EFFECT OF TEACHING METHODS ON STUDENTS' ACADEMIC PERFORMANCE IN CHEMISTRY IN NIGERIA: META-ANALYTIC REVIEW

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Abstract. A lot of research studies have been conducted on effects of teaching methods on academic performance of students and they proved to be significant. But there is a discordant view on their results. This study uses meta-analytic review to harmonize studies conducted in Nigeria from 1990 to 2010 on effect of teaching method on students' academic performance in chemistry. This quasi experimental review was carried out under six phases namely; collection of the study, coding of the study, determination of inter-raters reliability, setting a benchmark for selecting a study, calculation of effect sizes and carrying out analysis. The required research studies must have statistics descriptions for computation of effect size. Fifty-one research works were sampled and used because they met the benchmark set for selection. Seven classes of teaching method were identified and they include: mastery learning (-0.013), Computer Assisted Instruction (0.146), Instructional Materials (0.208), Problem solving (0.315), Constructivist/concept mapping (-0.203), games/simulation/animations (0.173), student grouping/cooperative learning (0.218). The overall effect size

is 0.147. The significant variations in the magnitude of effect sizes were resolved to some extent by application of random-model effect size meta-analytic technique. The major implication of this review is that we generated the most effective method of teaching chemistry**.**

Keywords: academic performance, effect size, meta-analysis, teaching method

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Introduction

In Nigeria, senior secondary three students participate in annual West African Examination administered by West African Examination Council. The examination is being conducted twice a year, between May/June and November/December period. After the assessment of the students in chemistry, the Chief Examiner usually reports on the overall performance of students in Nigeria, pointing out their weakness and strength.

It is disheartening to note that despite all the laudable objectives of science in secondary schools, and its importance in the nation's economy, students' achievement in West African Senior School Certificate has been poor from 2005 to 2014 (Ojediran et al., 2014). This fact was further buttressed by the trend in the students' achievement in West African Secondary School Certificate examination in chemistry from 2005 to 2014 as shown in Table 1.

Table 1 showed that the percentage of failure in the SSCE from 2005 to 2014 was higher than the percentage of credit pass. Examining these results enables the researchers to understand how students are doing in chemistry. To improve on the performance of students, there is a need to provide professional development (Whitebook et al., 2009) for chemistry teachers for their improvement on the effectiveness of instruction.

Table 1. Percentage performance of students in chemistry in the Senior Secondary Certificate Examination (SSCE) May/June 2005-2014

Examination Year	NO OF STUDENTS	% CREDITS	% FAIL
2005	15970	5047(31.60%)	68.40%
2006	15947	6705(39.60%)	60.43%
2007	17308	4865(28.10%)	71.90%
2008	18239	5761(31.58%)	68.42%
2009	18546	4877(26.30%)	73.70%
2010	19440	5886(30.28%)	69.72%
2011	18770	5327(28.38%)	71.62%
2012	20182	7832(38.81%)	61.19%
2013	19860	7205(36.28%)	63.72%
2014	21680	6781(31.28%)	68.72%

Source: West African Examination Council, 2014

Teacher effectiveness

Teacher effectiveness refers to the teacher's ability to transfer information to students. Wright et al. (1997) were of the view that teachers have a remarkable effect on students' achievement. Wright et al. (1997) in their longitudinal analyses of schools, class sizes, teachers affecting student achievement concluded that teacher effectiveness mostly affect students achievement when compared with others. Teacher effectiveness in chemistry is determined by the level of pedagogical content knowledge possess by the chemistry teacher.

Pedagogical content knowledge (PCK)

Shulman (1987) introduced the concept of pedagogical content knowledge (PCK) as additional form of teacher professional knowledge which is formed from harmonization of content knowledge (CK) and pedagogical knowledge (PK). Shulman (1987) defined PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding". In addition to the above definition, PCK

is unique form of knowledge that distinguishes a science teacher from a content specialist (scientist) (NRC, 1996; Shulman, 1987).

From the above definition, it is imperative to note that a professional teacher should possess both the content knowledge (the subject matter s/he is teaching) and pedagogical knowledge (methods/strategies of teaching the subject matter). This assertion was not put in consideration in recent recruitment made by Nigerian government under the Federal Ministry of Education in 2017 and 2018 when she employed 500000 workers which is mainly teachers under the N-power scheme across the nation to carter for the inadequacy of teachers especially science teachers in schools. This is because most of the teachers did not study education but are specialist in the content area they teach (possess only the content knowledge). Although studies have provided positive findings on content knowledge as a foundational component of PCK and important for teaching (Abell, 2007; Davis et al., 2006), it is also worthy to note that mastery of subject matter alone without pedagogical knowledge cannot make one an effective teacher but "teachers' understanding of how to help students understand specific subject matter" according to Magnusson et al. (1999) can make teacher effective. One of the noted five components of PCK according to Magnusson et al. (1999) is "knowledge of instructional strategies". This component is rooted on pedagogical knowledge of the teacher. If instructional strategies (pedagogy) chemistry teachers made use of during the teaching process can be singled out and possibly use to train the N-power chemistry teachers during professional development (in-service training), their pedagogical knowledge will be enhanced which invariably improve students learning.

Teaching strategies / teaching methods

Over the past decades, researchers have engaged in conducting studies in chemistry classrooms in order to establish an effect of a particular teaching method/strategy on students' academic achievement (Offiah & Egolum, 2006; Okonkwo, 2007). Empirical evidence has shown that studies on effects of using

the learning cycle method in teaching (Qarareh, 2012), Demonstration strategy (Giridharan & Raju, 2016), jigsaw method (Abdulkadir, 2016), concept mapping (Qarareh, 2010), experiential and generative learning strategies (Adeyemi & Awolere, 2016), computer simulations (Okwuduba et al., 2018) on academic achievement of students in chemistry and sciences have been successfully carried out. Although most of these innovative instructional strategies proved to be significant when compared with conventional strategies used by the regular chemistry teachers, the results of these studies are such that there are variable magnitudes of the effect of the different teaching strategies on students' achievement in chemistry. For instance, Abdulkadir, (2016) carried out a study on effect of jigsaw method with 63 students studying elementary science education for the period of seven weeks. An independent sample t-test was used for data analysis and the research reveals that jigsaw method enhances students' academic achievement in chemistry laboratory. Similarly, Qarareh, (2010) study on effect of concept mapping with 80 students reveals that concept mapping has a positive and greater effect on students' achievement in science. Although both studies came up with similar findings, they differ in their sample size, and method of analysis. While Abdulkadir (2016) sample size is 63 students and data analysis was done using independent sample t-test, Qarareh (2010) sample size was 80 students and data was analysed using analysis of variance. This inconsistency in different researches on effect of teaching methods can be statistically harmonized using meta-analysis. Hence, the need to conduct a meta-analysis of those studies arises.

Meta-analysis

To reconcile these discordant views on the result of instructional methods on achievement in chemistry, integration of the result becomes necessary so that composite figure is produced. Glass (1976) proposed a Meta-Analytic approach as a method for combining the results of a series of studies in the same

area. Glass introduced phases of the meta-analytic process to include formulation of the problem, data collection (literature search), data evaluation, data analysis and presentation. The objective of meta-analytic study is to obtain the overall effect size of the studies integrated. Presently, researchers' attention have been shifted to the area of meta-analysis in different areas of education and it has been successfully carried out in the area of in-Service professional development programs (Egert et al., 2018), Reading for Writing (Graham et al., 2018), Teacher–Student Interactions (Vandenbroucke et al., 2018), children with poor reading comprehension (Spencer & Wagner, 2018) and "…effect of teaching strategies on students' achievement in science…." (Schroeder et al., 2007). Evident from the literature pointed out that meta-analysis has not been conducted in the area of effect of teaching methods on achievement of students' in chemistry with research works carried out from 1990 to 2010 in Nigeria. Hence, this study is set to fill this gap

Procedure

Studies acquisition/gathering

120 studies were gathered from the initial search in journal articles, conference proceeding papers, unpublished research works (dissertations, thesis and undergraduate project works). The search was conducted in Journal of Science Teachers association of Nigeria, International Education Research and development, UNIZIK STM journal, Journal of UNIZIK undergraduates, and proceedings of Science Teachers association of Nigeria.

Departments of Science Education in Nigeria Federal Universities were written for the researchers to assess their unpublished undergraduate projects and postgraduate theses Out of 26 federal universities in Nigeria, the researchers only sampled two from each of the six geopolitical zones. Although the intense nature of the security problem posed by Bokoharam insurgent, Fulani Hardsmen crash with farmers in the North-East and North-West zone constrained the researchers to visit only one university in each of the zone.

Coding of studies

The coding document used for data collection was adapted from the coding document developed by Schroeder et al. (2007). The present instrument differed from Schroeder et al. (2007) instrument because some items were not included in the present study. For instance, type of study, text content area and study duration in the original coding document were not included in the present study. Type of study was not included because all the studies gathered are quasi-experimental studies and the duration of their experiment lasted between four of eight weeks. Also, the present study only review studies done in one content area which is chemistry hence there is no need of text content area. There is an inclusion of study location in the present study which was not part of the variable in the original instrument. In Schroeder et al. (2007), the dependent variable was achievement in science while the present study was on achievement in chemistry.

Intercoder objectivity

An inter-rater reliability was determined for the instrument. Two studies other than those included in the analysis were given to two independent observers both are experts in measurement and evaluation to rate. The reliability estimate of 0.91 was obtained.

Criteria for selection of studies

The criteria for inclusion of a particular study in the research include: (i) the study will be carried out between January 1, 1990 to December 31, 2010; (ii) the subjects used for the study will be secondary school students in Nigeria; (iii) the dependent variable for the study will be student achievement or performance in chemistry; (iv) the independent variable for the study will be teaching strategies; (v) the study will be quasi experimental research design; (vi) the

study will be published in Nigeria STAN journal, STAN conference proceedings and any other Nigeria journals as well as theses, dissertations and undergraduate projects from Nigeria Universities; (vii) the study will report either effect size or the statistics necessary for computation of effect size (mean and standard deviation, etc.; (viii) there will be no inclusion of the same study more than once even if it is presented in conference and published in a journal also.

Studies that were not included in the computation of effect size is 69 in number. 40 studies were excluded because their independent variables were achievement in other science subjects and mathematics and 29 studies were excluded because they did not fall within the year for which the present meta-analysis covers.

Method of data analysis

Analysis of data was done using frequency tables, percentages, effect size using Hedges & Olkins (1990) statistical approach. Effect size was then used to determine the strength of effect of teaching strategies on student achievement in chemistry. Finally, the Hedges and Olkins' (1990) effect size approach was used to test the null hypotheses common to the analysed studies at 0.05 level of significance.

Computation of effect size

The effect size (ES), according to Neil[1)] is the mean difference between groups in standard score form. Basic effect size calculations are based on Hedges & Olkins' (1990) using the formula $ES = (X_T - X_C)/ S_{pooled}$, where X_T and X_C are the means for the treatment and control group in each study and S_{pooled} is pooled standard deviation. According to Borenstein et al. (2006), effect size can be interpreted based on the following criteria: (a) $g < 0.2$ represents small effects; (b) $0.2 \leq g \leq$ represents medium effect; (c) $g > 0.5$ represents large effect

Results

Description of the studies examined

Table 2. Frequencies and percentages of variable properties for studies included in meta-analysis

Independent variable	Frequencies of variable	Percentage (%)
Publication type		
Journal article	**25**	**41.67**
Dissertation	**4**	**6.67**
Theses	**23**	**38.33**
Undergraduate project	**7**	**11.67**
Conference proceeding	**1**	**1.67**
Publication year		
1990 - 1995	**2**	**3.33**
1996 - 2000	**4**	**6.67**
2001 - 2005	**25**	**41.67**
2006 - 2010	**29**	**48.33**
Study location		
North East	**1**	**1.67**
North Central	**6**	**10.00**
South East	**23**	**38.33**
South West	**11**	**18.33**
South South	**10**	**16.67**
North West	**1**	**1.67**
Missing information	**8**	**13.33**
Totals (for each independent variable)	**60**	

` Table 2 showed a breakdown and percentages of the variable properties of the research works included in this meta-analytic review. The table revealed that most of the research works used these meta-analytic review were journal articles and postgraduate theses and the researches were conducted mainly from 2001 to 2010. The study locations were mainly in the South-East, South-West and South-South.

Meta-analysis for all studies

Table 3. Meta-analysis and 95% confidence interval associated with all the studies examined

Total	Σ weight	Weight x effect size	Summary Effect	Variance	Standard Error	Confidence interval		Prediction interval	
N	Σ W*	Σ w*y	M*	Vm* = 1/ Σw*	SEm*	LLM*	ULM*	LLpred	ULpred
51	317.203	46.665	0.147	0.003	0.056	0.037	0.257	-0.473	0.767

Table 3 shows that the computed value of the summary effect for all the fifty-one findings analysed is 0.147. This indicates that the mean magnitude of the effect of teaching strategies on students' academic achievement in chemistry is small and positive.

Table 4 reveals that mastery learning and constructivist instructional learning strategy have a negative effect size while the computer assisted instruction, instructional material, problem solving, games and student grouping have a positive effect size.

From the Table 5, the calculated z-value is 2.62 and p-value associated with this z-value is 0.0044. Hence, the overall effect of teaching strategies on students' academic achievement in chemistry is significant.

Table 6 shows that the mean effect size of mastery learning, CAI, constructivist, games and students grouping were not significant while the mean effect size of instructional material and problem solving were significant.

Table 4. Meta-analysis for studies associated with the indices of teaching strategy examined

Index of teaching	**Total no of cases N**	Σ weight ΣW*	**Weight x Effect size Σ(w*y)**	**Summary effect size**	**Variance Vm* =1/Σw***	**Standard Error SEm***	**Confidence interval**	**ULM***

strategy			M*			LLM*		
Mastery learning	4	15.505	-0.204	-0.013	0.064	0.253	-0.509	0.483
Computer Assisted Instruction	6	32.517	4.742	0.146	0.0308	0.175	-0.198	0.49
Instructional Material	12	72.392	14.824	0.208	0.014	0.118	-0.024	0.44
Problem Solving	10	66.858	21.085	0.315	0.015	0.122	0.075	0.555
Constructivist	7	52.067	-10.575	-0.203	0.019	0.139	-0.475	0.069
Games	7	47.093	8.13	0.173	0.021	0.146	-0.113	0.459
Student Grouping	5	31.771	8.821	0.278	0.031	0.177	-0.069	0.625
Total	51	317.203	46.665	0.147	0.003	0.056	0.037	0.257

Table 5. Z-test for all the studies at 0.05 level of significance

Mean effect size	variance	Standard error	Lower confidence interval	Upper confidence interval	z-value	prob	decision
0.147	0.003	0.056	0.037	0.257	2.62	0.0044	Reject

Table 6. Summary of random-effects model (pooled estimate of T^2) for the seven indices of teaching strategies/gender

	Mean effect size	**Variance**	**Standard error**	**Lower confid interval**	**Upper confid interval**	**z-value**	**p-value**	**Decision**
Mastery learning	-0.013	0.064	0.253	-0.509	0.483	-0.051	0.48	Accepted
CAI	0.146	0.031	0.175	-0.198	0.49	0.834	0.203	Accepted
Instructional material	0.208	0.014	0.118	-0.024	0.44	1.763	0.04	Rejected

Problem Solving	0.315	0.015	0.122	0.075	0.555	2.582	0.005	Rejected
Construc-tivist	-0.203	0.019	0.139	-0.475	0.069	-1.46	0.072	Accepted
Games	0.173	0.021	0.146	-0.133	0.459	1.185	0.117	Accepted
Students Grouping	0.278	0.031	0.176	-0.069	0.625	1.58	0.057	Accepted

Measure of heterogeneity for the 51 effect sizes

Table 7 revealed that the entire studies did not share a common effect size. Thus the true effect is not the same in all the studies which is a basic assumption of the random effect model. The table also shows that the absolute amount variation or estimate of the variance is 0.093 which gives a standard deviation of the true effects of 0.31. This value of (T) implies that the distribution of the effect sizes about the mean effect is from -0.5 to 0.7. This agrees with the predictive interval of I^2 . Finally, I^2 which shows that the proportion of the observed variance that constitutes real difference has a value of 65.2%. Thus the observed effect sizes are considered to be moderate.

Table 7. Summary of the measures of heterogeneity for the 51 effect sizes

Sum Effect size	Df	T^2	Conf inter for T^2		T	Conf inter for T		I^2	Conf inter for I^2		Pred inter for I^2		Q	p-valve
			LLT^2	ULT^2		LLT	ULT		LLI^2	ULI^2				
0.147	50	0.093	0.057	0.143	0.31	0.238	0.378	65.2	53.09	74	-0.47	0.745	143.72	0.0

Summary and discussion

The main objective of this research was to review the studies on chemistry achievement in order to provide a clear picture and harmonized empirical fact on effectiveness of teaching strategies. 51 research works met the base line for selection. All the research works were grouped into seven teaching strategies and were analysed to determine their mean effect size, mastery learning (-0.013), Computer Assisted Instruction (0.146), Instructional Materials (0.208),

Problem solving (0.315), Constructivist/concept mapping (-0.203), game/simulation/animations (0.173), student grouping/cooperative learning (0.218).

Problem solving has the largest effect size of 0.315. Problem solving is a student based method of teaching which allows the students to discover things by themselves when placed in a learning situation. Chemistry been an activity oriented subject requires students to experiment and discover on their own with the help of the teacher acting as the facilitator. This is basis for meaningful learning and discourages rote learning. It is also observed that effect size of student grouping/ cooperative learning follows problem solving. This shows that students can perform high in chemistry if they are placed in a team during the conduct of chemistry experiment. Allowing them to work cooperatively provides an avenue for them to work as a team and be accountable to each other during the learning process. This is in line with Schroeder et al. (2007) assertion that "collaborative learning strategies such as flexible heterogeneous groupings and group inquiry projects also displayed a strong effect" during the learning process. Finally, provision of instructional materials makes learning of chemistry to be concrete because it helps to create a real environment for learning processes.

Combination of these three strategies will increase achievement of students in chemistry. This is in line with Wise (1996) as cited in Schroeder et al. (2007) who states that an innovative teaching method is a combination of different teaching strategies, hence, one teaching strategy is not as effective as using a combined teaching approach. Therefore, if in-service training in form of professional development can be provided for N-power teachers in Nigeria based on the effectiveness of these teaching strategies, their pedagogical content knowledge will improve.

Limitations

The major limitation is that the present study only used quasi-experimental studies excluding pure experimental and correlational studies which also

affect achievement of students in chemistry. Also, the year of the study was limited to 2010 due to the fact that the time of conceptualization was in 2012. Hence studies conducted from 2011 and above that would have met the criteria were not included. The major sources of the articles included in this study were from unpublished research work. Although this might not be assumed totally as limitation because Dickersin et al. (1992) ascertained that one of the major meta-analytic review bias is the tendency of publishing more significant findings than non-significant findings by the researchers possibly because the researchers tend not submit non-significant research work. Hence, to overcome this bias, the use of unpublished research works conducted in different universities in Nigeria form the larger part of the sample works.

Finally, equal opportunity was not given to universities in Northern part of Nigeria due to Bokoharam and Fulani herdsmen crisis in some Northern parts of Nigeria.

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NOTES

1. http://www.wilderdom.com/research/meta-analysis.html

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