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Effects of Chemistry-Based Puzzles on Senior Secondary School Chemistry Students' Achievement and Gender in Chemical Periodicty

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Abstract
This study investigated the effects of chemistry-based puzzles on senior secondary school chemistry students' achievement and gender in chemical periodicity. The quasi-experimental design with a pre -test and post- test was adopted in the study. A sample of 129 students from a population of 4369 was used in the study. Students were classified to control and experimental groups. Students in the experimental groups were instructed with chemistry-based puzzles while students in the control groups were instructed with the demonstration method. An achievement test called Chemical Periodicity Concepts Achievement Test (CPCAT), constructed by the researchers and validated by experts from three universities in Nigeria, was used in the study. Reliability coefficient of the instrument was found to be 0.96. Three research questions and three hypotheses were raised in the study. The research questions were answered using mean and standard deviation while hypotheses were tested at 0.05 confidence level with Analysis of covariance (ANCOVA). Findings showed that students in the experimental group who were taught with Puzzle-Based Strategy (PBS) achieved higher scores than those in the control group who were taught with the Demonstration Method. Further analysis with ANCOVA showed that there was significant difference in achievement in the two groups. There was no significant difference in gender by achievement. Text writers and publishers were advised to write texts which should include puzzles as exercises. It was recommended that teachers should incorporate puzzle-based instructional strategies in their teaching as a variety to curb boredom in the classroom due to monotony of the conventional methods, among others.

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I. Introduction

Science educators have always sought ways to make the teaching and learning of science very easy. This is because of the awareness of the importance of science in raising the quality of life of mankind. There is no gainsaying that science continues to contribute to man's physical life especially in the areas of shelter, leisure, comfort and communication. Science is also used in solving problems resulting from human interactions with the environment such as water and air pollution.

Chemistry is one of the three main branches of pure science, the other two being biology and physics. Chemistry deals with the composition, properties and uses of matter (Ababio, 2011). However, chemistry proves a difficult subject for many students (Sirhan, 2007). Chemistry is a human endeavor that relies on basic human qualities like creativity, insights, reasoning, and skills (Banya, 2005).

Ezeliora (2009) rated chemistry as the most important of all the sciences due to its central position to man's survival. Chemistry is commonly viewed as the "central science", as mastery of its concepts regarding the structure of matter is essential to further course work in all sciences. In essence, chemistry performs the function of gatekeeper for future study in many sciences.

Despite the relevance of chemistry to society, it is observed that the achievements of students in the subject as measured by their scores in the senior secondary school certificate examinations have been very poor (Bassey, Asim&Essien, 2005). Studies have been carried out to establish the causes and probably to proffer solutions to the problem of students' poor achievement in the subject but not much has been achieved since chemistry students still achieve poorly. Some of these studies bother on students' characteristics and teaching methods (Akpan, 2008). Certain topics and concepts have been tagged "difficult" because, teachers either find them difficult to teach or students find them difficult to understand, hence they avoid questions from these areas or perform poorly if such areas are attempted (Udo&Eshiet, 2007). Earlier, Udo (2006) noted that the effective and meaningful teaching of abstract scientific concepts require active students' involvement in the teaching-learning process through meaningful and relevant hands-on activities.

The use of teaching aids induces active participation in learning and helps students to learn with interest and understanding. Arokoya and Ugonwa (2012) have observed that teaching aids would inevitably better the performance of the students, thus helping to prepare them for useful and purposeful living within the wider environment. Upahi and Olorundare (2012) assert that chemistry is one of the most conceptually difficult subjects on the school curriculum. Upahi and Olorundare, however, advised that any one teaching the subject should be aware of the areas of difficulty in it. One of such areas is the Periodic Table otherwise referred to as Chemical Periodicity.

The Periodic Table is a topic which is taught at the senior secondary school level in year two of the chemistry syllabus. At the tertiary level, it is treated in detail as sub-divisions of the various blocks of elements known as the s-block, the p-block, the d-block, the Lanthanides and actinides (f-block).The Periodic Table provides information on properties of elements such as number of protons, neutrons and electrons, boiling points, densities, states of elements at room temperature, known isotopes and atomic masses (Mainstreet Theatre, nd). A breakdown of topics under the Periodic Table includes; metals, non-metals and noble gases, net electric charge, oxidation state patterns on the Periodic Table, non-metals forming covalent bonds, periodic trends in atomic size, electronegativity and ionization energy (Toon, Kwong, Sadler, Tsoi, Edema &Umobi, 2011). Questions on trends in the Periodic Table have continued to pose difficulty for candidates (WAEC chief examiner's reports, 2002, 2010, 2011& 2012).

Analysis of past question papers of examining bodies such as WAEC and NECO by the researcher indicate that a high percentage of questions in chemistry are set based on the content of the periodic table. As an example, the 2013 WAEC chemistry paper II which has two parts (1 & 2) had 11 out of 50 questions in the part I (objectives) which is 22% of the total questions coming from the periodic table as well as two sub questions in the essay part set from the content of the periodic table. In addition, the NECO SSCE Chemistry II of 2013 had nine out of 60 objective questions making up 15% of the total questions set from the content of the periodic table and two questions from the essay section (part B). The implication of this analysis to students and teachers is that much attention need to be given to the topic at this level. Students in particular need to be well grounded in the topic.

The chemistry teacher is a crucial factor in chemistry education delivery. This is in line with the view of Ogunkunle and Mbedele (2008) who noted that no matter how well the curriculum is planned, it is useless, if not well delivered. In order to alleviate the problem of teaching of chemistry concepts, particularly the Periodic Table, the use of puzzles (games) has been suggested by the researcher as a useful tool. Scientific- based puzzles can be of benefit to the user as they promote the development of scientific attitudes such as objectivity, honesty, curiosity, patience, open-mindedness. Users also develop science process skills such as observing, classifying, predicting, drawing conclusion, recording data and hypothesizing (Achimugu, 2012). Achimugu also noted that chemistry-based puzzles arouse and maintain curiosity in chemistry students and discourage rote memorization.

Chemistry -based puzzles fall under the category of serious games called edutainment, which is educating through entertainment (Michael & Chen, 2006). Games may be played seriously or casually, according to Michael and Chen and they have explicit and carefully thought out educational purpose and are not to be played primarily for amusement. Studies with games show that peoples motivation increase when they participate in game-based activity (Siang &Rao, 2003). For this reason, the educational games (puzzles) are considered in this study.

Gender is another variable which needs to be tested in this study because concern has been shown by researchers on this issue in science. Gender is an attribute of being male or female. Gender differences have become the hot list of critical issues around the world. Studies on gender and achievement in science have not been consistent. While the majority of studies found out that female's out- performed males, others found the opposite; on the other hand, other researchers found no differences at all between males and females concerning academic achievement and success. Gender differences according to Khwaileh and Zaza (2011) are widest at secondary level of education. It is for these reasons that the researcher seeks to ascertain the effects of science-based puzzles and its interaction with gender on achievement, retention and interest of students on the periodic table.

Statement of the Problem

The problem of underachievement in chemistry has been blamed on poor teaching methods as a major factor. The concept of chemical periodicity has been established as difficult to students. The periodic table itself is complex for students to memorise or learn all the elements in it, so as to meet up with their knowledge in examination questions set on them. Activity oriented classes are needed to enhance better understanding of the arrangement, trends and properties of all the elements on the periodic table. This activity based teaching is lacking in the teaching of this topic as is evident in literature that most teachers depend on the traditional

method. This brings about poor performance in this topic during examination and subsequent failure in the subject and low achievement at the long run.

Lastly, gender stereo-typing has not helped matters. To this end, the researchers adopted puzzle-based teaching strategy using chemistry-based puzzles which they hoped would alleviate the problem of underachievement and poor performance in chemical periodicity.

Purpose of the Study

The general purpose of the study was to determine the effects of science-based puzzles on senior secondary students' achievement in chemical periodicity. Specifically, the study ascertained the

1. effect of teaching with chemistry-based puzzles on the mean achievement scores of students in chemical periodicity.
2. effect of gender on the mean achievement scores of students in chemical periodicity.
3. interaction effect of gender and treatments on students' mean achievement scores in chemical periodicity.

Theoretical Background

This study was anchored on Vygotsky's social constructivist theory. The emphasis is on social interaction to explain children's cognitive developments. Puzzles are an aspect of games which promote children's social interaction both in and outside the classroom. They can be applied in teaching of specific concepts and can aid students to learn faster.

Research Questions

The following research questions were answered in the study:

1. What is the difference in the mean achievement scores of students taught chemical periodicity with chemistry- based puzzles and those taught with the demonstration method?
2. What is the difference in the mean achievement scores of male and female students taught chemical periodicity using chemistry-based puzzles?
3. What is the interaction effect of gender and treatments on students' mean achievement scores in chemical periodicity?\

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance.

1. There is no significant difference in the mean achievement scores of students taught chemical periodicity with chemistry-based puzzles and those taught with the demonstration method.
2. The mean achievement scores of male students do not significantly differ from their female counterparts who are taught chemical periodicity with chemistry-based puzzles and those taught with the demonstration method.
3. There is no significant interaction effect of gender and treatments on students' mean achievement scores in chemical periodicity.

II. Research Methodology

The study used the quasi-experimental design. Specifically, the non-randomized control group, pretest-posttest design was adopted in the study. The design is represented as follows:

Group	Pretest	Independent Variable	Posttest
E	O_1	X_1	O_2
C	O_1	X_2	O_2

Where E = Experimental group
C = Control group
O_1 = Pretest for the two groups
O_2 = Posttest for the two groups
X_1 = Treatment for the Experimental group
X_2 = Treatment for the Control group.

The study was carried out in Makurdi Local Area of Benue State, Nigeria. The population of the study was 4,369 Senior Secondary Two (SS2) chemistry students in Makurdi Local Government Area of Benue State. This comprised 2,439 male and 1,930 female science students spread in the 76 senior science schools (MOE, 2013).

A sample of 129 students was obtained through multistage sampling procedure. All senior secondary schools located in Makurdi metropolis were proportionally *stratified* into North bank and South bank schools. *Purposive* sampling technique was carried out to select four schools; two each from the North and South banks.

The instrument, Chemical Periodicity Concepts Achievement Test (CPCAT) was generated based on the SS2 chemistry curriculum covering the area of the topic chemical periodicity (Periodic Table) and used in the study. A table of specification was constructed based on the cognitive domain of the Taxonomy of Education by Bloom (1956).

Items in CPCAT were validated by experts from University of Nigeria Nsukka, Benue State University and University of Agriculture Makurdi.

A trial test was conducted to test the appropriateness of the instruments on 30 SS2 chemistry students. The research questions were answered using descriptive statistical tools; means and standard deviations. Analysis of covariance (ANCOVA) was used to test all the hypotheses at a 0.05 level of significance.

III. Results

The results of the study are hereunder presented in tables in accordance with the research questions and hypotheses guiding the study.

Research Question 1:

What is the difference in the mean achievement scores of students taught chemical periodicity with chemistry based puzzles and those taught with the demonstration method?

Table 1 shows that the mean achievement score of students taught with PBS was 28.14 with a standard deviation of 6.82 at post-test while those taught with DEM had a mean achievement score of 27.55 and a standard deviation of 6.23 at post-test. The difference in the mean gain of the two groups suggests that the experimental group achieved higher than the control group. Also the mean gain score of 16.67 between the pre-test and post-test scores in the PBS group indicates that teaching with chemistry-based puzzles enhanced students achievement in chemical periodicity.

Hypothesis 1:

There is no significant difference in the mean achievement scores of students' taught chemical periodicity with chemistry-based puzzles and those taught with demonstration method.

Table 2 shows that the probability associated with the significance of the effect of treatment on students' achievement in chemical periodicity is 0.000. Since the probability value of 0.000 is less than 0.05 level of significance ($P < 0.05$), the null hypothesis is rejected. This means that there is significant difference in the mean achievement scores between students taught chemical periodicity with chemistry-based puzzles and those taught with the demonstration method.

Research Question 2:

What is the difference in the mean achievement scores of male and female students taught chemical periodicity with chemistry-based puzzles and those taught with the demonstration method?

Table 3 shows that the mean achievement score of male students at posttest was 28.61 with a standard deviation of 7.28, while that of the female students was 26.82 with a standard deviation of 6.67. The difference in mean gain scores between males and females shows that the male students achieved higher than their female counterparts.

Hypothesis 2:

The mean achievement scores of male students do not significantly differ from their female counterparts who are taught with chemistry-based puzzles and those taught with the demonstration method.

With reference to table 2, the probability associated with the calculated value for the effect of gender on students' achievement in chemical periodicity is 0.12. Since the probability value of 0.12 is greater than 0.05 level of significance ($P > 0.05$), the null hypothesis was not rejected. Thus, gender has no significant influence on the achievement of students in chemical periodicity.

Research Question 3:

What is the interaction effect of gender and treatments on students' mean achievement scores in chemical periodicity?

Table 6 shows the interaction effect of gender and treatment on students' achievement in chemical periodicity. It shows that the male students who are taught with PBS had a mean achievement score of 29.79 with a standard deviation of 6.79 while the male students in the taught DEM had a mean score of 27.29 with a standard deviation of 5.38 at post-test. For the female students, the mean achievement score of the students in PBS is 25.65 with a standard deviation of 5.37 and the mean achievement score of females in DEM is 27.86 with a standard deviation of 4.66 at post-test. This implies that the male students in PBS group did better than

their male counterparts in DEM. On the other hand, the females in PBS scored higher than their counterparts in the PBS. This shows that that there is interaction effect of gender and treatments on students mean achievement scores in chemical periodicity.

Hypothesis 3:

There is no significant interaction effect of gender and treatments on students mean achievement scores in chemical periodicity.

The result of this hypothesis is presented in table 2.The result showed that the calculated value for the interaction effect of treatment and gender on students' achievement scores has a probability value of 0.11. Hence there is no significant interaction effect of gender and treatments puzzles on students' mean achievement scores in chemical periodicity since the probability value of 0.11 is greater than the probability at 0.05 level of significance (P>0.05).

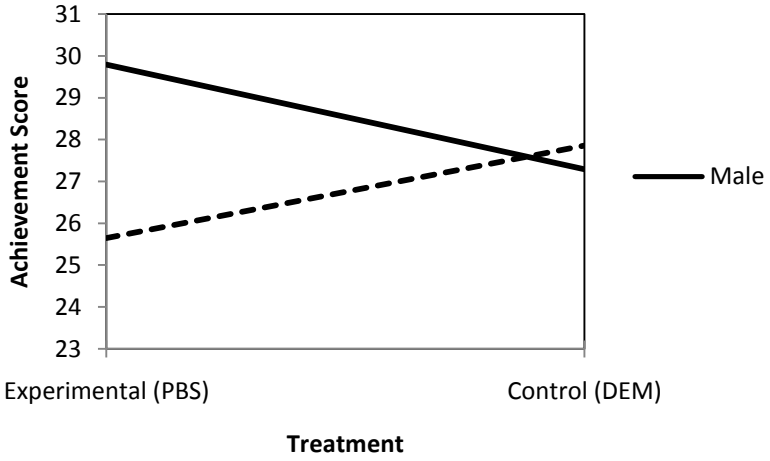

Figure 3: A plot of Treatments by Gender Interaction.

A plot of the interaction is shown in figure 3. The plot reveals a disordinal interaction.

IV. Discussion

Result of data analysis in table 1 has shown that students taught with chemistry-based puzzles had a higher mean achievement score than their counterparts who were taught with the demonstration method. There was also a high mean gain from pretest to post test. On testing the hypothesis associated with this research question, the result was significant at 0.05 level of significance. This result is in agreement with the findings by Eze (2005), Alake (2007), Davis et al. (2009), Michalewicz and Michalewicz (2007), and Adedoja et al. (2013) whose results showed that puzzles have a significant effect on students' achievement at various levels: primary, secondary and tertiary levels of education. The researchers advised that teachers should adopt PBS (crossword & word search) in teaching concepts to students in order to enhance achievement.

The fact that there was a difference in the achievement scores of students taught chemical periodicity with chemistry-based puzzles against those taught with the demonstration method means that puzzles could enhance achievement if properly utilized in the classroom for teaching of chemistry concepts. Moreover, Franklin et al. (2003) and Moore and Dettlaf (2005) have indicated that puzzles have been shown to be effective teaching and learning tools. Moreover puzzle-based teaching strategy is a new innovative strategy which is child centered and has many advantages to both the teacher and the learner as highlighted by Michalewicz and Michalewicz (2007). The reason for the keen competition of puzzle-based strategy with the demonstration method could be due to the short period of treatment for both groups which lasted for only three weeks.

The study further confirmed Vygotsky's theory of social constructivism that learning in a social environment makes students to interact and collaborate by sharing ideas and scaffolding. These attributes were witnessed by research assistants who taught in the two experimental groups (PBS) and reported to the researchers. The research assistants also reported that learners, irrespective of their gender participated actively in the classroom and the more knowledgeable ones were seen helping the weaker ones. This resulted to deep understanding of the topic by the students. Nevertheless, the demonstration method, being a conventional teaching method also proved effective and competed favourably with the puzzle-based strategy.

The result of data analysis on gender is presented in table 3. The analysis reveals that male students achieved higher than their female counterparts in chemical periodicity although the males had a higher standard

deviation (7.06) than the females which shows a higher dispersion of scores from the mean in males than in females whose standard deviation was 6.67.When the result was subjected to inferential analysis, it tested not significant. This indicated that gender was not a significant factor in students' achievement in chemical periodicity. This finding agrees with the findings of Ejimaji and Emekere (2012), Babajide (2010) Alevis and Hoseini (2009), which indicated that gender is not a factor in students' achievement in science. They indicated that male and female students would perform well and achieve academically when exposed to the same teaching methods in science. This paves way for the teacher to use puzzles as instructional resources when teaching in the classroom.

On the other hand, the finding of this study on gender is not in agreement with the findings of Okwo and Otubor (2007), Ezirim (2006), Ogunenye (2003) and Ogunleye (2002), which have shown that gender has significant influence on achievement in science. Studies on gender issues are not conclusive due to the conflicting results. For example the study carried out by Ezeudu (2013) and, Ezeudu and Obi (2013) on gender and achievement were not consistent. In one, gender was a significant factor in fostering academic achievement, in the other; gender was not found to be a significant factor.

However, the research assistants in the experimental groups (PBS) reported that both male and female students were excited with the strategy used by their teachers and would not like to leave the lesson even after the lesson period was over.

A plot of interaction effect by treatment and gender shown in figure 3 indicated that there was interaction between gender and treatments on achievement of students in chemical periodicity. This was evident from the two gender slopes which crossed each other when plotted on one graph.

Analysis in table 4 indicates that the mean achievement scores of male students in the experimental group were higher than the male students in the control group. The reverse was the case for the female students in both groups. Also with regard to the overall gender effect, the male students' mean achievement score was higher than that of female students in both groups. However, after testing the hypothesis relating to this research question, it showed that there was no significant interaction effect of gender and treatments on students' mean achievement score in the post test.

This means that the two treatment methods are independent of each other and that gender is not a factor in fostering achievement of students in both teaching methods. The finding of this study is in agreement with Obiekwe (2008) who discovered that there was no interaction effect between gender and instructional methods. On the other hand, Ezeudu (1995) indicated a significant interaction effect between gender and instructional methods. However, the use of puzzles for instruction is activity oriented and the learners are allowed to learn at their own pace. Also, gender gaps between PBS and DEM were not consistent since a wider gap existed in the PBS group between the male and female students. This reason could be that the male students were more familiar with puzzles than the female students.

Earlier on, Okigbo and Okeke (2011) pointed out that puzzles help to bring joy to the learners and break down resistance to learning by reducing tension, clearing boredom and providing an enabling environment for skill development. These views are in line with the views of Zaveleta et al. (2005) who showed that games in general promote independence, creativity, and cooperation among players. Lastly, MaCmanus (2004) affirmed that puzzles promote deep rather than surface learning and encourage interactive teaching.

V. Conclusions

Based on the findings of this study, the following conclusions were drawn:

1.Chemistry-based puzzles did not significantly enhance students' achievement in chemical periodicity when compared with the demonstration method although descriptive statistics showed that achievement was higher in the experimental group.

2. There was no significant difference in the achievement of male and female students taught with Puzzle-Based Strategy.

3. There was no significant interaction effect of gender and treatments on students' mean achievement score.

VI. Recommendations

1. Chemistry-based puzzles should be introduced in secondary schools at the senior school level to teach chemistry concepts explicitly to students.

2. Teachers should be trained at workshops to adopt the puzzle-based teaching strategy so as to make their classrooms activity- based and more interesting. Teachers should also be resourceful, and should not wait for their employers to do everything for them.

3. Authors and publishers of educational resources would tap into the findings of this study to write texts which can incorporate puzzles as part of the main text or as a section for questions.

4. Puzzles are available on the internet and can be created by individuals or group, parents and guardians are advised to encourage their wards to use them and occupy their idle hours.

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TABLES

Table 1:Mean ($\overline{X}$) and Standard Deviation (SD) of achievement scores of students in chemical periodicity

Group	Pre-test			Post-test		Mean Gain
	N	Mean	SD	Mean	SD	
PBS (Experimental)	65	21.47	6.23	38.14	6.82	16.67
DEM (Control)	64	22.51	5.03	27.55	6.23	5.03

PBS= Puzzle Based Strategy N= no of students in group.
DEM = Demonstration Method SD= standard deviation.

Table 2: Analysis of Covariance of the effect of treatments on students' achievement in chemical periodicity

Sources	Sum of squares	DF	Mean square	F	Sig level
Pretest	1390.818	1	1390.818	36.707	.000
Main effect	98.489	2	49.245	1.300	.276
Group	1245.411	1	1245.411	32.064	.000
Gender (Sex)	94.145	1	94.145	2.485	.117
Gender*Group	98.679	1	98.679	2.605	.109
Explained	1674.883	1	418.721	11.052	.000
Residual	4698.016	124	37.887		
Total	6372.899	128	49.788		

Table 3: **Mean ($\overline{X}$) and Standard Deviation (SD) of achievement scores of male and female students in chemical periodicity**

Group	Pre-test	Post-test	Mean Gain

	N	Mean	SD		Mean	SD				
Male	74	21.75	6.14		28.61	7.28			4.86	
Female	55	21.99	5.66		26.82	6.67			4.83	

Table 4:Mean and standard deviation of achievement scores of students for the interaction effect of gender and treatments

Group	Gender					
	Male			Female		
	N	Mean	SD	N	Mean	SD
PBS	39	29.79	6.79	26	25.65	5.37
DEM	35	27.29	5.38	29	27.86	4.66

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