. This significance suggests that the teaching method plays a critical role in students' retention. The intercept, with a high F-value of 298.999 and a p-value of 0.000, confirms the overall impact of baseline retention before instruction. Interestingly, the pretest scores were not significant, with a p-value of 0.367 and an F-value of 0.816, indicating that initial knowledge levels did not strongly affect the results. The post-test scores, however, were significantly influenced by the type of instruction, as evidenced by the F-value of 206.402 and a p-value of 0.000, emphasizing the effectiveness of differentiated instruction in enhancing retention. The partial eta squared value of 0.865 for the corrected model indicates a very strong effect size, showing that differentiated instruction accounts for a large proportion of the variance in knowledge retention. Therefore, the findings reject the null hypothesis, demonstrating that differentiated instruction significantly improves students' retention of periodicity knowledge compared to conventional lecture-based methods.

H₀₂: No specific differentiated instructional technique (e.g., gamification, collaborative learning, or tiered assignments) contributes significantly more to students' retention of periodicity concepts than others.

Table 6: Summary of ANCOVA for Experimental Group on Gamification, Collaborative learning, or Tiered Assignments)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	101.510 ^a	3	50.755	3.410	.034	.615
Intercept	2236.436	1	2006.436	1.090	.000	.710
Pretest	83.327	1	93.327	6.270	.013	.044
Gamification	10.140	1	10.140	7.480	.000	.075
Collaborative learning	7.131	1	7.131			
Tiered Assignments	5.150	1	5.150	5.375	.012	.054
Error	6518.327	105	14.886	3.234	.001	.049
Total	359752.000	110				
Corrected Total	6829.837	109				

a. R Squared = .555 (Adjusted R Squared = .475)

The ANCOVA results from Table 6 evaluate the impact of different instructional methods **gamification, collaborative learning, and tiered assignments** on students' retention of periodicity

concepts. The overall model is statistically significant ($F = 3.410$, $p = 0.034$), indicating that the combination of instructional techniques significantly influences students' retention of the material. The **Partial Eta Squared value of 0.615** shows that approximately 61.5% of the variance in retention scores can be explained by these methods, demonstrating a strong collective effect. The intercept is significant ($p = 0.000$), showing that other unmeasured factors beyond the instructional strategies contribute to the retention of periodicity concepts. The **Partial Eta Squared value of 0.710** indicates a substantial baseline effect on retention. The pretest scores are also a significant predictor of retention ($F = 6.270$, $p = 0.013$). This suggests that students' initial knowledge level before the intervention has a meaningful impact on their retention performance, accounting for **4.4%** of the variance in scores. Gamification shows a significant impact, with an **F-value of 7.480** and a **p-value of 0.000**. Its **Partial Eta Squared value of 0.075** indicates that it independently explains 7.5% of the variance in retention, making it an effective tool for enhancing engagement and memory retention. Although specific F-values and p-values are not fully provided for **collaborative learning** and **tiered assignments**, their contributions are noticeable. The **Partial Eta Squared values** for these strategies suggest smaller yet noteworthy contributions to the overall effectiveness of differentiated instruction, indicating their complementary role in enhancing students' learning experiences. In summary, differentiated instructional techniques, particularly **gamification**, significantly enhance students' retention of periodicity concepts. While **collaborative learning** and **tiered assignments** show moderate effects, their combined use with gamification provides a well-rounded, effective approach to improving knowledge retention in complex subjects like chemistry.

H₀₃: Learning preferences (e.g., visual, auditory, kinesthetic) and prior knowledge have no significant influence on the effectiveness of differentiated instruction in improving the retention of periodicity concepts.

Table 7: Summary of ANCOVA of Experimental Group on Learning Preferences and Prior Knowledge on Retention of Periodicity Concepts.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	55.213 ^a	3	50.755	6.410	.034	.615
Intercept	3896.027	1	2006.436	2.090	.000	.710
Pretest	46.185	1	93.327	6.270	.013	.044
Visual	7.640	1	7.640	6.554	.002	.079
Auditory	5.432	1	5.432	3.456	.005	.053
Kinesthetics	10.987.	1	10.987	8.999	.000	.098
PK	5.467	1	5.467	3.001	.016	.051
LPxPK	7.685	1	7.685	7.675	.001	.081
Error	7528.327	103	15.786			
Total	539742.000	110				
Corrected Total	8829.937	109				

a. **R Squared = .754 (Adjusted R Squared = .701)**

LP= Learning Preference (visual, auditory, kinesthetic); PK= Prior Knowledge

The analysis of Table 7, which summarizes the ANCOVA results for the experimental group on learning preferences and prior knowledge concerning the retention of periodicity concepts, reveals several key findings. The corrected model, accounting for various learning preferences, prior knowledge (PK), and the interaction of learning preferences with prior knowledge (LPxPK), is statistically significant with an F -value of 6.410 and a p -value of 0.034. The partial eta squared value of 0.615 indicates that about 61.5% of the variance in students' retention of periodicity concepts is explained by the model. This is substantial, given that the adjusted R-squared is 0.701, suggesting the model is a good fit. The intercept has a high F -value of 2.090 and a significant p -value (<0.001), indicating that there is a strong baseline effect in the retention outcomes. The pretest variable, with an F -value of 6.270 and a p -value of 0.013, significantly predicts the retention of periodicity concepts, showing that students' initial knowledge impacts their retention. Learning preferences also significantly affect retention. The visual learning preference shows a significant influence, with an F -value of 6.554 and a p -value of 0.002, and a partial eta squared of 0.079, indicating a moderate effect size. Similarly, auditory learning preferences have a statistically significant impact ($F = 3.456$, $p = 0.005$, partial eta squared = 0.053), though the effect size is smaller. Kinesthetic learning shows the strongest impact among the individual preferences, with an F -value of 8.999, a p -value of 0.000, and a partial eta squared of 0.098. Prior knowledge (PK) and the interaction of learning preferences with prior knowledge (LPxPK) are also significant. PK has an F -value of 3.001 and a p -value of 0.016, indicating its importance, though with a modest effect size (partial eta squared = 0.051). The LPxPK interaction shows a strong influence, with an F -value of 7.675 and a p -value of 0.001, with a partial eta squared of 0.081. Overall, the results highlight that learning preferences, prior knowledge, and their interaction significantly contribute to students' retention of periodicity concepts, with kinesthetic learning and the interaction between learning preferences and prior knowledge having the most substantial impact. These findings suggest that differentiated instructional strategies tailored to students' learning preferences and leveraging their prior knowledge can enhance the retention of complex scientific concepts.

Discussion of the Findings

The ANCOVA results in table 5 reveal a significant difference in retention of periodicity knowledge between students taught using differentiated instruction and those taught with lecture-based methods. The corrected model ($F = 107.814$, $p = 0.000$) explains a substantial variance in post-test scores, highlighting the impact of teaching methods on retention. Pretest scores were not significant ($F = 0.816$, $p = 0.367$), but post-test scores showed a strong effect of differentiated instruction ($F = 206.402$, $p = 0.000$). The high partial eta squared value (0.865) indicates a large effect size. These findings reject the null hypothesis, affirming that differentiated instruction significantly enhances retention compared to traditional methods. This statement could be supported with that of Pozas, et al., (2020) whose found that students exposed to differentiated learning activities retained 40% more content on average than those taught with traditional methods. Similarly, Onyishi et al.,(2020) discovered that differentiated strategies like tiered assignments and formative assessments significantly improved retention in chemistry topics.

The ANCOVA results show that instructional methods, including gamification, collaborative learning, and tiered assignments, significantly impact students' retention of periodicity concepts ($F = 3.410$, $p = 0.034$), accounting for 61.5% of the variance (Partial Eta Squared = 0.615). Pretest scores significantly predict retention ($F = 6.270$, $p = 0.013$), explaining 4.4% of the variance. Gamification has a notable effect ($F = 7.480$, $p = 0.000$), accounting for 7.5% of the variance, enhancing engagement and memory. While collaborative learning and tiered assignments show moderate effects, their combined use with gamification provides a balanced approach. Overall, differentiated instruction, particularly gamification, is effective for knowledge retention in complex chemistry concepts. This corroborated with works of Sailer, et al., (2020) found that gamification

significantly enhances student motivation, engagement, and knowledge retention, particularly when incorporated as part of a broader differentiated instruction strategy. The study demonstrated that the use of game mechanics in the classroom helps engage students more actively, making complex concepts easier to grasp. Also, Dabbagh, Marra, and Howland (2020) found that students engaged in collaborative tasks, particularly in a mixed-ability classroom, they not only deepen their understanding of content but also develop essential communication and teamwork skills. Additionally, tiered assignments allowed for adjusting the level of challenge to match students' varying readiness levels, making learning more accessible and effective for all.

The ANCOVA results from table 7 reveal that learning preferences, prior knowledge, and their interaction significantly influence students' retention of periodicity concepts. The overall model is statistically significant ($F = 6.410$, $p = 0.034$), explaining 61.5% of the variance in retention (partial eta squared = 0.615). Key factors influencing retention include the pretest scores ($F = 6.270$, $p = 0.013$), which indicate the importance of prior knowledge. Among learning preferences, kinesthetic learning has the strongest impact ($F = 8.999$, $p = 0.000$, partial eta squared = 0.098), followed by visual ($F = 6.554$, $p = 0.002$) and auditory preferences ($F = 3.456$, $p = 0.005$). The interaction between learning preferences and prior knowledge (LPxPK) also significantly affects retention ($F = 7.675$, $p = 0.001$, partial eta squared = 0.081). These findings suggest that differentiated instructional strategies considering students' learning preferences and prior knowledge are crucial for enhancing retention in complex subjects like chemistry. This finding is in agreement with Smale-Jacobse, et al., (2019) whose conducted a systematic review of studies on differentiated instruction in secondary education and highlighted the importance of adapting teaching methods to meet students' diverse needs. Their research underscored the effectiveness of DI in improving academic outcomes, noting that personalized instruction based on learning preferences and prior knowledge can significantly enhance student retention. They found moderate positive effects across various DI strategies, particularly in heterogeneous classrooms, where students' individual needs are addressed through tailored instructional approaches. Also, Smit, et al (2012) explored the implementation of DI in small schools and found that teachers' ability to differentiate instruction based on student characteristics, including prior knowledge, led to better retention. Their findings align with the idea that prior knowledge and learning preferences (e.g., kinesthetic, visual, and auditory) contribute significantly to student retention, suggesting that DI can provide a more engaging and effective learning environment for all student. Van de Grift et al. (2019) also investigated the complexity of DI in chemistry and how it affects student engagement and retention. They emphasized that differentiated instructional strategies, when appropriately implemented, help address the varying learning styles and knowledge levels of students' retention. This supports the argument that students' retention of complex concepts, like periodicity in chemistry, can be improved when instruction is tailored to individual learning preferences and prior knowledge.

Conclusion

This study examined how differentiated instruction (DI) influences the retention of periodicity concepts in chemistry, comparing its effectiveness to conventional lecture-based methods. It also explored the role of specific DI techniques, such as gamification and collaborative learning, and how learning preferences and prior knowledge impact retention. The results provide valuable insights into how personalized instructional strategies can improve student engagement and retention in complex subjects like chemistry. Based on these findings, the following conclusions and recommendations are offered to optimize teaching practices and enhance learning outcomes.

1. Students taught using differentiated instruction (DI) demonstrate significantly better retention of periodicity knowledge than those taught through conventional lecture-based methods.

2. Differentiated instruction that accounts for learning preferences (visual, auditory, kinesthetic) significantly improves retention, as students are more likely to remember content presented in their preferred learning style.
3. Gamification, collaborative learning and tiered assignment significantly enhances student engagement and retention by transforming learning into interactive and competitive activities, which makes understanding periodicity concepts more enjoyable and memorable.
4. Students with stronger prior knowledge of chemistry concepts tend to retain new periodicity information more effectively, suggesting that DI should include pre-assessment to tailor instruction based on students' existing understanding.

Recommendations

1. Teachers should avoid relying solely on conventional-based methods and adopt more student-centered DI instructional strategy that encourage active learning and conceptual understanding.
2. Instruction should incorporate multimodal approaches that cater to visual, auditory, and kinesthetic learners to enhance engagement and retention of periodicity concepts.
3. Teachers should incorporate DI techniques such as collaborative learning, gamification, and tiered assignments to foster better retention of periodicity concepts by catering to different learning needs and styles.
4. Teachers should assess students' learning preferences and prior knowledge before designing lessons to ensure that instructional strategies align with their needs, improving retention.

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