IMPLEMENTATION OF FLIPPED CLASSROOM PEDAGOGY TO ENHANCE STUDENTS' PERFORMANCE AND RETENTION OF ELECTRON CONFIGURATION CONCEPTS

Francis Kwadjo Addo[1], Boniface Yaayin[2]
[1]Department of Science, Mankessim Senior High Technical School, Mankessim, Ghana
[2]Department of Chemistry Education, University of Education, Winneba, Ghana
Corresponding author email: byaayin@uew.edu.gh

ABSTRACT

Electron configuration is a fundamental topic in chemistry education at the senior high school level such that failure to understand the basic concepts will gravely affect students' comprehension of several other chemistry topics as they progress. This study investigated the implementation of flipped classroom pedagogy to enhance students' academic performance and retention of electron configuration concepts in a senior high school setting. The study, conducted at a selected Senior High Technical School in Ghana, addressed the prevalent issue of students' inadequate conceptual understanding resulting in low performance and retention of electron configuration concepts. Utilizing a single-group, a classroom action research design guided this study. The intervention involved a four-week implementation of the flipped classroom learning approach. The instrument used was test, which was developed in a form of pre-intervention test, post-intervention test and delayed post-intervention test. Participants were selected by purposive sampling, by engaging students in an intact class with the challenge of understanding electron configuration. The findings revealed a significant enhancement in students' academic performance in electron configuration due to application of the flipped classroom pedagogy. The study further found that the magnitude of the effect the flipped classroom pedagogy had on the students' performance was large. The study also found that the flipped classroom pedagogy was effective in retaining electron configuration concepts among the students. Consequently, the study concludes that flipped classroom learning is a valuable pedagogical tool for improving students' academic performance and retention of electron configuration concepts in chemistry education. The study recommends the integration of flipped classroom methodology by chemistry teachers in teaching electron configuration and other chemistry topics in the selected school. *[African Journal of Chemical Education—AJCE 14(3), July 2024]*

INTRODUCTION

The perceived abstract nature of chemistry and its difficulty is widespread among many students across the globe. This notwithstanding, chemistry is one of the engines of national growth and development. It is the backbone of industrialization in any developed or developing nation. Many sectors of national growth: Health, agriculture, education, technology, water and sanitation and several others thrive based on the application of chemistry concepts. Thus, it is an imperative subject to study in school. Whatever the difficulty that is associated with its learning, the role it plays in national development should be the motivation for students to take the subject serious and learn fundamental concepts from the early stages so as to progress with it.

It is true that several chemistry concepts are abstract and cannot be directly observed or linked to occurrences in the immediate environment. Research has shown that the abstract nature of chemistry, combined with the requirement to comprehend concepts that are not directly observable, adds to the subject's challenge [1]. One particular area of chemistry among others where there are abstract concepts is electron configuration. It is a very important and fundamental topic in chemistry, yet most of its concepts are abstract. For example, the concept of an atom, electron or an atomic orbital cannot be directly associated with any tangible object in the environment for a student to appreciate. At best, symbols and other illustrations are used by chemistry teachers to portray the existence of some of these concepts that cannot be directly observed.

An essential aspect of starting chemistry education, especially in Ghanaian senior high school is establishing the concept of electron configuration, which involves discussing atomic orbitals that is fundamental to the study of other chemistry topics. The importance of electron configuration to the study of other chemistry concepts cannot be underestimated, yet it is one of the challenging topics for students in senior high school. Students' comprehension of electron configuration lays a good foundation for the study of periodicity, hybridization, chemical bonding, the mole concept and other topics in chemistry.

The idea of electron configuration, which explains how electrons are organized within an atom, originates from the Bohr atomic model. This model emerged after the discovery of electrons. However, the primary interest of this study is in the electron configuration that stems from a subsequent atomic model, known as the quantum mechanics' atomic model. According to this model, an electron configuration is defined by four quantum numbers: the principal quantum number (n), azimuthal quantum number (l), magnetic quantum number (m), and magnetic spin quantum number (s) [2]. To accurately and meaningfully write electron configurations, students must understand the implication of these four quantum numbers. Also, they must understand and appropriately apply the three fundamental rules: Aufbau's principle, Hund's rule, and Pauli's Exclusion Principle, which govern the arrangement of electrons in atomic orbitals [3].

However, it is important to note that achieving a correct understanding of electron configuration requires more than just knowledge of these principles. To understand the abstract nature of electron configuration, students must also possess adequate knowledge of atomic symbols, atomic numbers, the concept of atoms and ions, as well as the ability to determine the number of protons and electrons in an atom. Since students have never directly observed an atom, these concepts may appear foreign and unfamiliar to them. Consequently, establishing connections between these relevant concepts becomes crucial for constructing a robust understanding of electron configuration.

To address the challenges associated with comprehending electron configuration by students, it is essential to implement effective instructional strategies. Several studies have explored various approaches to enhance students' understanding in this area, yet the problem still persists. One study conducted by [4], investigated chemistry teachers' knowledge and application of electron configuration. The findings revealed that teachers often struggle with accurately and appropriately explaining the concept and its related principles. This highlights the importance of teacher professional development programs that focus on deepening their understanding of electron configuration and the use of effective instructional strategies. Additionally, [5] conducted a comparative study examining the difficulties students face in understanding electron configuration based on their learning approaches. The results indicated that students who adopted a surface approach, simply memorizing information without a deep conceptual understanding, encountered more difficulties in comprehending electron configuration compared to those who employed a deep approach. These findings emphasize the significance of promoting meaningful learning experiences that encourage students to actively engage with the underlying principles and concepts of electron configuration.

As part of the difficulties encountered by students in understanding the concept of electron configuration, [6] identified a lack of solid understanding of atomic orbitals among students, suggesting that their understanding is primarily derived from textbooks or teachers. To enhance students' understanding of electron configuration, it is imperative to relate this concept to other relevant concepts. In light of these research findings, implementing instructional strategies that facilitate students' comprehension of electron configuration becomes crucial, thus, the need for this study. Educators can incorporate interactive activities such as modeling exercises, computer simulations, and hands-on laboratory experiments to provide students with concrete experiences related to electron configuration as alternative approaches to learning the topic. These experiences help students bridge the gap between the abstract nature of the concept and their understanding of the submicroscopic world. Furthermore, integrating technology into the learning process can enhance and sustain students' engagement and understanding of electron configuration. Online resources, virtual laboratories, and interactive visualization tools can aid in visualizing complex concepts, allowing students to explore and manipulate electron configurations in a dynamic and interactive manner to offset the abstract nature of the topic.

To attain a comprehensive understanding of chemical knowledge, it is essential to explicitly teach the interplay between the submicroscopic, microscopic, and symbolic levels [7]. Given that atoms are inherently invisible to the naked eye, students must comprehend the concepts at both the microscopic and symbolic levels to fully understand ideas such as electron configuration. Difficulties in comprehending this topic may arise if students lack a solid foundation of understanding on these two levels. In order to bridge the gap and facilitate students' comprehension, it becomes necessary for educators to emphasize the relationship between the sub microscopic world of atoms, the observable microscopic world, and the symbolic representations used in chemistry. By clearly teaching the connections between these levels, students can develop a more holistic understanding of chemical phenomena that will make them appreciate the concept of electron configuration.

The question is, how do teachers introduce concepts when teaching? Many students come to the classroom with conflicting ideas, and it behooves on the teacher to find solution to all of these issues in the learning environment. The most significant issue with teaching chemistry, according to [8] is how concepts are introduced. The ideas should make it possible for students to understand chemistry without having to memorize definitions or utilize meaningless formulae and words. The language or ideas that students employ should ideally and progressively influence their way of thinking. According to a study conducted by [9], the occurrence of conceptual change in chemistry education relies on the design of lessons that encourage students to express their own ideas and test them against accepted scientific viewpoints.

To foster meaningful discussions, it is crucial for teachers to establish a supportive learning environment that allows students to freely articulate their thoughts without the fear of being ridiculed. Consensus in the field suggests that promoting students' collaboration, integrating technology, and employing effective teacher facilitation all contribute to enhanced academic achievement in secondary level chemistry classrooms [10]. Consequently, studies have recommended a comprehensive transformation of our public education system [11] and have proposed that educators explore alternative approaches to traditional classroom settings [12]. The advent of the internet has revolutionized education, providing learners with extensive access to technological resources as alternative to the traditional teaching approaches. According to [13] and [14], technology has made information readily available, allowing individuals to access and share it at anytime and anywhere. In the modern world, Information, Communication and Technology (ICT) has become relevant in various aspects of human life, including education [15]. ICT environment is a platform that promotes and meets diverse learning needs of students. The use of ICT in education caters for students' needs, learning styles, aspirations, and provides a wide range of learning experiences [16]. Consequently, employing multimedia in educational setting has proven effective in enhancing performance and retention rates [17].

One instructional pedagogy that is of interest to the researchers in this study and worth exploring is the flipped classroom learning approach. Researchers have indicated that active learning pedagogy coupled with instructional technology innovations has led to the adoption of the flipped classroom model [18, 19]. It is however, important to recognize that while students today are highly adaptable to new technologies, educators should not overlook the significance of direct instruction, which plays a crucial role in the learning process [19]. The Flipped Classroom Learning (FCL) method of instruction effectively combines the strengths of both traditional teaching methods and modern technology to facilitate the dissemination of concrete information and foster critical evaluation among learners, leading to improved performance and retention. The relevance and the choice of the flipped classroom learning approach in this study cannot be downplayed. The FCL model stands out from other teaching approaches, such as video conferencing, computer-based teaching (CBT), and mobile learning, which lack the interactive nature of a direct classroom session. For instance, pre-recorded videos on various subjects for primary and secondary school students, stored on CD or DVD, may only benefit a selected group of students, as there is no opportunity for feedback or assessment of their understanding and comprehension of complex concepts [18]. Furthermore, students are deprived of the invaluable one-on-one interaction with their teachers, making it difficult to address individual needs and modify teaching approaches based on students' contributions.

The flipped classroom-learning model offers a dynamic alternative by utilizing technology to engage students actively in the learning process. By assigning pre-recorded teachings and educational materials as homework, class time can be dedicated to collaborative activities, discussions, and problem-solving exercises. This interactive approach allows students to delve deeper into the subject matter, apply their knowledge, and receive immediate feedback from their peers and instructors [18]. Consequently, students develop stronger cognitive, emotional, behavioural, and agentic engagement, resulting in more positive perceptions towards the flipped classroom across various areas of learning [20]. The flipped classroom learning model emphasizes the importance of student-centered learning, where learners take ownership of their education and actively contribute to the learning process [21].

The significance of flipped classroom pedagogy to both the teacher and the learner cannot be overemphasized. Teachers gain the confidence to customize the curriculum for a group of students while in the classroom because enough classroom time allows the teacher to work with students more individually per this pedagogy [22]. Teachers can also deliver more meaningful lessons because they do not have to repeat instructions as frequently. Although research on the FCL has been increasing in recent years, to best of the researchers' knowledge, there is still a limited study performed in senior high school chemistry education in Ghana, specifically teaching of electron configuration. Additionally, there is limited research on how flipped classroom learning approach impacts students' learning achievement and retention of chemistry concepts. Researchers have noted that, when students are not provided with sufficient assistance when modelling detailed knowledge and proficiency, their learning achievement and self-efficacy may reduce substantially [23]. As a result, this current study employed the flipped classroom learning pedagogy in teaching electron configuration in an intact class in a selected Senior High Technical School in Central Region of Ghana, where students in the said class had difficulties in understanding the concept of electron configuration.

The purpose of this study was to implement flipped classroom pedagogy to enhance students' performance and retention of electron configuration concepts. The study was guided by the following null hypotheses, which were tested at the 0.05 level of significance.

H_o1: Flipped classroom learning approach has no significant effect on students' academic performance in electron configuration.

H_o2: Flipped classroom approach has no significant effect on students' retention of electron configuration concepts.

LITERATURE REVIEW

Theoretical Framework

This study was anchored on Vygotsky's social constructivism theory [24] and Bandura's social learning theory [25]. Figure 1 presents the theoretical framework, which serves as the foundation of this study and connects to the research problem understudy.

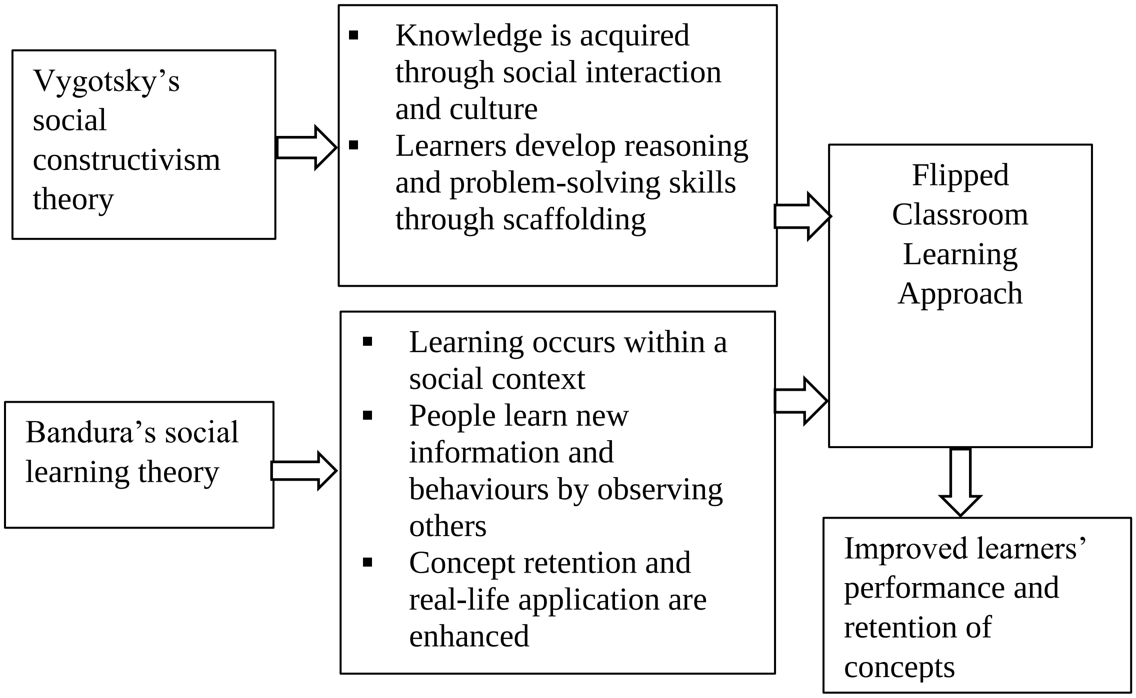

Figure 1: Theoretical Framework within the Context of Flipped Classroom Learning Approach

Vygotsky's social constructivism theory posits that students acquire knowledge through social interactions and culture, as social exchanges play a critical role in cognitive development [24]. Instructions must be designed so that students interact effectively within the classroom and construct their own understanding [26, 27]. The flipped classroom approach aligns with Vygotsky's theory by providing scaffolding at a meta-cognitive level to support learners' reasoning and problem-solving skills [28]. The social interactions and collaborative learning in the flipped classroom help learners develop deeper meaning of the content area. In the flipped classroom, learners access instructional materials, such as videos, outside the class and engage in collaborative and cooperative learning and peer instruction during class time, facilitating the development of the learner effectively [18, 29]. However, the role of the facilitator is crucial in guiding learners' understanding and providing feedback to help learners make deeper meaning of the content area [26, 27].

The premise of the social learning theory is that people learn new information and behaviours by observing others. Bandura believed that learners acquire new behaviours by watching others, forming ideas about how to perform those behaviours, and then imitating them [25]. For observational learning to be effective, the learner is expected to meet the following four conditions: attention, retention, reproduction, and motivation [30]. In the flipped classroom, the social learning theory is continuously evident. The learner is exposed to media where a presenter models appropriate behaviour. When the learner pays attention to the instruction, retention, reproduction, and motivation are likely to occur [31, 32]. Collaboration is another key aspect of the flipped classroom that aligns with Bandura's social learning theory. By working collaboratively with their peers, students have the opportunity to observe and learn from one another [31]. In collaborative learning, many students succeed as opposed to individualised learning. As students share ideas in a collaborative manner, the weak students learn from the abled ones, together, they succeed in the learning process and that is the beauty of a flipped classroom pedagogy ably anchored on Vygotsky's social constructivism theory and Bandura's social learning theory.

Empirical Review

Effect of flipped learning on students' performance and retention of chemistry concepts

The application of flipped classroom pedagogical approach has garnered attention within the realm of secondary education, particularly in the domain of chemistry instruction. Flipped classrooms have shown a positive effect on senior high school students' understanding and performance in chemistry. Flipped classroom model encourages critical thinking and deeper exploration of chemistry topics. In this learning approach, students have more opportunities to ask questions, seek clarification, get feedback on unresolved questions raised during learning outside the classroom setting and engage in hands-on activities during class time. This active learning environment has led to a more comprehensive grasp of complex chemical concepts.

A meta-analysis conducted by [33] indicated that students exposed to flipped instruction consistently outperformed their peers in traditional settings in terms of examination scores and course completion rates. This enhanced performance can clearly be attributed to the personalized nature of the flipped approach, which enables learners to address their specific learning needs and engage in targeted remediation or enrichment. Furthermore, flipped classroom approach places emphasis on peer interaction and collaborative problem solving that cultivates a deeper understanding and retention of chemistry concepts. Johnson et al. [34] asserted that collaborative learning uniquely enhances students' ability to articulate their thought processes, defend their ideas as well as integrate diverse perspectives. This process of articulation and debate nurtures metacognitive skills, giving students the opportunity to reflect on their learning strategies and refine their approaches to problem solving in the realm of chemistry that promotes performance.

Several studies have explored the effects of flipped learning on students' academic performance in various science subjects [35, 36]. A study by [37] examined the impact of a flipped learning approach on students' performance in learning the electronic configuration of atoms. The study engaged 70 high school students who were randomly assigned to either a flipped learning group or a traditional lecture-based group. The flipped learning group watched instructional videos on electronic configuration before attending class, while the traditional group received lectures during class time. The results of the study showed that the flipped learning group undoubtedly outperformed the traditional group on the post-test assessing the understanding of electronic configuration. The flipped learning group also demonstrated higher levels of engagement, motivation, and interest in the subject matter. The authors suggest that flipped learning approach offers students with more flexibility and control over their learning and creates room for more individualized and personalized instruction. Similarly, studies have indicated the effectiveness of flipped classroom learning approach in promoting self-directed learning, critical thinking, and problem-solving skills, which are crucial for understanding abstract topics like electron configuration [38, 39].

Another study by [40] investigated the impact of a flipped learning approach on students' understanding of the electronic configuration of atoms in a college-level chemistry course. The study involved 64 students who were randomly assigned to either a flipped learning group or a traditional lecture-based group. The flipped learning group watched instructional videos and completed online quizzes before attending class, while the traditional group received lectures during class time. The results of the study revealed that the flipped learning group performed significantly better on the post-test assessing the understanding of electronic configuration than the traditional group. The authors acclaimed that flipped learning approach promotes active learning and engages students in higher-order thinking skills, leading to deeper understanding and better performance on assessments. Similarly, [41] also investigated the effects of the flipped classroom model on students' academic achievement, motivation, and self-regulated learning in a chemistry course. The study found that students in the flipped classroom achieved significantly higher scores on the final examination compared to those in the traditional classroom.

Traditional lecture-based approaches have been scrutinized for their limited effectiveness in promoting deep understanding [42]. In contrast, active learning methods, such as flipped classrooms and problem-based learning, have shown promise in enhancing student engagement and retention [43]. Again, studies have shown that peer discussion and interactive collaborative learning as well as incorporating active learning strategies contribute to long-term retention [44, 45].

METHODOLOGY

Research Approach

The approach to this study was quantitative. The data collected and analysed to determine students' performance and retention of electron configuration concepts were numeric, hence, a quantitative approach was adopted in this study. Statistical analysis such as paired sample t-test used in this study indicates a quantitative orientation.

Research Design

This investigation employed a single-group pre-test and post-test classroom action research design. Action research, according to [46], is a democratic and participatory methodology that aims to generate valuable data for the development of acceptable human objectives. It is a research method that focuses on a specific problem and aims to formulate an action plan to address or resolve the identified problem.

Figure 2 presents the design for this research that encompasses the three phases of action research through which data were collected and analysed.

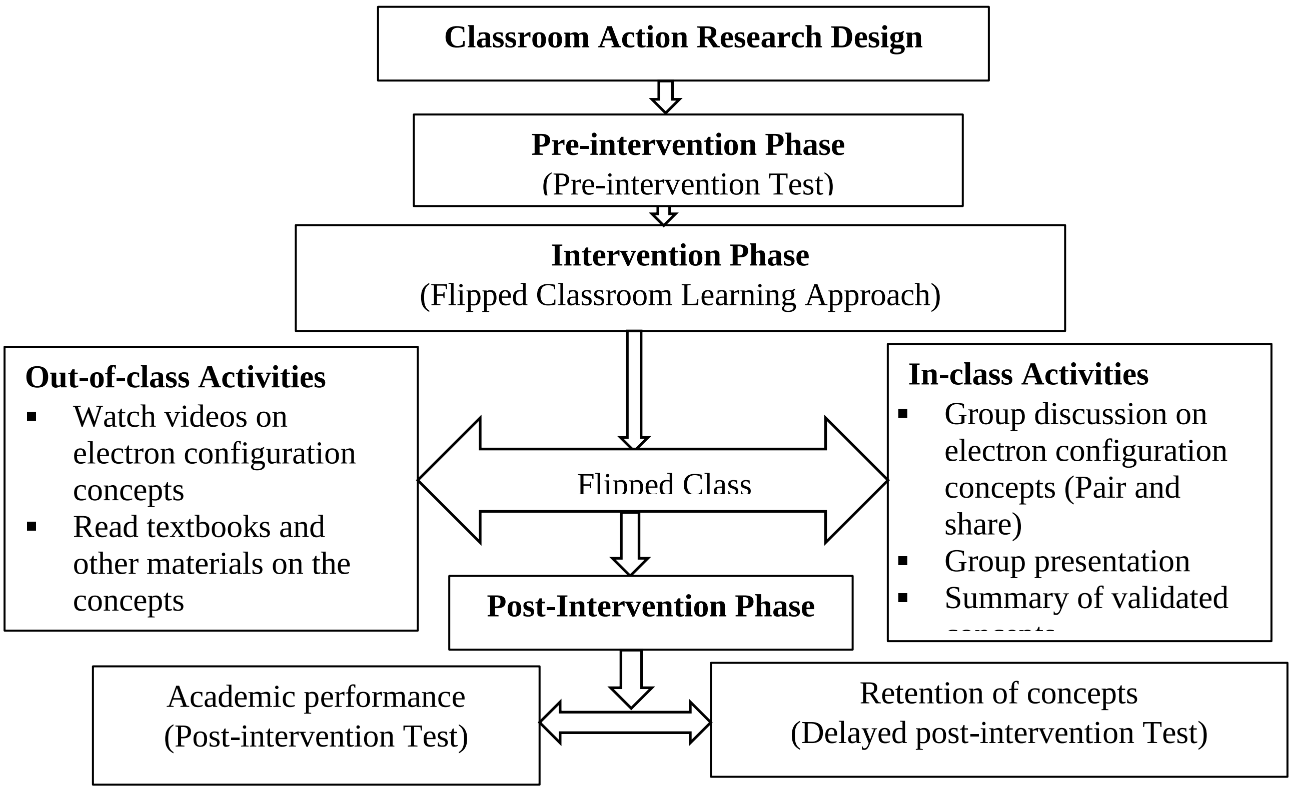

Figure 2: Action research study navigation scheme using flipped learning

From Figure 2, the design gave the blueprint through which the study was conducted. It followed sequentially through the pre-intervention phase, intervention phase to the post-intervention phase. Pre-intervention test was used to further diagnose the problem of students' low performance as a result of inadequate understanding of electron configuration concepts, which had been identified through classroom practice. The flipped classroom pedagogy was implemented at the intervention phase, while the post-intervention test and delayed post-intervention test were conducted at the post-intervention phase to assess the effectiveness of the flipped class learning paradigm in enhancing students' performance and retention of electron configuration concepts.

Sample and sampling procedure

A purposive sampling technique was utilized to engage 45 students from a single class (in-tact class), which was an existing class already organised per the institutional arrangement and was not supposed to be disrupted because of research. These students were selected due to their prior knowledge of chemistry, particularly electron configuration, which is the main focus of this study. As action research, the difficulty in understanding electron configuration concepts among the students was characteristic of the selected intact class for this study, hence, the use of purposive sampling technique.

Research Instrument

The research instrument was 'Electron Configuration Achievement Test' (ECAT), which was structured as a pre-intervention test, a post-intervention test and a delayed post-intervention test. The post-intervention test and the delayed post-intervention were modified forms of the pre-intervention test. The instrument was developed by the researchers.

Validity and Reliability of the Instrument

To ensure face and content validity of the instrument, experts in chemistry education in the Department of Chemistry Education, University of Education, Winneba, Ghana validated the instrument based on their experience in the subject area. The items in the test were adequate to address the various aspects of the concepts in electron configuration. A test re-test approach was used to determine the reliability of the 'Electron Configuration Achievement Test'. Before the pre-intervention test was administered to the research participants, a test re-test approach was carried out on twenty students who were not part of the research participants but shared similar characteristics with them. This involved administering the same test twice within a 24-hour interval to the individual students concerned [47]. A reliability correlation coefficient of 0.710 was obtained after the test re-test approach. The post-intervention test and the delayed post-intervention test were then modified from the pre-intervention test to avoid threats to internal validity of the test items.

Data Collection Procedure

Data collection was done at the pre-intervention phase through the administration of pre-intervention test. At the post-intervention phase after the flipped classroom pedagogy was implemented at the intervention phase, two sets of data were collected using the post-intervention test and delayed post-intervention test. The test scores were collated and formed the data for this study.

The flipped classroom approach was implemented through various planned activities for both in-class and out-of- class engagement. The electron configuration topic was divided into various subtopics and taught progressively using the flipped class approach. Some of the subtopics that were taught included atom's electron energy levels, quantum numbers, rules and principles governing writing of electron configuration using the s, p, d, f format and that of orbital diagrams and the use of concept maps as worksheets to test students' comprehension of the aspects learnt. During the out-of-class engagement by students themselves, video lessons on the electron configuration concepts were installed on computers in the school's computer laboratory to facilitate students' learning as they flipped from the regular classroom session. Again, during the out-of-class learning, students were assigned to take notes, solve guided questions, note down unresolved questions and areas they were not able to understand on their own for onward discussion during the in-class session. As students flipped to the in-class session, collaborative learning under the facilitation of the class teacher was initiated. This was done through group discussion (pair and share), group presentation and summary of validated concepts as scientifically accepted. This process continued within the period of implementation until all the sub-topics under the electron configuration were covered as contained in the senior high school chemistry syllabus.

Data Analysis Procedure

Data were analyzed with regards to the research hypotheses. A relationship was established between the independent variable, which is the flipped classroom learning approach on one hand and students' academic performance and retention of electron configuration concepts as dependent variables on the other hand.

A dependent-samples t-test was used to establish any significant difference that existed between the pre-intervention test and post-intervention test to determine the academic performance of the students in electron configuration after the intervention. Also, a dependent-samples t-test was used to determine any significant difference that existed between the post-test and the delayed post-test to ascertain students' retention of electron configuration concepts. The hypotheses were tested at a significance level of 0.05.

The eta square formula for dependent-samples t-test was employed to calculate the effect size (η^2) to determine the magnitude of the effect the flipped classroom learning approach has on the students' performance and retention of electron configuration concepts. The criteria for measuring the effect size according to [48] for interpreting the eta square values are as follows: 0.01 = small effect, 0.06 = moderate effect and greater than or equal to 0.14 as large effect.

Ethical considerations

The researchers secured an introductory letter from the Chemistry Education Department, University of Education, Winneba for the purpose of this study. This letter was presented to the headmaster of the selected school for the study to request permission to engage the students as research participants. The researchers also coordinated with the school's headmaster, ICT coordinator, and Head of the Science Department at the school to schedule data collection and intervention dates. Before participating, the students were briefed about the purpose of the study. Their consent to the study was sought and participation was solely voluntary. They were also given the option to withdraw from the study at any time if they were no longer willing to be part of it without victimisation.

To maintain anonymity, the students were instructed not to include their names or index numbers on the test items. They were also assured of confidentiality in terms of the data collected.

Throughout the data collection and analysis processes, the researcher ensured objectivity and avoided any influence of the responses provided by participants.

RESULTS AND DISCUSSION

The results were presented based on the null hypotheses formulated to guide the study, which were tested at a 5% significance level. H_o1: Flipped classroom learning approach has no significant effect on students' academic performance in electron configuration. Table 1 presents the results from the analysis of the data using the dependent-samples t-test. This was done by comparing the students' performance in the pre-intervention test and the post-intervention test. Eta squared was also calculated to determine the magnitude of the effect the flipped classroom learning had on the students' academic performance.

Table 1: Dependent-samples t-test of the students' scores in the pre-intervention test and post-intervention test

Test	*N*	*M*	*SD*	*df*	*t*	*p*	η^2
Pre-intervention test	45	34.67	13.46	44	12.46	0.000	0.780
Post-intervention test	45	71.30	11.7	44			

Significant at $p < 0.05$

In Table 1, the results show a notable difference in the mean scores between the pre-intervention test and the post-intervention test. A statistically significant difference emerged in the mean scores between the pre-test (M = 34.67, SD = 13.46) and the post-test (M = 71.30, SD = 11.77; t (44) = 12.46, p = 0.000). Consequently, the null hypothesis was rejected. Notably, the magnitude of this difference in means was substantial, with an effect size (η^2) value of 0.780, indicating that the flipped classroom learning approach was highly effective in improving the students' academic performance in electron configuration, as reflected by the significant increase in mean scores from the pre-test to the post-test with a large effect size.

H_o2: Flipped classroom approach has no significant effect on students' retention of electron configuration concepts. This hypothesis was also tested at the 5% level of significance. The post-intervention test and delayed post-intervention test scores were analysed to determine the students' retention of electron configuration concepts. The results of the dependent-samples t-test of the post-intervention test and delayed post-intervention test are presented in Table 2.

Table 2: Dependent-samples t-test of the students' scores in the post-intervention test and delayed post-intervention test

Test	*N*	*M*	*SD*	*df*	*t*	*p*	η^2
Post-intervention test	45	71.30	11.77	44	3.31	0.001	0.190
Delayed post-intervention test	45	80.00	15.22	44			

Significant at $p < 0.05$

As shown in Table 2, there is a statistically significant difference in the mean scores between the post-intervention test (M = 71.30, SD = 11.77) and the delayed post-intervention test (M = 80.00, SD = 15.22; t (44) = 3.31, p = 0.001). With a statistically significant difference between the post-intervention test and the delayed post-intervention test scores, it showed that the flipped classroom learning did have a significant effect on students' retention of electron configuration concepts. Therefore, the null hypothesis was rejected. The significant difference in mean scores between the post-intervention test and delayed post-intervention test, in conjunction with the effect size (η^2) value of 0.190, provides a more comprehensive understanding of the extent of the effect of flipped classroom learning in retaining the electron configuration concepts among the students. An effect size of 0.190 signifies the magnitude of the effect was large. Consequently, the study found that the flipped classroom learning pedagogy had a significant effect on students' retention of electron configuration concepts. As students in this study flipped their classroom lessons in electron configuration, it led to retention of concepts learnt.

Discussion of Findings

Effect of flipped classroom approach on students' performance in electron configuration

The findings under this section highlight the significant effect of the flipped classroom learning approach on students' performance in electron configuration. The substantial increase in mean scores from the pre-intervention test to the post-intervention test underscores the efficacy of this teaching methodology. The large effect size ($\eta^2 = 0.780$) indicates that a substantial proportion of the variance in students' performance could be attributed to the flipped classroom learning approach. In practical terms, this suggests that the intervention led to a remarkable improvement in students' understanding, performance and application of electron configuration concepts.

These findings in this current study are consistent with the broader literature on the effectiveness of the flipped classroom learning approach in improving students' academic performance [40, 37, 33]. This approach lays emphasis on active learning, self-directed study, and the use of digital resources has been shown in previous studies to enhance students' comprehension and performance. The findings in this current study attributed the students’ enhanced performance in electron configuration to their active engagement in group presentations and discussion as well as the integration of the digital learning platform that sustained their interest and engineered them to comprehend the topic. Collaborative and supportive learning did the magic within the context of the flipped classroom learning pedagogy, which led to students’ improved performance in electron configuration and this finding aligns with what have been previously found in other studies [41, 34]. Jensen et al. [39] suggested that the improvements observed in flipped classrooms might be attributed to the incorporation of active learning, reinforcing the idea that students’ engagement is pivotal in enhancing performance. By providing students with pre-lessons electronically and allowing them to engage with the content at their own pace before attending class, the flipped classroom approach promotes a deeper understanding of complex topics like electron configuration.

This current study also corroborated the findings of [38], which emphasized the effectiveness of the flipped classroom learning approach in promoting self-directed learning, critical thinking, and problem-solving skills, which are crucial for understanding abstract topics like electron configuration. Furthermore, the findings support the practical application of the flipped classroom approach in addressing the specific challenge of students' inadequate understanding of electron configuration. This approach, by leveraging online resources, can help bridge resource constraints in schools and improve access to quality instructional materials, even under situations where there are limited physical resources like textbooks and other materials.

Effect of flipped classroom approach on students’ retention of electron configuration

This current study found that the flipped classroom learning approach had a significant effect on students' retention of electron configuration concepts. The magnitude of the effect was large. This finding corroborates the findings of previous studies contained in existing literature that support the effect of flipped classroom approach on long-term retention of complex scientific concepts. As indicated in the study of [43], active learning methods, such as flipped classrooms and problem-based learning, have shown promise in enhancing students’ engagement and retention. This previous finding conforms to the findings of this current study that resulted in enhancing students’ retention of electron configuration concepts by virtue of the implementation of flipped class learning strategy.

Similarly, [44] and [45] emphasised the effect of peer discussion and interactive collaborative learning coupled with active learning strategies does not only enhance students’ initial understanding of concepts, but contribute to long-term retention. Teaching and learning approaches that only focus on students memorising concepts for purposes of passing examination cannot lead to long-term retention. It is thus disastrous if students learn concepts only for passing examinations. In the field of work, chemistry concepts are applied in solving problems, so the effectiveness of flipped classroom learning pedagogy to enhance students' retention of electron configuration concepts is in the right direction.

CONCLUSION

This study concludes that flipped classroom learning is a valuable pedagogical tool for improving students' academic performance and retention of electron configuration concepts in chemistry education. Flipping a classroom appropriately has the propensity to enhance students' academic performance and retain concepts that are learnt. Flipped classroom learning pedagogy guarantees active learning, self-directed learning, problem-solving skills and interactive collaborative learning.

RECOMMENDATIONS

The following recommendations are put forward based on the findings of the study.

1. **Educational Practice:** The study recommends the integration of flipped classroom methodologies in chemistry education by chemistry teachers at senior high schools to enhance students' conceptual understanding, performance, and retention of challenging topics like electron configuration in the selected school.

2. **Professional Development:** Flipped classroom learning pedagogy should be incorporated into the Professional Learning Community (PLC) fora organised by management of senior high schools so that chemistry teachers will be trained on the use of this approach in teaching.

CONFLICT OF INTEREST

The researchers declare no conflict of interest in respect of this study.

REFERENCES

1. Stowe, R. L., & Cooper, M. M. (2019). Assessment in chemistry education. *Israel Journal of chemistry*. *59* (6-7), 598-607.
2. Chang, R. (2010). *General Chemistry: The essential concepts.* (10th, Ed.) New York: MacGraw Hill.
3. Anslyn, E. V., & Dougherty, D. A. (2006). *Modern Physical Organic Chemistry* (Vol. 1). University Science Books.
4. Bio, B., Saurdana, N. I., & Kima, M. I. (2014). Analysis of learning difficulties of Senior High school students in learning atomic structure. *E-journal Kimia Visvitalis universitas Pendidikan Ganesha*, *2* (1), 108-116.
5. Choda, J., & Chenprakton, P. (2015). A hands-on physical model for teaching quantum numbers and rules for writing electron configuration. *Proceedings of the 3rd global submit in education 2015, Kuala Lumpur, Malaysia*, e-ISBN 978-967-0792-01-1.
6. Tsaparlis, G., & Papaphotis, G. (2009). High-school students' conceptual difficulties and attempts at conceptual change: The case of basic quantum chemical concepts. *International Journal of Science Education*, *31* (7), 895-930.
7. Aydin-Gunbatar, S., & Akin, F. N. (2022). Pre-service chemistry teachers' use of pedagogical transformation competence to develop topic-specific pedagogical content knowledge for planning to teach acid–base equilibrium. *Chemistry Education Research and Practice*, *23* (1), 137-158.
8. Primon, C. S., & Arroio, A. (2016). The pedagogical knowledge of higher education chemistry teachers. *Química Nova*, *39*, 376-382.

9. Ezema, M., Ugwuanyi, C., Okeke, C., & Orji, E. (2022). Influence of cognitive ability on students' conceptual change in particulate nature of matter in physics. *Journal of Turkish Science Education*, *19* (1), 194-217.
10. Pondee, P., Panjaburee, P., & Srisawasdi, N. (2021). Preservice science teachers' emerging pedagogy of mobile game integration: A tale of two cohorts improvement study. *Research and Practice in Technology Enhanced Learning, 16* (1), 1-27.
11. Osei, G. M. (2006). Teachers in Ghana: Issues of training, remuneration and effectiveness. *International Journal of Educational Development*, *26* (1), 38-51.
12. Akyeampong, K. (2017). Teacher educators' practice and vision of good teaching. *Educational Researcher*, *46* (4), 194-203.
13. Symonds, W. C. (2013). cash-cow universities. *Business Week*, *17* (11), 71-74.
14. Yusuf, M. O. (2006). using the internet for teaching, learning and research in tertiary institutions. *The Journal of Nigeria Association of Teachers of Technology*, *6* (1), 163-171.
15. Yusuf, M. O., Afolabi, F. O., & Lotto, A. B. (2013). Appraising the role of information communication and technology as a change agent for higher education in Nigeria. *International journal of Education Administration and Policy Studies*, *5* (8), 177-183.
16. Asamoah, R., Asiedu, N. K., & Baudi, D. W. (2022). Use of ICT in teaching and learning in second cycle institutions: Understanding the technological aspect of the TPACK model. *International Journal of Development*, *9* (1), 537-550.
17. Oshinaike, A. B., & Adekunmisi, S. R. (2012). use of multimedia for teaching in Nigerian University System: A case study of University of Ibadan. *Journal of library philosophy and practise*, *45* (8), 1502-1522.
18. Bergmann, J., & Sams, A. (2012). Flip your classroom: Reach every student in every class every day. *International Society for Technology in Education, 70(6)*, 16-20.
19. Zappatore, M. (2023). Incorporating collaborative and active learning strategies in design and development of a master course on computer-assisted scientific translation. *Journal of Technology, Knowledge and Learning*, *2* (11), 1-56.
20. Herreid, C. F., & Schiller, N. A. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching*, *42* (5), 62-66.
21. O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, *25*, 85-95.

22. Aidoo, B., Macdonald, M. A., Vesterinen, V. M., Pétursdóttir, S., & Gísladóttir, B. (2022). Transforming teaching with ICT using the flipped classroom approach: Dealing with COVID-19. *Education Sciences*, *12* (6), 421.
23. Fitriza, Z., & Gazali, F. (2018, May). Diagnosing Students' conception on atomic structure using open ended questions. *In Journal of Physics: Conference Series* (Vol. 1013, No. 1, p. 012097). IOP Publishing.
24. Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.
25. Bandura, A. (1977). Social-learning theory of identificatory processes. *Handbook of Socialization Theory and Research*, *213*, 262.
26. Alvarez, B. (2007). Interactivity and adaptation in self-paced digital environments: Relevance of interactivity and adaptation in the student's learning experience. *Journal of Educational Multimedia and Hypermedia*, *16* (2), 171-191.
27. Berrett, D. (2012). How "flipping" the classroom can improve the traditional lecture. *The Chronicle of Higher Education*, *27*, 34-41.
28. Suh, K. (2010). The effects of scaffolding strategies on students' performance in technology-enhanced open-ended learning environments. *Journal of Educational Technology & Society*, *13* (3), 49-58.
29. Johnson, L. E., & Renner, J. D. (2012). The effect of the flipped classroom on student achievement and stress. *Health and Human Performance Faculty Publications*, *48* (2), 88-95.
30. Nabavi, R.T. (2012). Bandura's social learning theory and social cognitive learning theory. *Theory of Developmental Psychology, 1(1),* 1-24.
31. Alvarez, B. (2012). Flipping the classroom: Homework in class, lessons at home. *The Education Digest*, *77*(8), 18.
32. Fulton, K. (2012). Upside down and inside out: Flip your classroom to improve student learning. *Learning and Leading with Technology*, *39*, 12-17.
33. Van Vliet, E. A., Winnips, J. C., & Brouwer, N. (2015). Flipped-class pedagogy enhances student metacognition and collaborative-learning strategies in higher education but effect does not persist. *CBE—Life Sciences Education*, *14* (3), ar26.
34. Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal on Excellence in College Teaching*, *25* (4), 85-118.

35. Roehl, A., Reddy, S. L., & Shannon, G. J. (2013). The flipped classroom: An opportunity to engage millennial students through active learning. *Journal of Family and Consumer Sciences*, *105* (2), 44.
36. Yilmaz, R. (2017). Exploring the role of e-learning readiness on student satisfaction and motivation in flipped classroom. *Computers in Human Behavior, 70*, 251-260.
37. Yang, L., Sun, T., & Liu, Y. (2019). A bibliometric investigation of flipped classroom research during 2000-2015. *International Journal of Emerging Technologies in Learning (Ijet)*, *12* (6), 178-186.
38. Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research. *Higher Education Research & Development*, *34* (1), 1-14.
39. Jensen, J. L., Kummer, T. A., & Godoy, P. D. (2015). Improvements from a flipped classroom may simply be the fruits of active learning. *CBE—Life Sciences Education*, *14* (1), 5.
40. Kim, Y., Kim, N., & Chae, M. (2021). Effects of flipped learning on nursing students: A mixed methods study. *Japan Journal of Nursing Science*, *18*(3), 12425.
41. Hung, H. T. (2015). Flipping the classroom for English language learners to foster active learning. *Computer Assisted Language Learning*, *28* (1), 81-96.
42. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.
43. Prince, M. (2004). Does active learning work: A review of the research. *Journal of engineering education*, *93* (3), 223-231.
44. Smith, M. K., Wood, W. B., Krauter, K., & Knight, J. K. (2011). Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *CBE—Life Sciences Education*, *10* (1), 55-63.
45. Stefenile, A. (2020). The transition from classroom to zoom and how it has changed education. *Journal of social science research, 16* (7), 33-40.
46. Van de Ven, K., Boardley, I., & Chandler, M. (2022). Identifying best-practice amongst health professionals who work with people using image and performance enhancing drugs (IPEDs) through participatory action research. *Qualitative Research in Sport, Exercise and Health*, *14* (2), 199-215.

 ISSN 2227-5835

47. Cohen, R. J., Swerdlik, M., & Sturman, E. (2012). EBOOK: *Psychological Testing and Assessment*. McGraw Hill.
48. Cohen, J. (1988). *Statistical power analysis for the behavioural sciences*. Hillsdale: NJ: Erlbaum.