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Effects of Using Molecular Model Kits, Charts and Board Drawings in Teaching Chemical Bonding to Secondary School Chemistry Students in Anolga, Rivers State

OWO, Wisdom. J.

Department of Integrated Science, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Email:owowisdom70@hotmail.com

Abstract:

Many science students see chemistry as an abstract subject because of their inability to visualise the atoms or molecules and how they bond with themselves or with other atoms or molecules to form compounds. This research therefore investigated the effects of using molecular model kits compared with the use of charts and board drawings in teaching chemical bonding to SSS 1 chemistry students in the Andoni Local Government Area of Rivers State. The study adopted a quasi-experimental design. One research question and one hypothesis were formulated to guide the study. The sample of the study comprised one hundred and thirty-five (135) students, randomly divided into two experimental groups and one control group, each having 45 students. A Chemical Bonding Achievement Test (CBAT) was the instrument used for data collection. Mean and ANOVA were used in the analysis of the data, and the results obtained showed that there was a significant difference between the achievements of students taught chemical bonding using molecular model kits (MMK) and those taught with charts and board drawings (BD), with those taught using MMK having the highest mean score and those taught using BD having the lowest achievement score. This led to the conclusion that using molecular model kits is more effective in teaching chemical bonding to SSS1 chemistry students in the Andoni Local Government Area of Rivers State, as it has positive effects on the academic achievements of the students. Based on the findings, the researcher recommends the use of stereochemistry models like molecular models in teaching chemical bonding and other concepts in chemistry, like the IUPAC nomenclature for organic compounds, in secondary schools.

Keywords: Molecular, model, chart, drawing, board, chemical bonding, academic achievement.

INTRODUCTION

1.1 Background to the study

Along with biology and physics, chemistry is considered to be one of the three primary subfields that make up the field of pure science. It is concerned with the study of matter, including its make-up, characteristics, and applications (Ababio, 2000). The study of chemistry, both as a scientific endeavour and as a subject in schools, is predicated on models (Noor Dayana, Mohamad, Noraffandy & NohdNihra, 2013). As a consequence of this, the study of chemistry opened doors for the creation of chemical models and led to knowledge of how these models should be used in various situations. There are three distinct levels that can be used to describe chemistry. The first level is the macroscopic level, which refers to phenomena that can be seen or touched. The second level is the microscopic level, which refers to atomic and molecular phenomena. The third level is the symbolic level, which refers to the representation of matter using equations and formulas (Hinton &Nakhleh, 1999). It is essential for students of chemistry to be able to conceive on a tiny scale while still being able to describe phenomena on a larger scale (Chandrasegaran, Treagust & Mocerino, 2008).

Due to the abstract and theoretical character of the subject matter, chemical bonding is considered to be one of the most difficult topics to cover in chemistry classes (Taber, 2001; Taber and Coll, 2002; de Jong and Taber, 2014). Numerous research studies (Dhindsa & Treagust, 2009; Kind & Kind, 2011) have explored the constant challenges that students have with comprehending chemical bonding. These issues have caused them (the students) to have difficulty in learning of advanced chemistry courses (Coll &Treagust, 2001; Hilton & Nichols, 2011). Students need to understand the nature of chemical bonding in order to understand the nature of chemical reactions, thermodynamics, molecular structure, chemical equilibrium, and some physical properties such as densities, solubilities, boiling points, and melting points. Taber & Coll (2002) reported that one cannot understand the concepts of reactivity, spectroscopy and organic chemistry without understanding the theories behind chemical bonding. In order to get students involved in learning chemistry, Erlina, Cane & Williams (2018); Tsai, Chen, Chang & Liu (2020) opined that teaching chemistry should be made fun. According to Jones and Kelly (2015) one of the means by which students' comprehension of abstract concepts in chemistry can be enhanced is to make the student visualize what is being learnt.

Because of their proven ability to improve students' comprehension as well as their ability to communicate about and investigate scientific phenomena, models are an essential component of effective science education (Harrison & Treagust, 2000). Gilbert (2004) argued that models may be used to convey theoretical phenomena and show components of scientific experiments that would otherwise be hard to do in the classroom. In addition, he was of the opinion that models are not difficult to get and that pupils often like this approach to academic study. Models are required in order to effectively explain abstract information due to the fact that many scientific notions predate our perceptual experiences. Continuing with Gilbert's line of thinking, models are one approach to make scientific instruction seem more real (Gilbert, 2004). According to Erlina, Eny & Rahmat (2021), simple molecular models are beneficial learning resources that have the potential to improve students' understanding of the geometry of molecules. This is because the models enable students to understand the impacts of the lone pair to the molecular geometry as well as the bond angle, and as a result, they are beneficial for the teaching of chemistry.

1.2 Statement of the Problem

According to a plethora of surveys, students of all academic levels reported finding chemistry to be a challenging subject to learn. The inability of pupils to envision the atoms or molecules and the way in which these atoms and molecules connect with one other or with other atoms or molecules to create compounds is the primary factor that contributes to the difficulty.This incited the quest for an innovative method like using molecular model kits in the teaching of chemical bonding to ensure that students achieve the desired learning outcomes in chemical bonding.

Although research studies have revealed that molecular models go a long way in influencing teaching and learning as well as improving the academic achievements of all categories of students in some concepts in chemistry, there has not been any research study known to the researcher covering the effects of using molecular model kits (MMK) compared to the use of board drawing method and charts in teaching chemical bonding in chemistry in senior secondary schools. The purpose of this research is to assess the effectiveness of employing MMK versus charts and board drawings in teaching chemical bonding to SS 1 chemistry students in the Andoni Local Government Area of Rivers State.

1.2 Purpose of Study

The purpose of this study is to investigate the effects of using MMK compared to board drawing method and charts in teaching chemical bonding to SS 1 chemistry students in Andoni Local Government Area of Rivers State.

1.3 Significance of the study

The significance of this study is that the results of the study is expected to help the chemistry teachers in knowing the concepts in chemistry that would require teaching with molecular model kits and preparing their students for external examination like the Senior School Certificate Examinations (SSCE). It will also be of benefit to the government and school administrators who will see the need to equip schools with the relevant and adequate chemistry models.

1.4 Research Questions

One research questions (RQ) guided the study:

RQ1: What are the mean achievement scores of students taught chemical bonding using molecular model kits (MMK), those taught with charts and those taught with board drawings (BD)?

1.5 Research Hypotheses

One research null hypothesis (Ho) guided the study:

Ho_1: There is no significant difference between the achievements of students taught chemical bonding using molecular model kits,those taught with charts and board drawings.

2.0 LITERATURE REVIEWS

Gyasi, Ofoe, and Samlafo (2018) did a study in which they evaluated the influence of molecular model sets on the naming of simple organic compounds, with a particular focus on the method of nomenclature used by the International Union of Pure and Applied Chemistry (IUPAC). According to the findings of the research, the use of molecular model set techniques in the classroom has the potential to assist students in overcoming, if not entirely eliminating, the challenges they experience while identifying organic compounds in accordance with IUPAC nomenclature.

The researchers Ibrahim, Abubakar & Ogabi (2018) conducted a study to investigate the influence of the use of Ball-and-Stick Models (Molecular models) in teaching nomenclature to SS 3 chemistry students. Specifically, they were interested in the students' perceptions of the usefulness of the models. According to the findings of the research, there was a discernible gap in performance between the groups of students who were instructed to name organic compounds using the ball-and-stick method and those who were instructed to use the chart. The findings also revealed that there was a statistically significant gender gap in the performance of students who were instructed to name organic compounds using the ball-and-stick method. Because of the increased exposure that students had to both virtual and physical models, as well as the active learning that they participated in, there was a considerable improvement in the students' overall level of comprehension. They did, however, make the recommendation that the government should ensure that a blend of virtual and physical models be incorporated in the teaching and learning of chemistry as a means to foster meaningful learning and spatial comprehension of molecular structure, which would ultimately increase their academic achievements in the nomenclature of organic compounds in organic chemistry.

An investigation was carried out by Erlina, Eny & Rahmat (2021) with the purpose of improving students' comprehension of molecular geometry. The researchers used simple molecular models as the learning resources to assist students in visualising the shape of molecules. The researchers found that the simple molecular model consisting of polystyrene balls improved students' comprehension of molecular geometry. Aybüke and Omer (2012) conducted research to determine whether or not students' conceptual grasp of chemical bonding ideas improved when they were taught in a way that focused on conceptual change. According to the findings of the research, conceptual change centred training led to improved comprehension, and two different modalities of instruction created comparable attitudes about chemistry. It was also noted that scientific process competence was a major predictor in comprehending chemical bonding; however, there was no significant difference between the effects of gender on students' attitudes or their comprehension of chemical bonding.

A significant number of researches that looked into the learning and teaching of chemical bonding employed various measures to evaluate the challenges faced by pupils. For example, Birk & Kurtz (1999) conducted a test consisting of two tiers of multiple-choice questions in order to identify common misunderstandings about chemical bonding. According to the findings of their investigation, one of the most widespread misunderstandings among first-year college students was the idea that all covalent connections include an equal distribution of the electron pair. The two-tier multiple-choice diagnostic tool was also used by Kim-Chwee & Treagust (1999) in order to evaluate the students' misunderstandings about chemical bonding that were between the ages of 14 and 16. According to the findings of their investigation, the widespread belief among students in the age range of 14 to 16 years old was that metals and non-metals both create molecules during the process of chemical bonding.

3.0 METHODOLGY

3.1 Research design

The study adopted a quasi-experimental design with one control group and two experimental groups. The choice of this design is necessitated by the fact that the independent variables (MMK, Charts and BD) can be maneuvered and their impacts on academic achievement (dependable variable) examined.

3.2 Population of the study

The estimated population of this study wasone thousand and eleven (1011) Senior Secondary School I students in Andoni Local Government Area of Rivers state.

3.3 Sample and Sampling procedure

As the researcher was unable to analyse the whole population of students enrolled in senior secondary school I (SSS1) in the area, a representative number was chosen to serve as the sample population. The study sample consisted of one hundred thirty five (135) unique students. The sample consisted of 45 students randomly selected from each of the three (3) secondary schools in Andoni that were also selected at random as sample sites.

3.4 Instruments

The instrument used for collection of data was the Chemical Bonding Achievement Test (CBAT) validated by two experts from Chemistry Department, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State. The reliability of the instrument ($\alpha = 0.84$) was obtained using Cronbach alpha technique.

3.5 Method of Data Collection

In each of the selected schools, the researcher distributed the participants randomly into three instructional material groups – molecular model kits (MMK), charts and board drawings (BD) and briefed them on the importance of the research and the need for them to cooperate. Afterwards a pretest (Chemical Bonding Achievement Test) (CBAT) was administered to them to gain the level of their background knowledge on the topic. They were then taught the topic-chemical bonding for three weeks with the instructional materials assigned to their groups and a posttest administered to them in the fourth week to measure their achievement.The test lasted for one hour and at the end of the one hour, the test answer scripts were retrieved on the spot and scored to generate data (marks).

3.6 Method of Data Analysis

The Data collected from the three groups were analyzed in line with the research question and hypothesis using mean, standard deviation (SD) and one-way ANOVA. A post hoc test (Tukey) was used to reveal the source(s) of significant difference. The hypothesis was tested at $p<0.05$ level of significance in which a probability less than 0.05 indicates that the hypothesis is significant otherwise not significant.

4.0 RESULTS

Table 1: Mean achievement scores of students taught chemical bonding using molecular model kits (MMK), Board drawings (BD), and those taught with charts.

Variables	N	Mean	Std. Deviation	Std. Error Mean
Molecular model kit	45	58.669	10.881	1.622
Charts	45	50.911	11.879	1.771
Board Drawings	45	44.867	11.940	1.780

Table 1 showed that the students that were taught chemical bonding using MMK as an instructional material had mean achievement score of 58.669 and SD of 10.881, those taught with charts as an instructional material had mean achievement score of 50.911 and SD of 11.879 while those taught with BD had mean achievement score of 44.867 and SD of 1.780.

Table 2: Analysis of Variance of the effect of teaching chemical bonding with molecular model kits compared to chart and board drawing on students' achievements.

Source	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4321.244	2	2160.622	16.120	.000
Within Groups	17692.489	132	134.034		
Total	22013.733	134			

Table 2 shows a one-way ANOVA performed to compare the effect of teaching chemical bonding with molecular model kits, charts and board drawing on the academic achievement of students. The table revealed that there was a statistically significant difference ($F_{2, 132}$ =16.120 at $p<0.05$) in the academic achievements of students taught chemical bonding with molecular model kits (Group 1) when compared to those taught with chart (Group 2) and those taught with board drawing (control group).

Table 3:Tukey's HSD test for multiple comparisons of mean academic achievement scores of students taught with MMK, charts and board drawings.

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Chart	MMK	-13.82222*	2.44071	.000	-19.6078	-8.0367
	BD	-6.04444*	2.44071	.038	-11.8300	-.2589
MMK	Chart	13.82222*	2.44071	.000	8.0367	19.6078
	BD	7.77778*	2.44071	.005	1.9922	13.5633
BD	Chart	6.04444*	2.44071	.038	.2589	11.8300
	MMK	-7.77778*	2.44071	.005	-13.5633	-1.9922

*. The mean difference is significant at the 0.05 level.

Table 3 is the Tukey's HSD test for multiple comparisons of mean academic achievement scores of students taught with MMK, charts and BD. From the table it was found that the mean difference in academic achievement test scores was significantly different between charts and MMK (mean difference =13.82222, p=0.000), chart and BD (mean difference = 6.04444, p=0.038) and MMK and BD (mean difference =7.77778, p=0.005).

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

This research demonstrated that the majority of students had difficulties reproducing chemical bonds in compounds, especially when they were introduced to the notion of chemical bonding utilising charts and board diagrams. However, they encountered several challenges when introduced to the notion of chemical bonding via the use of board drawings, but none when taught using a molecular model kit (MMK). This is buttressed by the fact that the students that were taught chemical bonding using molecular model kit (MMK) as an instructional material academically achieved The ANOVA test for the mean difference revealed a significant difference in mean achievement. This study seems to indicate that teaching chemical bonding using molecular model kits or other higher score followed by those taught using charts while the achievement score of those taught using board drawing (BD) was the least. stereochemistry models is successful. These findings concur with those of Ibrahim, Abubakar & Ogabi (2018) and Erlina, Eny & Rahmat (2021). Ibrahim et al. (2018) investigated the effect of using Ball-and-Stick Models (Molecular models) in teaching nomenclature to SS 3 chemistry students and reported that there was a significant difference in the performance of students taught to name organic compounds using ball-and-stick versus those taught using a chart. Erlina, Eny, and Rahmat (2021) conducted a study that attempted to improve students' comprehension by employing basic molecular models as learning materials to assist students perceive the form of molecules. Based on the findings of their investigation, it was determined that the basic molecular model comprised of polystyrene balls enhanced students' comprehension of molecular geometry in the same manner that it enhanced their comprehension of chemical bonding. One benefit of molecular model kits over chart and board diagrams is that the bonds binding the participating atoms are clearly shown, while the atoms and functional groups are portrayed in colours and sizes, as opposed to the sketchy shapes of the compounds on chart and board diagrams.

The observed improvement in the academic of students taught chemical bonding using MMK over those taught using charts and board drawings is that the teaching was made a fun with the use of MMK as an instructional material making the students to be interested and engaged in learning as they interact with the MMk and using it to build models in line with the molecular geometry of the molecules under study. Again, the students are able to visualize what they are taught using MMK because visualization with modeling kits presents information more vividly and accurately about images of how the atoms might bond in a molecule.

5.2 Conclusion

Studies have revealed that molecular models go a long way in influencing teaching and learning.For students to comprehend the nature of chemical reactions, thermodynamics, molecular structure, chemical equilibrium, and certain physical characteristics such as densities, solubilities, boiling and melting temperatures, understanding of chemical bonding is essential. From the results of the study, it is evident that using molecular model kits is more effective in teaching chemical bonding to SSS1 chemistry students as it has positive effects on the academic achievements of the students.

5.3 Recommendations

Based on the findings in this study, the researcher recommends the use of stereochemistry models like molecular models in teaching chemical bonding and other concepts in chemistry like IUPAC nomenclature for organic compounds in secondary schools.

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