INTERACTIVE ACTIVATION AND COMPETITION (IAC) MODEL AS A METACOGNITIVE STRATEGY AND STUDENTS' ACADEMIC ACHIEVEMENT IN ELECTROCHEMISTRY IN CROSS RIVER STATE, NIGERIA.

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Abstract
This study investigated the efficacy of interactive activation and competition (IAC) model as a metacognitive strategy on students' achievement in Electrochemistry in Calabar Education Zone of Cross River State, Nigeria. Quasi- experimental research design involving pre-test, post-test, non-equivalent control groups was adopted. A sample of 142 SS2 Chemistry students selected purposively constituted four intact classes assigned to experimental (EXG) and control (COG) groups. Electrochemistry achievement test (EAT) with reliability coefficient of 0.8, using Kuder-Richardson's (KR-20) formula was used as the instrument for obtaining data. Mean and Standard deviation used, addressed the research question, while analysis of covariance (ANCOVA) tested the null hypothesis at 0.05 levels of significance. Results showed that IAC-model enhanced students' achievement in Electrochemistry more than conventional teaching method. Conclusion was drawn and recommendations made to include among others that; science teachers should be trained and retrained on the use of rehearsal - based method like IAC-model of instruction to enhance students' achievement and improve on teachers' teaching proficiency.

***Key Words*:** IAC-Model, Achievement, Activated-Nodes, Activation-pool, Neural-networks, Cognitive Science.

Introduction

The study of Chemistry, like all other sciences, requires active participation of students in knowledge-driven activities. It involves thought-provoking processes and persistent application of any or collective science process skill(s) that pertains to critical thinking, reasoning, collaboration, communication and analyzing information in order to solve collective or individual problems of life (Akpan, 2018). Therefore, Chemistry has tremendously impacted positive values on all facets of human life and existence; leading to increasing demands of its knowledge. The increasing demand of chemical knowledge has in recent times led to reorientation in the teaching style of chemistry in schools. Faced with these challenges and demands of everyday living expectations and life activities, individuals now in the pursuit of their personal and collective goals, respond sporadically and competitively towards acquiring meaningful scientific knowledge. Suggesting that the meaningful knowledge may help to enhance students' achievement in school and facilitate economic, socio-political and technological development of their nations (Efiklides, 2009).

This has translated into making chemistry to become attractive and relevant to students in recent times. The problem of students' proper grasping of chemistry concepts taught at school despite their initial perceived difficulties have been established and solutions proffered from studies (Idiege & Nja, 2018; Njoku & Akwali, 2016; Ekemobi & Mumuni, 2015; Nja, Kalu & Neji, 2015; Aniodoh & Egbo, 2014; Okereke & Onwukwe, 2011; Achimugu, 2011; Jegede, 2007; Idiege, 2006; Yousuo, 2005). Yet, students' poor performance in chemistry has continued to remain abysmal and unabated at various school locations across the country, especially in Cross River State, Nigeria. This dissatisfaction expressed with the students' poor performance at West African Senior Secondary Certificate Examinations (WASSCE) and National Examinations Council (NECO) over the years accounted for their being denigratingly described as either underachievers or low ability students in chemistry. Evidences of students' poor performance in chemistry abound from WAEC Chief Examiner's Reports (2008 - 2018), showing this reported underachievement records in the aspects of electrochemistry. This is because electrochemistry questions from the reports show that students usually skip, solve half or poorly attempted them.

This description from the report demonstrates that students' innate potentials and academic abilities have not yet been successfully tapped for exploit by teachers through their teaching methodology so as to reflect the students' intellectual brain-functioning towards electrochemistry concepts. Therefore, from studies (Onwioduokit & Akinbobola, 2005, Idiege, 2006; Kalu, 2008; Obomanu & Ekenobi, 2011; Nja, 2012; Nbina & Wagbara, 2012; Aniodoh & Egbo, 2014; Idiege, Nja & Ugwu, 2017; Idiege & Nja, 2018), are pointers to claims suggesting that inappropriate teaching technique seems to be the major reason for students' poor performance in chemistry. However, many teachers prefer the conventional teaching method as the easiest for covering wide curriculum content than other methods (Yousuo, 2005; Njoku & Akwali, 2016; Idiege & Nja, 2018). Yet, the conventional teaching method seemed not to have yielded the desired positive results. This suggests that there should be a need for change in the style of teaching electrochemistry which may guarantee students' meaningful understanding and mastery of the concept. To achieve this may be through the use of interactive activation and competition (IAC) model as a metacognitive strategy, that connects network of learning experiences and activities into understandable forms or precepts as there are being processed (Thagard; Sulton & Barto; McClelland; Craig & Lockhart, in Idiege, 2006; Idiege & Nja, 2018) based on the frequency of rehearsals made on the learning activities. Rehearsal in learning process involved strategies like summarizing, reviewing, rereading, self-questioning, telling to another person or writing as it is. This is to allow individuals to think on the subject-matter, give meaning to what is learnt and put it meaningfully in perspective (Craig & Lockhart, in Idiege, 2006; Kumari & Jinto, 2014). A strategy is simply, a method to follow in order to achieve success in something or implementation of a developed plan of action to achieve a goal (McClelland, in Idiege, 2006). Strategies facilitate the acquisition of knowledge and skills towards self-learning as individuals transfer information from sensory records to the short-term memory after the encoding process; and thereafter, to long-term memory for recall when necessary (Feldman & Ballard, in Idiege, 2006; Idiege & Nja, 2018).

McClelland's interactive activation and competition (IAC) model was design and developed by J. L. McClelland in 1981 as a connective learning strategy. It shows a cluster of information connectivity of processing networks that foster the understanding of concepts taught in cognitive science through strong activation threshold of signals. These strong activation thresholds originated from the rehearsal strategies or efforts which individuals often engages themselves as they get involved in thought-provoking activities over time

(Idiege, 2006). The model holds that as individuals continue to engage themselves in thought-provoking activities like repeated rehearsals, strong information signals are prompted in the neural core system of the brain and sent into different nodes for processing. The mechanisms of processing these information within and outside the nodes is complex but portrays strong activation from the level of input layer of units to the layer of hidden units and thereafter, progresses effectively and steadily into the output units until understanding is achieved through weighted activated connections (Idiege, 2006). Therefore, it clearly illustrated those salient properties of information processing system in humans that are often overlooked in classical theories of cognitive science. It advocated for strong activation of information processing tasks in cognitive science learning, which should occur swiftly or gradually with understanding through active participation and engagement in thought-provoking activities (Idiege, 2006). Specifically, it explains how information is processed by humans in quick succession for understanding to be achieved in cognitive science. Through connecting a framework of nodes placed at output, hidden and input layer of units, it receives, encode and process information basically to achieve understanding. Information signals are often received through a connection of weighted nodes to yield the desired understanding at output layer of units as outcomes (Craig & Lockhart; Feldman & Ballard; McClelland, in Idiege, 2006; Idiege & Nja, 2018).

The modus operandi and its mechanisms of processing involved the application of the theory and principles of connectionism (Idiege, 2006) which literally, takes strong threshold of activations to simultaneously drive the weaker activation pools in humans to function at optimal amplitude. This would promote the understanding of concepts taught with ease. Nevertheless, stronger activation pools of connectivity progresses interactively from thoughtful-mind activities within the same threshold to achieve understanding as outcomes. The weaker pools in each node would require constant activation of information in order to prevent any blockade from encoding information for learning. These strong activation pools radiate from thought-views are usually excitatory and bi-directional. Which suggests, that node usually accumulate excitatory signals when connected appropriately to other activated nodes during the encoding process of information to bring understanding with ease. Nodes process information based on the intensity of activations made through repeated rehearsals on the same threshold. Basically, there are two types of nodes; represented as "*instance*" and "*property*" nodes (Sultan & Barto; Craig & Lockhart; McClelland, in Idiege, 2006).

These nodes receive signals as information from interactive rehearsal activities for competitive processing based on its intensified strength. The signals may either be "*excitatory"* or "*inhibitory"*, depending on its strength. The "instance node" has inhibitory connections to other nodes and hinders the understanding of concepts taught, especially when connected by defaults to property nodes. Except or otherwise, when they are strongly activated through interactive activities from rehearsals, understanding is barely achieved (Craig; Craig & Lockhart; Zemel, in Idiege, 2006).

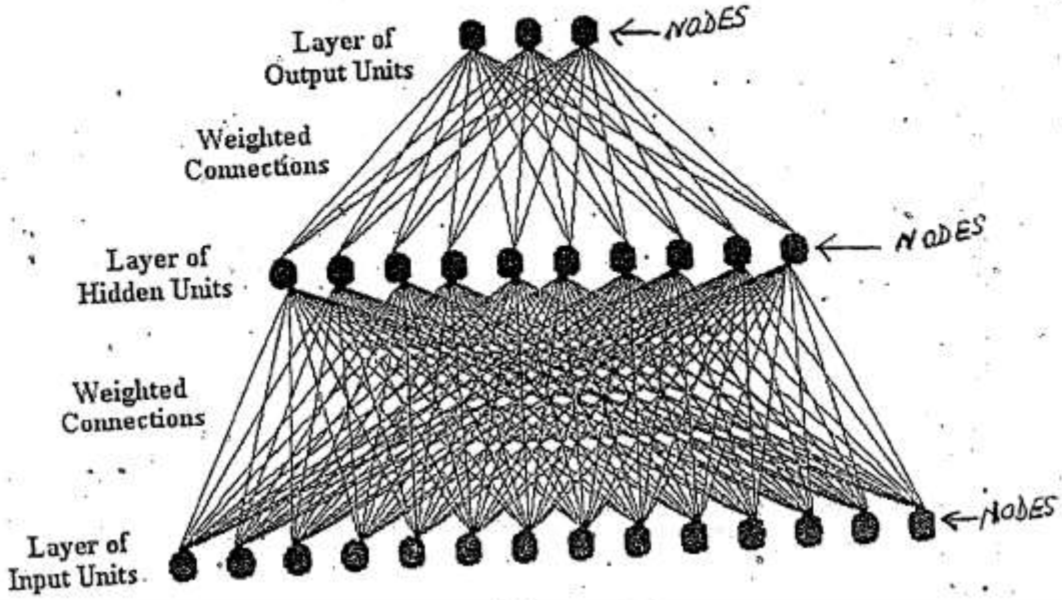
Apparently, when the activation pool is not strong enough, the inhibitory signals may block the thresholds of understanding from making any progress, let alone, recalling information from stored memory (McClelland; Zemel; Craig, in Idiege, Nja & Ugwu, 2017). The property node encodes specific information and transfer to long-term memory which aids the characterization of human experiences for recognition When individuals rehearse activities often and un-relenting, information is processed quickly to promote the understanding of concepts taught (Craig & Lockhart; Feldman & Ballard; McClelland, in Idiege, Nja & Ugwu, 2017). These property nodes are assembled after activation into cohorts of mutually exclusive values, with longer lifespan thresholds in the memory of the individual's cognitive framework (Feldman & Ballard, in Idiege, 2006). This brings the expected understanding and recall of information when necessary. Furthermore, when strong signals in the layer of hidden units are activated, equilibrium is attained with ease to promote the understanding in output units (Craig & Lockhart; Gallant; McClelland, in Idiege, 2006). The activation process involved an assemblage of the cohorts of mutually exclusive values, within the same threshold (in property nodes), to make for the achievement of understanding without stress (Meddler; McClelland, in Ni, Rohadi & Alfana, 2016).

This suggests that all learning tasks involving students' active participation in critical thinking and reasoning with hands-on activities are metacognitive and is cued to link newly gathered information to the existing knowledge in the individual's cognitive framework. The network of interconnectivity between activated nodes makes for meaningfulness and understanding to be achieved easily during the teaching – learning process. So, students should be allowed ample opportunities to freely engage themselves in classroom interactive sessions with activities that would guarantee and promote critical reasoning and thinking in schools (Idiege, Nja & Ugwu, 2017; Rohadi & Alfana, 2016; Idiege & Nja, 2018).

The IAC model may be applied effectively through active students' engagement in interactive activities simply to construct their own knowledge from past experiences. Therefore, teachers should engage students adequately with minds-on and hands-on activities that would make them stay alert in their thinking and reasoning so as to talk what they learn, write about it, relate it to past experiences and apply it when necessary to their everyday lives. The teacher can as well evaluate students' learning through appropriate frameworks for meaningful learning to occur as the case may be (Idiege, Elenwoke & Okore, 2017).This is because students hardly learn meaningfully when they just sit in class to just listen to their teacher doll out instructions, while they memorize repackaged assignments through rote learning as they spit out memorized answers as claim to learning (Nja, Kalu & Neji, 2015). Teachers should ensure that students take responsibility of their learning and make what they learn part and parcel of themselves in all social contexts appropriately through interactions with others.

The teaching of electrochemistry concepts through this approach would make the students to meaningfully construct learning on their own. These actions would guarantee students' ownership of their learning, which may be lacking with the use of conventional teaching method. The conventional teaching method from studies (Smith, in Nwachukwu, 2000; Kalu, 2008; Ezeudu & Obi, 2013; Ni, Rohadi & Alfana (2016) cannot offer any meaningful and active learning paradigm that would guarantee students' ownership of learning and enhanced achievement adequately, except with, strategies that utilized neural networks for learning (Feldman & Ballard; Gallant; McClelland, in Ni, Rohadi & Alfana, 2016).

McClelland's (1981) interactive activation and competition (IAC) model showing networks of interconnectivity with nodes.



In view of the weakness of conventional teaching methods in failing to ensure in-depth understanding electro-chemistry concepts taught in school, the advocates of some cognitive instructional psychologists (McClelland; Thagard; Sultan & Barto; Feldman & Ballard; Gallant; Flavell, in Ni, Rohadi & Alfana, 2016) advised that teachers should evolve strategies that allows and provides for more students' active participation in science learning process than the conventional teaching strategies. Essentially, it is to provide students with the opportunity to actively self-regulate their learning behaviours and pursue their learning activities in an independent, active, consistent and deliberate manner that would guarantee credible meaningful learning (Idiege, 2006; Kumari & Jinto, 2014). The students in turn, would become more efficient and effective in the management of their learning experiences and become motivated as well as independent, with evidential show of metacognitive activeness in the learning process than before (Flavell; Thagard, in Idiege, 2006). Metacognition is majorly concerned with the various strategies adopted by an individual to consciously detect, outline and control his/or her knowledge (Feldman & Ballard, in Idiege, Nja & Ugwu, 2017). Consequently, metacognitive strategy adopted by learners usually empowers them to take charge of their own learning in a highly fashionable and meaningful manner. Kumari and Jinto (2014: 74) attempted to categorize metacognitive strategies into four but not limited to only;

- ✓ Chunking or organizing strategies
- ✓ Spatial learning strategies e.g. framing, concept mapping, V-mapping, mind-mapping, etc.
- ✓ Bridging strategies e.g. Advance organizers, metaphor, etc.
- ✓ General purpose strategies e.g. rehearsals, imagery and mnemonics etc.

The interactive activation and competition (IAC) model in this study, belongs to the general purpose (rehearsal) category involving continuous activation of property nodes (Feldman & Ballard, in Ni, Rohadi & Alfana, 2016) to achieve the understanding of electrochemistry concepts taught at school.

Electrochemistry concepts in this study are introduced in forms that connote familiar ideas in the learner's cognitive structure; but it may require constant rehearsals to make meaning of the concepts taught and put into perspectives. The rehearsal procedures are carefully and skillfully selected on the basis of their usefulness in explaining, organizing and processing information within the nodes for understanding to be achieved. In doing so, the body of knowledge and experiences gathered from the rehearsals carried out may be linked internally through neural networks to that which already is possessed by the student and afterwards, understanding is achieved.

However, a number of studies have been conducted on the use of bridging strategies (Favell; Ausubel; Feldman & Ballard; Elkin; Craig & Lockhart; in Idiege, 2006; Nwachukwu, 2000; Eze, Ugwu & Ugwu, 2000; Ekemobi & Mumuni, 2015; Kumari & Jinto, 2014; Ni, Rohadi & Alfana, 2016; Idiege, Nja & Ugwu, 2017; Idiege & Nja, 2018). However, these studies seemed to have contradictory findings as to the effectiveness of these strategies in assisting students to learn different concepts meaningfully in school. For instance, while Eze, Ugwu and Ugwu (2000), Idiege (2006), Idiege, Nja and Ugwu (2017), Ekemobi and Mumuni (2015), Kumari and Jinto (2014), Idiege and Nja (2018) reported that bridging strategies are relatively effective in assisting students to learn science instructions with ease, the studies of Ni, Rohadi and Alfana (2016), Zemel; Elkin; in Idiege (2006) doubted the efficacy of some of these strategies in assisting students to learn meaningfully as claimed. This clearly shows that some of these learning strategies and their impact in enhancing students' academic performance have not been adequately resolved. With these contradictions, it would be inaccurate to conclude so hastily that IAC model have capacity to enhance the students' understanding of electrochemistry concepts better than other methods. Besides, many of these studies reviewed on metacognitive strategies are seemingly foreign based. Hence, it may not be effectively applied to Nigerian learners considering their different socio-cultural backgrounds. These, basically, are the reasons that informed this study.

This assertion is also strengthened by the findings of Eze (2010), Ezeudu and Obi (2013), Njoku and Akwali (2016) which contended that school location, gender and environment affects students' performance in the sciences. In view of these inconsistencies and contradictions from wide spread studies, this study examines the relative effectiveness of **IAC model** as a metacognitive strategy on students' achievement in learning Electrochemistry concepts in Nigerian secondary schools.

Statement of the problem

Chemistry as a core science subject is taught in nearly all senior secondary schools in Nigeria by graduate or non-graduate teachers, where there are presence or near absence of laboratory attendants and equipped laboratories. Nevertheless, adequate emphasis and recognition is still being accorded chemistry. Despite this recognition and emphasis, studies have continued to report students' poor performance in chemistry, especially the electrochemistry aspects, in both internal and external examinations. Empirical evidence identified inadequate utilization of appropriate instructional strategies among others as being responsible for the repeated failure. There is now need and indeed, great pressure being mounted on chemistry educators/teachers to explore more effective strategies for enhancing students' performance in chemistry. One of the strategies is the application of IAC metacognitive instructional model in teaching chemistry. Therefore, in this study, the problem is: how would IAC metacognitive instructional model of teaching enhance students' achievement in Electrochemistry?

Purpose of the study

The purpose of this study was to investigate the relative effectiveness of IAC metacognitive instructional model on students' achievement in Electrochemistry. Specifically, the study sought to examine the effectiveness of IAC metacognitive instructional model on students' achievement in electrochemistry

Theoretical framework

The study is anchored on the "subsumption" theory of meaningful verbal learning proposed by David Ansubed in 1963. Ausubel's (1963) theory holds that meaningful learning occurs when there is interaction between the learner's knowledge base and the new materials to be learned. The theory explains that for individuals to learn meaningfully, they must choose to relate new information (or knowledge) to relevant concepts and propositions that they already know or have in the reference frame/conceptual frame of reference. This means, the new information, knowledge, propositions, or experiences must be related to the learner's frame of reference already in existence. If such interactions and relationships are not established, then, "rote learning" also called "memorization" may obviously occur.

In the classroom situation, some levels of adequate understanding of the components of cognition or metacognition is required because different meta-cognitive components are often called to play when students are processing learn tasks information for their understanding. First, students choose to connect new information to previous knowledge in order to determine their extent of understanding the concept (McClelland; Meddler, in Idiege, 2006; Idiege & Nja, 2018). Then, they would select and regulate appropriately the most effective skills/strategies of rehearsal that would facilitate the tasks at hand to achieve the understanding (Gallant; Sulton & Barto, in Idiege, 2006; Idiege & Nja, 2018). These actions are executed to portray their becoming aware of monitoring the different components of metacognition consciously and sometimes quite slowly before yearning for the solution. Although, the Smart and average think ing students do quickly automatize the rehearsal strategies they know best and when applied effectively becomes appropriate (Ni, Rohadi & Alfana, 2016; Elkin; Craig & Lockhart, in Idiege, 2006). In doing so, the students chart the direction of their thinking, keep eyes on their progress and revalidate their thought processes through rehearsal strategies as accurately as possible, which is a form of metacognitive operation of learning how to learn (Efiklides, 2009; Thagard; Novak & Godwin, in Ni, Rohadi & Alfana, 2016). The application of IAC model in this study shows a metacognitive transfer of information processing pathways in the learning task of electrochemistry concepts.

Research methodology and procedure

The study adopts a quasi-experimental research design involving a pretest, post- test, non-equivalent control groups. It was carried out in Calabar Education Zone of Cross River State, Nigeria. The sample consisted of 142 SSII chemistry students belonging to four (4) intact classes selected through purposive sampling technique and grouped into two (2); – Experimental (EXG: n = 79) and Control (COG: n=63). The two groups were first pre-tested before treatment and thereafter, post-test was administered using electrochemistry achievement test (EAT) as instrument for obtaining data. The EXG were taught electrochemistry using IAC metacognitive instructional model, while the control group was taught using the conventional teaching method. Electrochemistry achievement test (EAT) consisted of 50- objective test items with response options lettered A-D covering all the sub-topics of Electrochemistry as contained in the blue-print of table of content. The treatment lasted for 6 weeks. The reliability coefficient of 0.8 for EAT using Kuder-Richardson formula (KR-20) was determined after its validation by two experts in test and measurement as well as one expert in chemistry education.

Both the EXG and COG were taught by their regular class teachers as research assistants to prevent "Hawthorne effect" after their attending sensitization workshop for a week. The data obtained was analyzed using Analysis of Covariance (ANCOVA) with pretest scores as covariate. The mean scores and Standard deviation was used to address the research question, while, ANCOVA was used to test the null hypothesis further at 0.05 levels of significance.

Results of Data Analysis

Research question: What are the mean achievement scores of students taught electrochemistry using IAC metacognitive instructional model and those taught using conventional teaching method?

Hypothesis ($H0_1$): There is no significant difference between the mean achievement scores of students taught electrochemistry using IAC metacognitive instructional model and those taught using the conventional teaching method.

Table 1: Table of analysis of Mean and Standard deviation; and ANCOVA for the mean differences between EXG and COG when taught electrochemistry

Group	Pretest mean	SD	Post-test mean	SD	Mean achievement gain	SD	N
COG	24.18	1.76	48.36	2.12	24.18	2.14	63
EXG	29.44	1.89	68.88	2.24	39.44	4.98	79
TOTAL							142

Source variation	Sum of Squares	df	Mean Square	F-value	Sig.
Corrected model	16849.53[a]	2	8424.769	535.950	0.000
Intercept	4683.120	1	4683.120	297.921	0.000
pre-test	2.246	1	2.246	0.143	0.706
Groups	16849.245	1	16849	0.143	0.706
Error	4542.884	139	15.719		
Total	308844.000	142			
Corrected Total	21872.421	141			

a. R squared = 0.788 (Adjusted R squared = 0.786)

Results of the analysis above shows that the mean scores of students taught electrochemistry using IAC model is 39.44. This value is greater than the mean scores of 24.18, for those taught using conventional teaching method. This implies that the students taught electrochemistry using IAC-model performed academically better than those taught using the conventional teaching method. To further test this result, ANCOVA was used to test the hypothesis at 0.05 levels of significance. The result showed that obtained F-value of 1071.88 was significant at $p < 0.05$. Since, the p-value of 0.000 is less than the critical p-value of 0.05 set for the hypothesis, it implies that the null hypothesis is rejected. Therefore, there is a significant difference between the mean achievement scores of students taught electrochemistry using IAC metacognitive instructional model and those taught using conventional teaching method.

Discussion of findings

The findings of the study showed the potency of IAC-metacognitive instructional model over conventional teaching method as the results is supportive of the findings of Ekemobi and Mumuni (2015) and Kumari and Jinto (2014) who respectively investigated the efficacy of advance organizers strategies on chemistry students' cognitive achievements in Redox reaction concepts and the effectiveness of KWL metacognitive learning strategy on achievement in social sciences when instructions combine with cognitive abilities and cognitive styles. The ANCOVA results of Ekemobi and Mumumi's (2015) study showed F-value of 3.04 which was significant at $P < 0.05$. This means there exist a significant difference between mean achievement scores of students taught redox reaction concepts using advance organizer strategy and those taught using conventional lecture method. The difference in mean achievement scores was in favor of those taught redox reaction concepts using advance organizers strategy as they obtained mean score of 34.72 higher than those taught using conventional lecture method with mean scores of 23.18. Similarly, Kumari and Jintos's (2014) study favoured students taught using KWL strategy with higher mean of 45.17 than those taught using conventional teaching method with mean of 32.46 in Social Science.

However, the findings of this study disagree with those of Ni, Rohadi and Alfana (2016), who investigated students' achievement in mathematics and computer studies using advance organizer cognitive strategies. They found that advance organizer metacognitive strategy did not enhance students' achievement in mathematics and computer studies in elementary schools in some parts of Asia.

Besides, in this study, students exposed to application of IAC-model performed better academically than those taught using conventional teaching method. This might be as a result of their active involvement in thought-provoking rehearsal activities through class interactions that promoted their reasoning abilities. The students' reasoning abilities propel strong activation of property nodes from rehearsals to foster the understanding of electrochemistry concepts taught. This superior performance of students taught using the IAC-model is a clear indication of the model's potency over conventional teaching method. Students' active role and commitment to taking ownership of their learning in any instructional process brings the understanding that enhanced performance academically.

Conclusion

The study showed that IAC-model have positive influence on students' achievement in chemistry, especially the electrochemistry aspects. This electrochemistry aspect is often perceived as being difficult or abstract may require critical reasoning ability of the students to be able to excel academically. As students engage themselves in rehearsals of electrochemistry terms and concepts, they send strong activation signals to property nodes in the human brain to bring quick understanding of the concepts. In doing so, students' intellectual ability plays important role as they are allowed to interact freely and are better informed during lessons in the teaching-learning process. This encourages collaboration, problem-solving and critical reasoning ability among students as advocated in the partnership for the 21st century learning. This would certainly enhanced students' achievement in chemistry.

Recommendations

Based on the findings and the conclusion drawn, the following recommendations are made:

1. There is need for training and retraining of teachers towards innovative strategy like the application of IAC-model to enhance students' achievement in chemistry and all other sciences.
2. The need for chemistry teachers to develop and initiate critical reasoning and collaborative efforts among students in their teaching-learning process may help to improve on their proficiency.
3. Allowing students the freedom to freely interact and participate actively in class activities/discussions may encourage their taking ownership of meaningful learning which brings quick understanding of concepts taught. Therefore, it is highly recommended.

References

Achimugu, L. (2011). Strategies for effective conduct of practical chemistry work in senior secondary schools in Nigeria. *Journal of Science Teachers Association of Nigeria* (JSTAN), 46 (2), 130-140

Akpan, B. B. (2018).*Science, technology, engineering and mathematics (STEM) and economic growth*. Abuja: The STAN Place Ltd.

Aniodoh, H. C. & Egbo, J. J. (2014). Effect of gender on students' achievement in chemistry using inquiry-role instructional model. *International Journal of Social Science education,* 4 (2), 185-191.

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York: Grune and Stratton .

Crag, F. I. & Lockhart, R. S. (1972). Levels of information processing: A framework for memory research. *Journal of verbal learning and verbal behavior*,11, 671-684.

Craig, F. I. (1970). The fate of primary memory items in free recall. *Journal of verbal Behavior,* 9, 143-148.

Efiklides, A. (2009). The role of metacognitive experiences in learning process. *Psicotherma*, 21(1), 76-82.

Ekemobi, T. N. Mumuni, A. A. (2015). Efficacy of advance organizers strategies on chemistry students' cognitive achievements in Redox reaction concepts. *British Journal of Psychology Research,* 3 (5), 16-27.

Elkin, M. L. (1980). Graphic advance organizers and reading performance. *Dissertation Abstracts International*, 41(4), 1-5.

Eze, A. E., Ugwu, E. I. & Ugwu, R. R. (2000). The relative efficacy of using Advance organizer in teaching physics concepts in secondary schools. *ESUT Journal of Education*, 3 (2), 83-94.

Eze, F. N. (2010). Influence of school environment on academic achievement of students in public secondary schools in Enugu state. *Published M.Ed Thesis.* University of Nigeria, Nsukka.

Ezeudu, F. O. & Obi, T. N. (2013). Effects of gender and school location on students' achievement in chemistry in secondary schools in Nsukka L. G. A of Enugu State. *Journal Research on Humanities and social sciences,* 3(15), 50-55.

Feldman, J. A. & Ballard, D. H. (1983). Connectionist models and their properties. *Connection science,* 6, 205-254.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive development inquiry. *American Psychologists,* 34(10), 906-911.

Gallant, S. I. (1993). *Neural Network learning and Expert System*. Cambridge: MIT press.

Idiege, K, J., Nja, C. O. & Ugwu, A. N. (2017). Enhancing secondary school chemistry students' achievement using K.W.L instructional strategy. *Advances in Multidisciplinary and Scientific Research Journal*; 3(1), 51 - 62.

Idiege, K. J. (2006). Effect of modified interactive activation and competition model as Advance Organizer on learning chemistry concepts in secondary schools. *Unpublished M. Ed Thesis.* University of Port Harcourt, Choba, Port Harcourt.

Idiege, K. J. S. & Nja, C.O. (2018). Relative efficacy of PQ4R metacognitive learning strategy on students' academic achievement in Electrochemistry in Calabar Education Zone, Cross River State, Nigeria. *International Journal of Advanced Academic and Educational Research*, 13(3), 50 – 61.

Idiege, K. J., Elenwoke, U. E. & Okore, S. E. (2017). Evaluation procedures for the teaching and learning of Chemistry (Science) in Nigerian Secondary Schools: A conceptual approach. *Advances in Multidisciplinary and Scientific Research Journal*, 3(2), 13-22.

Jegede, S. A. (2007). Students' anxiety towards the learning of chemistry in some Nigerian secondary schools. *Educational Research and Review*, 2(7), 193-197.

Kalu, I. M. (2008). Classroom interaction patterns and students' learning outcomes in physics. *The Social Sciences,* 3(1), 57-60.

Kumari, V. S. & Jinto, M. (2014). Effectiveness of KWL metacognitive learning strategy on students' achievement in social science and metacognitive ability/cognitive styles. *International Journal of Educational Research and Technology,* 5(1), 92-98.

McClelland, J. L. (1981). Retrieving General and specific information from stored knowledge of specifics. In: *Proceedings of the 3rd Annual meeting of the Cognitive Science Society,* pp. 170-172.

McClelland, J. L. (1998). Connectionist Models and Bayesian Inference. In: M. Oaksford and N. Charter (Eds.) *Rational Models of Cognition 2*. Oxford: Oxford University press.

Medder, D. A. (1998). The Cross roads of connectionism: where do we go from here? *Ph.D Dissertation*, University of Alberta.

Nbina, J. B. & Wagbara, S. O. (2012). Relationships between some factors and students' performance in secondary school chemistry in Rivers State, Nigeria. *Journal of Africa Contemporary Research*, 7 (1), 19-24.

Ni, L. R., Rohadi, N. S. & Alfana, H. B. (2016). Advance organizer: Cognitive instructional strategy. *International Journal of Computer Networks and Wireless Communication (IJCNWC),* 6(2), 53-57.

Nja, C. O. (2012). Kitchen resources, classroom interactions, reasoning ability levels, academic performance and retention of SS2 chemistry students in thermochemistry in Calabar Education Zone, Nigeria. *Unpublished Ph.D Dissertation*. University of Calabar.

Nja, C., Kalu, I. & Neji, H. (2015). Gender, kitchen resources and students' academic performance and retention in thermochemistry in Cross River State, Nigeria. *Global Journal of Educational Research, 14,* 25-29.

Njoku, Z. C. & Akwali, C. P. (2016). Gender and school location as factors of students' motivation to learn chemistry in Nigeria secondary schools. *Journal of Science Teachers Association of Nigeria (JSTAN),* 51 (1), 53-57.

Novak, J. D. & Godwin, B. D. (1984). *Learning how to learn*. Cambridge: University press.

Nwachukwu, J. C. (2000). The effect of pictorial organizer on learning of Biology concepts. *ESUT Journal of Education* 3 (2) 71-82.

Obomanu, B. J. Ekenobi, T. N. (2011). Analysis of learning outcome in chemistry among SSIII students in urban and rural settings: using concept map technique. *Journal of Education and Practice,* 2 (4), 148-154.

Okereke, C. & Onwukwe, E. O. (2011). Influence of gender, school location and use of play-simulation on school achievement in chemistry. Retrieved15/12/2017 from: *https://www,transcampus.org/Journal_online/pdf…*

Onwioduokit, F. A. & Akinbobola, A. O. (2005). Effects of pictorial and written advance organizers on students' achievement in senior secondary school physics. *Journal of Science Teachers Association of Nigeria* (JSTAN), 40 (102), 109-116.

Smith, S. M. (1982). Enhancement of the recall using multiple environmental contexts during learning. *Memory and cognition,* 1, 405-412.

Sulton, R. S. & Barto, A. G. (1981). Towards a modern theory of adaptive networks: Expectations and predictions. *Psychological Review,* 88, 135-171.

Thagard, P. (1996). The *Mind: Introduction to cognitive science*. Cambridge: MIT press.

Thurstone, L. L. (1938). Primary mental abilities. *American Journal of Psychology,* 15, 201-223.

West African Examination Council (2008-2018). *Chief Examiner's Reports*. Lagos: WAEC Press

Yousuo, L. A. (2005). Students' perceived difficulties in the study of Electrochemistry in secondary schools in Bayelsa State. *Unpublished M. Ed. Thesis.* University of Port Harcourt, Choba-Port Harcourt.

Zemel, R. S. (1993). A minimum description of the length of frameworks/Nets in "Unsupervised" learning. *Ph.D. - Dissertation.* University of Toronto.