International Journal of Psychosocial Rehabilitation, Vol. 25, Issue 02, 2021
ISSN: 1475-7192

Exploring Studies on the Effect of Indirect Instruction on Student's Achievement in Chemistry using Meta-Analytical Approach

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Abstract

The trend of inconclusiveness in the studies on effect of indirect instructional methods/strategies on students' achievement in chemistry necessitated this study. The purpose of the study was to integrate the results of the previous research studies on the effect of indirect instructional methods on students' academic achievement in chemistry in Nigeria through a meta-analytic approach. Three research questions were posed and two hypotheses formulated to guide the study. The population of the study consisted of all previous research reports on indirect instructional methods and students' academic achievement in Nigeria between 1990 and 2017. The sample consisted of published and unpublished Ph.D and master's research reports on the effect of indirect instructional methods on students' academic achievement in chemistry between 1990-2017.Ttwenty nine (29) Studies constituted the sample. The data collected were analysed using percentages statistical transformations and computation of Winer combined test. The results of the findings among others were that the mean effect size for all the 29 findings examined in effect of indirect instructional method on achievement in chemistry is 0.75 which represents a high effect size. Based on the findings, recommendations were made.

Keywords*: Achievement, Chemistry, Indirect instruction, Meta-analysis*

I. Introduction

The world is a chemical world because everything in mans' environment consists of one chemical or the other. Chemistry has a lot to offer to humanity to solve problems and eradicate poverty among the citizens if its concepts, principles, theories, skills and attitudes are properly acquired and applied(Achimugu, 2016).Chemistry education in Nigeria faces major problems which may hinder its future development. These among others include low achievement in chemistry and a negative attitude towards chemistry as a subject which have resulted in a high number of students' dropouts in science track in secondary schools (Nbina, 2012). It is believed among Nigeria educators that the main reason for this problem is the way chemistry has been

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thought in schools (Mihinda,Wachanga & Anditi, 2017). A solution to this problem depends on finding effective teaching methods which maintain student's interest, improve student's achievement and provide opportunities to develop essential scientific skills. It is important to select the proper instructional strategy for a specific learning outcome in teaching chemistry. According to Rüütmann (2011), there are two broad types of learning outcomes: facts, rules and action sequences (on lower levels of complexity in the cognitive, affective and psychomotor domains), and concepts, patterns and abstractions (on higher level of complexity in the above named domains)Facts, rules and action sequences are taught using instructional strategies of direct instruction while concepts, patterns and abstractions are taught using strategies of indirect instruction .

Indirect instruction is a student-led learning process in which the lesson doesn't come directly from the teacher; instead, it is student-centered (https://study.com). The key is to have students actively engaged in the learning process, making inquiries, using critical thinking skills to resolve problems, and testing hypotheses for validation Indirect instruction is better suited for concept learning, inquiry learning, and problem-centered learning (Borich, 2011). Indirect instruction setups a student-to-student learning process with the teacher acting as more of a guide or moderator. This type of instruction helps students to learn higher-order thinking skills and gives them the chance to link content knowledge with real-world examples. An inquiry-based strategy and indirect instruction allow students to build their own concepts and establish patterns. This high level of active student involvement strengthens the connections to the learned concepts. Indirect instruction seeks a high level of student's involvement in observing, investigating drawing inferences from data or formulating hypotheses. It takes advantage of student's interest and curiosity, often encouraging them to generate alternatives or solve problems. In indirect instruction, the whole role of the teacher shifts from director to that of facilitator, supporter and resource person. The teacher arranges the learning environment, provide opportunity for student's involvement and when appropriate provides feedback to students while they conduct the inquiry. Indirect instruction is mainly student-centred and emphasizes on allowing students to get involved throughout a lesson by observing thus seeking their own meaning of the lesson. The methods of indirect instruction that can be used in class includes problem solving, case studies, concept mapping, Reflective discussion, Inquiry based learning etc (Rüütmann, 2011) and these are briefly discussed as follows:

Problem Solving: Problem solving strategy is a bridge between a problem and a solution by using information (knowledge) and reasoning. Mayer and Wittrock (2006), defines problem solving as "cognitive processing related at achieving a goal when no solution method is obvious to the problem solver. There is an old adage that states: 'Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime.' We could adjust it to say, 'Tell a student the answer and you solve a single problem; teach a student how to solve the problem and they can solve all the rest.' Helping students learn to navigate problem solving gives them problem-solving skills to use with all future problems. Problem solving deals with identifying steps to be taken in order to solve a problem.

Concept Mapping: Concept mapping is a way to organize conceptual information by using graphical tools. A typical concept map contains a particular concept usually enclosed in circles or boxes. The related ideas or concepts will be linked by a connecting line and sometimes linking words are written on the line to specify the relationship between those two concepts (Novak & Canas, 2008). There are several features of concept

mapping which includes that the concepts are represented in hierarchical fashion, the most general concepts were put at the top of the map followed by the less general concepts below and that. Cross links are included

Case Studies: Case studies consist of intense analysis of singular events or scenarios. These are best for older students but can be adjusted for middle levels of education as well. Students are assigned one event. After assigning topics, the teacher can take a backseat role and allow the students to discover and learn together. Student groups can come together to discuss each case study. This gives each student exposure to intense reviews of many examples of the topic at hand. Case studies require high levels of critical thinking about very specific topics, with the hope of being able to generalize lessons learned to larger populations.

Reflective Discussion: Reflective discussion is a method to internalize and realize perception in the form of viewpoints manifested within a discourse. Generally, it is a tool for learners to recall, reflect and talk about what is experienced using their senses. The usual steps in applying this method is that a teacher or a learner starts a conversation by asking a question that refers to an experience: a common or shared experience. Learners recreate or recall the experience and as they focus, refocus along with the angle of the experience, balancing thoughts with feelings and finally, speak. Within the process of thinking and speaking, learners might select and reselect words to describe the experience in the best suitable way according to their level of comprehension (based on background knowledge) and language (vocabulary). This process creates learners to reflect their own experience; listen, compare and categorize otherssimilar experiences to their own. As such, connections grow within their minds in terms of viewpoints or perspective on events and develop logical and moral meanings.

Inquiry Based Learning: Inquiry Based Learning (IBL) is yet another strategy under Indirect Instruction. It is a purely student-centered approach with teachers acting as facilitators. It is a strategy that promotes thinking and active learning (Murdoch, 2006). Through IBL, students will be encouraged to question things and to explore the answers to their questions. The strategy encompasses both minds-on and hands-on activities.

Chemistry as a subject is made up of topics which require complex mental processes that involve visualizing, manipulating analyzing, abstracting and associating ideas. It is a subject filled with many concepts, patterns, and abstractions. The structures and equations in organic and inorganic chemistry, the particulate nature of matter, stiochiometry of reactions, mole concept, redox reactions, electrochemistry etc are all patterns and abstractions which cannot be effectively taught using the conventional method but rather demands active involvement of the learners using indirect instruction. It therefore demands teaching methods that helps students to learn higher-order thinking skills and gives them the chance to link content knowledge with real-world examples. This study is therefore geared towards bringing together studies conducted on indirect instruction and academic achievement in chemistry using meta-analysis.

Meta-analysis is the statistical procedure for combining data from multiple studies. It is a statistical analysis of data from impendence primary studies focused on the same question, which aims to generate a quantitative estimate of the studied phenomenon (Gopalakrishnan & Ganeshkumar, 2013). When the treatment effect (or effect size) is consistent from one study to the next, meta-analysis can be used to identify this common effect. When the effect varies from one study to the next, meta-analysis may be used to identify the reason for the variation. Decisions about the utility of an intervention or the validity of a hypothesis cannot be based on the

results of a single study because results typically vary from one study to the next. Rather, a mechanism is needed to synthesize data across studies. Narrative reviews had been used for this purpose, but the narrative review is largely subjective (different experts can come to different conclusions) and becomes impossibly difficult when there are more than a few studies involved. Meta-analysis, by contrast, applies objective formulas (much as one would apply statistics to data within a single study), and can be used with any number of studies. The aims of meta-analysis are "to increase statistical power; to deal with controversy when individual studies disagree; to improve estimates of size of effect, and to answer new questions not previously posed in component studies (2015). From the foregoing, there is the need to determine the magnitude of effect sizes of the individual studies on indirect instructional strategy and academic achievement in chemistry with a view of finding the common effect size and this is what this study intends to do.

II. Method

The research design for this study is a meta-analytic research design. Meta-analysis is the technique of statistically combining the results of different studies done on different samples that have each examined and presented findings on a similar relationship (Jim, 2008). The area of study is Nigeria. The study examined reports of research works on the effect of indirect instructional methods on students' achievement in chemistry carried out in Nigeria. The population of the study consists of all the previous research reports on the effect of indirect instructional methods on students' academic achievement in chemistry in Nigeria between 1990 and 2017. These will include studies from journals, conference proceedings, theses, dissertations and technical reports covering the period from the year 1990 to 2017. The sample size consists of 29 published journal articles and unpublished Ph.D and masters research reports on the effect of indirect instructional methods on students' academic achievement in chemistry in Nigeria between 1990 to 2017. Purposive sampling technique was adopted in selecting the studies that constituted the sample. In purposive sampling, specific elements which satisfy some predetermined criteria are selected (Nworgu, 2006). Based on this, the researchers selected those studies that met with the research purpose. Statistical transformations, effect size and combined test approaches were used to analyze the data collected. In the different studies that were considered for meta-analysis in this study, different statistical methods were used in showing whether a relationship exists between different indirect instructional methods and achievement in chemistry. Most of the commonly used statistical methods include means, standard deviation, t-test, analysis of variance and use of analysis of covariance. The task of meta-analysis is the formulation of algebraic path from the reported statistics to a unique metric. Statistical transformations were used to convert the various statistics reported by the researchers into effect size r and, also to convert r to t-statistics for studies reported without t-value.

Effect size estimate is one of the basic methods of quantitative research integration. Effect sizes can each be expressed in terms of a test of significance (x^2, Z, t and F) and size of the study. The effect sizes calculated from the different formula were interpreted based on Cohen's (1977) guidelines on interpretation of effect size to find out which is large, medium or small. According to Cohen (1977), $r < 0.2$ represent small effect; $0.2 < r \leq 0.5$ represent medium effect while $0.5 < r \leq 0.8$ represent large effect.

In order to test the null hypotheses used in this study at 0.05 level of significance, Winer combined test method was used. Winer (1971) presented a procedure for combining independent tests that comes directly from the t-statistics in which the t-statistics associated with each test are summed up and divided by the square root of the sum of degrees of freedom (df) associated with each t after each degree of freedom has been divided by degree of freedom – 2. This is expressed as

$$Z_{cal} = \frac{\sum t}{\sqrt{\Sigma \frac{df}{df} - 2}}$$

III. Results

Table 1: Analyses of studies included

No. of studies based on type of publication		No. of studies based statistical method used		No. of studies based on significance of test			
				Significant		Non-significant	
				No	%	No	%
Journal Article	12	Mean and Standard deviation	2	26	89.7	3	10.3
Ph.D	15	ANOVA	1				
M.Ed	2	ANCOVA	18				
		t-test	8				
Total	29		29				

From Table 1, it is observed that out of the 29 studies investigated on the effect of indirect instructional methods on achievement in chemistry 26 (89.7%) of the studies yielded statistically significant results while (10.3%) yielded results that were not statistically significant. From Table 1, it could also be observed that out of 29 studies investigated considering the type of publication, 12 of the studies were Ph.D thesis, 2 studies were M. Ed thesis while 15 studies were published articles in journals or proceedings.

What is the magnitude of the effect size of each of the studies examined on instructional methods and students' academic achievement in chemistry?

Table 2: Effect Sizes Associated with the Studies examined on indirect Instructional Method and Academic Achievement in Chemistry.

Study	Statistic	Effect size "r"	Z value of "r"	N	n-3	Weighted z
1	ANCOVA	0.6436	0.7643	200	197	150.5671
9	t-test	0.5721	0.6506	90	87	56.6022
10	ANCOVA	0.29	0.2985	99	96	28.656
11	ANCOVA	0.4795	0.5223	99	96	50.1408
12	ANOVA	0.3373	0.351	35	35	12.285
16	t-test	0.3576	0.3741	92	89	33.2949
18	t-test	0.2138	0.2172	160	157	34.1004
20	t-test	0.3189	0.3304	40	37	12.2248
23	ANCOVA	0.2945	0.3035	160	157	47.6495
24	MEAN	0.7812	1.0484	320	317	332.3428
26	t-test	0.3546	0.3707	70	67	24.8369
27	t-test	0.5886	0.6755	66	63	42.5565
29	MEAN	0.9474	1.8055	275	272	491.096
30	ANCOVA	0.6817	0.8322	195	192	159.7824
33	ANCOVA	0.9465	1.7973	97	94	168.9462
34	ANCOVA	0.2299	0.2341	180	177	41.4357
35	ANCOVA	0.849	1.2525	189	186	232.965
36	ANCOVA	0.3994	0.4229	320	317	134.0593
37	ANCOVA	0.7488	0.9702	180	177	171.7254

39	ANCOVA	0.7816	1.0494	140	137	143.7678
40	ANCOVA	0.8073	1.1191	142	139	155.5549
41	ANCOVA	0.6849	0.8384	200	197	165.1648
42	ANCOVA	0.6429	0.7631	200	197	150.3307
46	ANCOVA	0.8353	1.2056	411	408	491.8848
48	ANCOVA	0.5702	0.6478	193	190	123.082
61	t-test	0.3592	0.3759	109	106	39.8454
65	t-test	0.0312	0.0312	360	357	11.1384
69	ANCOVA	0.6343	0.748	61	58	43.4188
76	ANCOVA	0.6057	0.7021	77	74	51.9554
					4676	**3601.3325**
Average z = <u>3601.33</u>					**4676**	**= 0.770**

Table 3: Summary of the effect sizes based on the Quality of effect size

No. of studies on quality of effect size		**Percentage**
Large	**17**	**58.62**
Medium	**11**	**37.93**
Small	**1**	**3.45**
Total	**29**	

Notes: effect size d <0.2 – small; 0.2< d ≤ 0.5 – medium; 0.5 < d ≤ 0.8 – large effect size (Cohen, 1977)

From Table 2, it is observed that among the 29 studies investigated, the results for 8 studies were reported using t-test, the results for 1 study was reported using one-way ANOVA. ANCOVA was used for 18

studies and mean and standard deviation for 2 studies. The resultant F-ratios, t-ratios, mean and standard deviation values were converted to effect size r using the appropriate formula as in appendix A. The interpretation of the effect sizes was done according to the guideline provided by Cohen (1977). From table 3, out of the 29 studies investigated 17(58.62%) were large effect sizes, 11(37.92%) were medium effect sizes and 1(3.45%) was a small effect size. This indicates that 17 studies show great degree of effect. The results of 11 indicate moderate degree of effect while the result of 1 indicates small degree of effect between indirect instructional method and students' academic achievement in chemistry

What is the mean effect size associated with indirect instructional methods?

Table 4: Mean Effect Size Associated with indirect Instructional Methods Examined

Categories of instructional method	No of Cases	∑ (N-3)	∑ Weighted z	Average Z_r = ∑ weighted z / ∑(N-3)	r value of average z (mean effect size)	% Variance
Indirect instruction	29	4676	4540.1542	0.9709	0.750	56.25

From Table 4, the mean effect size associated with indirect instruction as a category of instructional method is 0.750 which represents a large effect.This implies that the mean magnitude of effect between the various categories of indirect instructional method and students' achievement in chemistry is high, positive and significant. The Table also shows that the percentage variance of students' academic achievement in chemistry attributable toindirect instruction is 56.25% which is high.

Ho_1: The overall effect of indirect instructional methods onstudents' achievement in chemistry is not statistically significant.

Table 5: Winner Combined test for all the Studies examined on indirect

Instructional Methods and Achievement in Chemistry.

∑t	∑(df/df-2)	z-calculated	z-critical
383.00075	29.521	70.49	1.96

Table 5 reveals that the calculated z-value is 70.49 while the critical value of z at 0.05 levels of significance is 1.96. The calculated value is greater than the critical value. This implies that the null hypothesis is rejected. It therefore means that the overall effect of indirect instructional method on students' academic achievement in chemistry is significant.

IV. Summary of Findings

1. Out of the whole studies examined on the effect of indirect instructional method/strategy on achievement in chemistry, 94.74% indicate statistically significant effects while 5.27% indicate statistically not significant effect.

2. The effect sizes of the various studies examined on indirect instructional method and achievement in chemistry range from 0.0312 which is the smallest to 0.9462which is the largest.

3. The mean effect size for all the 29 findings examined on effect of indirect instructional method on achievement in chemistry is 0.755 which represents a high effect size.

4. The percentage variance in students' academic achievement in chemistry attributable to instructional methods generally is 59%.

5. The overall effect of all the studies on indirect instructional methods and students' academic achievement in chemistry is significant

V. Discussion of Findings

Twenty (29) studies on the effect of indirect instructional methods on achievement in chemistry were examined in this meta-analysis. The results of the 29 studies yielded a total of twenty-nine effect sizes. These 29 studies comprised of 12 Journal articles, 15 Ph.D thesis and 2 master's degree theses. From the results, it was found that 89.7% of the findings were positive and statistically significant while 10.3% were statistically not significant. This result indicates that greater percentage of the finding is statistically significant. The implication of this is that indirect instructional methods have positive significant effect on students' academic achievement in chemistry. This agrees with the majority of the findings such as Oboman and Ekenobi (2011) and Festus (2012) and Olufumilayo (2010) who also found that different indirect instructional methods/strategies have positive and significant effect on students' academic achievement in chemistry. The effect sizes for each of the studies on the effect of indirect instructional methods on achievement in chemistry shows that there is a variation in the effect sizes associated with the studies examined. The effect sizes ranged from 0.0312 which is the smallest to 0.9462 which is the largest. The results from table 2 also show that out of the twenty-nine studies investigated, 17(67.12%) are large effect sizes, 8 (26.32%) are medium effect sizes and 05 (6.58%) are small effect sizes. The implication of this is that the magnitude of the effect of indirect instructional methods on achievement in chemistry varies among the studies depending on the instructional strategy used. This finding of differences in the magnitude of effect of different indirect instructional strategies on achievement in chemistry is in line with the view of Ezemoka (2006) who observed that some methods of teaching are more effective than others in a given circumstance. Njelita and Okeke (2002) also opined that students' poor performance in chemistry is as a result of their inability to trace chemical concepts to everyday language, thereby viewing chemistry as an odd, dry and abstract subject. The extent to which an instructional method used in teaching chemistry is able to relate chemical concepts to everyday experiences of the learners determines the magnitude of effect of the instructional method on the students' academic achievement. This is because it determines the

extent to which the student understand chemical concepts which will invariably increase their achievement in chemistry.

The mean effect size associated with the twenty-nine studies examined is 0.75 which represents a high effect size. This result agrees with the finding of Ahmad and Umate (2019) and Kanadi (2016) and Johnson Johnson (2000). Ahmad and Umate (2019) in their meta-analytic result showed positive significant effect of Four modes Application Technique of teaching on students' achievement in science. Johnson, Johnson and Stanne (2000) in their meta-analysis also reported that co-operative learning method produces significantly higher effect on students' achievement even though their study was not restricted to science subjects alone. However, this result contradicts the meta-analytic result of Ugbaja (2012). The result of the meta-analysis carried out by Ugbaja on the effect of instructional methods on achievement in chemistry indicated a mean effect size of 2.14 which she described as a small mean effect. This interpretation is different from that used in this study.

The hypothesis stated for this study was tested using winner combined test. From the analysis, the results of the test of hypothesis 1,(table 5) show that the overall effect of indirect instructional method on students' academic achievement in chemistry is significant. This finding lends support to the view of Okeke and Leghara (2008) who noted that the method adopted by the teacher may promote or hinder learning. They maintained that it may sharpen mental activities or discourage initiative and curiosity thus leading to poor performance. The students learn and comprehend easily when the method adopted by the teacher suits their developmental level and creates room for their active participation.

VI. Conclusion

From the data presentation and analysis so far, it could be noted that the accumulated results of primary studies show that indirect instructional methods generally have a positive and statistically significant effect on students' achievement in chemistry in Nigeria. The mean effect size calculated also indicates that the strength of the effect on students' academic achievement is also high. Bearing this in mind, more efforts should be put in to help teachers to improve on their use of varieties of indirect teaching methods/strategies in the process of teaching chemistry.

Educational Implications of the Findings

The results of this study have educational implications for Nigerian government teachers, students, curriculum planners and researchers. The result of the data analysis of the study shows that the overall effect of indirect instructional methods on students' achievement in chemistry in Nigeria is highly significant. It also revealed that the magnitude to which the variation in the students' academic achievement in chemistry can be attributed to indirect instructional methods is also high. It therefore becomes imperative that both student-teachers as well as the on-the –job teachers be equipped with the current innovative teaching strategies especially those that relate to indirect learning to enable them to vary their methods to suit the different chemistry contents.

VII. Recommendations

Based on the results of the findings of this study and the implications of the study the following recommendations are made:

1. The curriculum of the institutions where teachers (i.e. graduates and NCE) are being trained should be broad so as to encompass the techniques involved in using different indirect instructional methods that promote teaching and learning of chemistry.

2. Government and relevant professional agencies should create on-the-job training opportunities to train teachers in line with the use of indirect teaching methods as they have been found to have high mean effect size.

3. . The government should also put in more effort in the provision of equipment, teaching aids and curriculum materials that will encourage the use of indirect teaching methods in teaching chemistry.

4. Government should provide financial incentives to science teachers in order to facilitate their commitment in the use of the activity-oriented teaching methods in the teaching and learning of chemistry.

5. Researchers should endeavour to provide details of their data and data-analysis in their research reports to make integration of such research findings easy.

Limitations of the Study

The following are the limitations of this study

1. The inability of some researchers to report the mean and standard deviations of their studies. This made the computation of the effect sizes difficult thereby reducing the number of studies that were integrated.

2. The duplicating of some research studies also led to the elimination of some studies. Some of the Ph.D/Masters thesis carried out in some Nigerian universities was also published in either Nigerian or international Journals. Non careful identification and elimination of suchstudies will lead to a duplication of some studies which then will affect the result of a meta-analysis.

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