Meta-Analysis of Studies on effect of Instructional Methods/Strategies on Students' Achievement Scores in Science Subjects

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ABSTRACT

This study investigated the effect sizes of Instructional Methods/Strategies on Students' achievement scores in science subjects (biology, chemistry, mathematics, physics and integrated science). The study adopted an Ex-post-facto design. Two research questions and hypothesis guided the study. The sample was made up of 41 research studies on Instructional Methods/Strategies (IMS). The researchers reviewed the STAN Journals and Conference Proceedings between 2010 to 2017 to identify the researches adopted in the study. Simple random sampling technique was used to select research studies on effects of IMS on students' achievement scores in science subjects. Converted t-statistics, frequency and mean were used to answer the research questions while one-way ANOVA was used to test the null hypothesis at 0.05 level of significance. The results revealed that the mean effect size of instructional methods/strategies (IMS) on students' achievement in biology was moderate. The mean effect sizes of IMS on students' achievement in chemistry, mathematics, physics and integrated science were small. There was no significant difference between the mean effect sizes of IMS on students' achievement across the five (5) science subjects. Based on the findings of this study it was recommended that researchers should include the effect sizes of their studies so as to aid in finding out the relative impact of a given treatment and help to identify the overall effectiveness of interventions. Also researchers should endeavour to report the mean and standard deviation gains of their studies in order to help for further analysis.

KEY WORDS: Meta-Analysis, Instructional Method/Strategies, Student's Achievement

Introduction

Educational research is concerned with educational issues. Akuezuilo and Agu (2007) noted that the major objective of educational research is that of improving the efficiency of the educational process and/or providing a guide for positive change in education practice.

They further stated that in a more specific way educational research is done to study pupils'/students' growth and development, study relationships among various education factors, evaluate current educational practices, provide information which will help education decision makers, develop instruments for use in educational tests and measurements. Also, educational research is done to study the effects of instructional methods/strategies on students' achievement.

Among the researches carried out on effects of instructional methods/strategies that have proved to be significant include vee-mapping (Bajulaiye, 1999); concept mapping (Novak, 1990); constructivist – teaching model (Osborne, 1996); and career oriented teaching approach (Obianyo, 2001). Glass (1977) stated that he had hoped to find research to support or conclusively oppose his belief that quality and integrated education is the most promising approach. Glass added that for every research study that contains a recommendation, there is another research study well documented that challenges the conclusions of the first. No one seems to agree with anyone else's approach, but more distressing; no one seems to know what works.

In the same vein, Mondale (2003) in http://www.ericdigests.org/2003-4/meta-analysis.html illustrates a common plight in educational research. Educational research often produces contradictory results. Differences among studies in treatments, settings, measurement instruments and research methods make research findings difficult to be compared. Even frequent replications of research studies can prove inconclusive. Literature on a topic may be so extensive as to observe trends with an overwhelming amount of information. Researchers in education have worried about how the findings of these researches can be synthesized and organized into coherent pattern for easy comparison for educational intervention (Glass, Mcgaw & Smith, 1981). This calls for meta-analysis of research works especially in science).

Meta-analysis is the approach to research integration which is the attitude of data analysis applied to quantitative summaries of individual experiments. It is a statistical technique for amalgamating, summarizing and reviewing previous quantitative research (Wolf, 1986). Glass (1977) defines meta-analysis as the analysis of analyses……the statistical analysis of the findings of many individual studies for the purpose of integration of finding involves the combination of individual findings to determine the average effect of a given technique. To meta-analyze, study outcomes are translated to a common metric called an effect size.

An effect size is a measure of the strength of the relationship between two variables in a statistical population or a sample-based estimate of that quantity (http://en.wikipedia.org/wiki/effectsize). It is an objective measure of the magnitude of the observed effect. It expresses increase or decrease in achievement of the experimental group (the group of students who were been exposed to a specific instructional technique) in standard deviation units. The effect size provides information about how much change is evident across all studies and for subsets of studies. Effect size is interpreted through the use of rules of thumb and comparison with field – specific benchmarks (Wikipedia, 2011). According to an arbitrary but commonly used interpretation of effect size by Cohen (1988), a standardized mean effect size of 0 means no change, negative effect size means a negative change, while 0.2 means a small change, 0.5 means a moderate change and 0.8 means a large change. In a meta-analysis, research studies are been collected, coded and interpreted using statistical methods similar to those used in primary data analysis. The coding of the study features are based on objectives of the review.

Meta-analysis has been used to give helpful insight into; the overall effectiveness of interventions; the relative impact of independent variables; and the strength of relationship between variables (Smith, Glass & Miller, 1980). Therefore, there is need to find out the relative impact of instructional methods/strategies on students' achievement scores in science subjects. Ibe (2000) defines instructional method as the distinct acceptable process of teaching or inculcating the subject matter to the learners. Instructional method is usually employed from the beginning to the end of the time allotted for the lesson to take place. Examples of instructional method according to Maduabum (1992) include: lecture or the chalk and talk method, discussion method, demonstration method, discovery and inquiry method, project method, field trips, individualized-- instructional method and laboratory method.

Instructional strategies according to Ibe (2000) are all the manoeuvres initiated by the teacher for the achievement of the stated objectives. Ifeakor, Njelita and Udogu (2008) identified lecture, concept mapping, demonstration, experimenting, use of analogues, use of advance organizers and co-operative learning in groups as examples of instructional strategy used for teaching sciences. In the context of this study, instructional methods/strategies were used interchangeably because Ibe (2000) stated that instructional strategy includes the teaching skill and the teaching technique. Also, if a skill or technique is used from the beginning of a lesson to the end it becomes a method. It implies that instructional method is subsumed in instructional strategy. Instructional methods/strategies are important, and are crucial factors in academic achievement. According to Johnson and Stanne (2000) achievement is a measure for some type of performance (standardized and teacher-made tests, grades, quality of performances such as compositions and presentations, quality of products such as reports and so forth). Okeke and Leghara (2008) noted that the method adopted by the teacher may promote or hinder learning. It may sharpen mental activities or discourage initiative and curiosity, thus leading to poor performance. The students learn better and comprehend easily when the method adopted by the teacher suits their developmental levels and creates room for their active participation (Okeke & Leghara), 2008).

Empirical researches are spawning and the findings are growing exponentially in Journals and Conference Proceedings on effects of instructional methods/strategies on students' achievement. Yet Ajagun (2001) noted that students do not achieve well as they should in science. There is need to check and balance the researches on effects of instructional methods/strategies on students' achievement so as to determine the best practices to improve instructions. It is against this background that the study is geared towards meta-analyzing the studies on effects of instructional methods/strategies on students' achievement scores in science subjects (Biology, Chemistry, Mathematics, Physics and Integrated Science).

Statement of the Problem

Research studies in science are growing at an exponential rate. It ranges from descriptive, casual, comparative, correlation to experimental designs. Hoffert (1997) estimated that there are 40,000 journals for the science and that researches filled those journals at the rate of one article every 30 seconds, 24 hours a day. This makes the results/findings to accumulate and it becomes increasingly difficult to understand and find knowledge in this flood of information.

As many researches are conducted on instructional methods/ strategies of teaching science subjects in secondary schools such as computer aided instruction (Ozofor, 2011) and peer tutoring (Ejezie, 2005) have often had significant results, suggesting the significance of the experimental treatment variables. Many of these researches had stopped at the test statistics and has led to conclusions which may not be meaningful for practical purposes. Further analysis however reveals the effect of the treatment variables so as to determine whether the effects are substantive. In order to show whether a particular method or strategy helps raise students' achievement on a test, the researchers would translate the results of a given study into a unit of measurement referred to as effect size, which is an objective measure of the magnitude of the observed effect. The effect size of the treatment variables (instructional methods/strategies) will enable the researchers to compare effects across different studies that have measured different variables or have different scales of measurements. The problem of this study therefore, is: what are the effect sizes of instructional methods/strategies on students' achievement in sciences (biology, chemistry, mathematics, Physics and Integrated Science)?

Purpose of the Study

The purpose of the study was to carry out a meta-analysis of studies on effects of instructional methods/strategies on students' achievement scores in science subjects (biology, chemistry, mathematics, physics and Integrated Science).

More specifically the study investigated the effect sizes of instructional methods/strategies on students' achievement scores from 2010-2017 in biology, chemistry, mathematics, Physics and Integrated Science.

Research Questions

To accomplish the purpose of this study, the following research questions were raised:

1. What is the mean effect size of instructional methods/strategies (IMS) on students' achievement scores in biology, chemistry, mathematics, physics and Integrated Science?

2. What is the mean effect size of IMS on students' achievement scores in the overall science subjects?

Hypothesis

One null hypothesis provided focus to the study.

The effect sizes of Instructional Methods/Strategies (IMS) on students' achievement do not differ significantly ($P<0.05$) across the five (5) science subjects (biology, chemistry, mathematics, physics and Integrated Science).

Methods

The design of this study is Ex-Post-Facto. According to Akuezuilo and Agu (2007), Ex-Post-Facto is a research design that seeks to find out the factors that are associated with certain occurrences, outcomes, conditions or types of behavior by analysis of past events or of already existing conditions. The reason for this choice is because in this kind of research design, the researchers have no control over certain factors or variables of interest. Also the researchers cannot manipulate variables because they already exist and cannot be changed or is unethical to do so (Nworgu, 2006; Akuezuilo & Agu, 2007). STAN Conference Journals and Proceedings from 2010 to 2017 were reviewed by the researchers to bring out the (IMS) researches, published therein for meta-analysis. The population of this study was all the research studies on effects of instructional methods/strategies on students' achievement scores in science subjects in STAN Conference Journals and Proceedings. It should be noted that the main thrust of any experimental study is to establish cause and effect relationship (Nworgu, 2006). This involves research studies in science subjects (biology, chemistry, mathematics, physics & Integrated Science) from 2010-2017.

The sample was made up of 41 research studies on instructional methods/strategies drawn from STAN Journals and Conference Proceedings.

Table 1: Sample Description

S/N	Science Subject	Population	Sample of No of Instructional Methods/Strategies (IMS)
1	Biology	12	10
2	Chemistry	7	7
3	Mathematics	15	10
4	Physics	8	6
5	Integrated Science	9	8
	Total	**49**	**41**

Simple random sampling technique was used in drawing the sample. According to Akuezuilo and Agu (2007), simple random sampling is a method of selecting a sample from a population so that all members of the population have equal chances of being selected.

The following steps were followed in the sampling:

i. All the research studies on effects of instructional methods/strategies on students' achievement scores in science from 2010-2017 were identified.

ii. The research studies identified were grouped based on science subject areas (biology, chemistry, mathematics, physics and Integrated Science).

    When studies with the same instructional methods/strategies (IMS) appear twice in a particular subject area (eg biology), flip of a coin was used to select one. When studies with the same IMS appeared more than twice, picking of slip without replacement was used to select one.

iii. For any study with more than one instructional method/strategy, all the instructional methods/strategies were used.

Data collected for this study were analyzed through the use of converted t-statistic, frequency and mean to answer the research questions. The reason for the use of converted t-statistic is because some of the research studies used in this study did not report the mean (mean gain) and/or standard deviations of their studies. Thus, Cooper (1989), thought it appropriate to use converted t-statistic for such study for the fact that it serves when studies did not report the means and standard deviations but have t-statistic. Also the effect size indexes calculated were rated. The frequencies of rated effect sizes were found for uniformity and easy computation of mean. The hypothesis was tested with One-way Analysis of Variance (ANOVA) at 0.05 alpha levels.

Result

Research Question One: What is the mean effect size of instructional methods/strategies (IMS) on students' achievement scores in biology, chemistry, mathematics, physics and Integrated Science?

Table 2: Mean effect sizes of instructional methods/strategies on students' achievement in science subjects

Science Subject Area	Number (n)	Mean ($\bar{x}$)	Standard Deviation (SD)
Biology	10	3.20	1.23
Chemistry	7	2.14	1.46
Mathematics	10	2.67	1.33
Physics	6	2.00	1.10
Integrated Science	8	2.04	1.18
Total	**41**	**2.75**	**1.42**

Table 2 shows that the mean effect size of instructional methods/strategies on students' achievement in biology was 3.20. Thus, the instructional methods/strategies had moderate mean effect on students' achievement in biology. The mean effect size of instructional methods/strategies on students' achievement in chemistry was 2.14. It indicates that the mean effect size of instructional methods/strategies on students' achievement in chemistry was small. The table also reveals the mean effect size of instructional methods/strategies on students' achievement in mathematics to be 2.67. Hence, the mean effect size of instructional methods/strategies on students' achievement in mathematics was small. It further revealed the mean effect size of instructional methods/strategies on students' achievement in physics to be 2.00. Thus, the instructional methods/strategies had small mean effect on students' achievement in physics. Likewise, the mean effect size of instructional methods/strategies on students' achievement in integrated science was 2.04. Thus, the instructional methods/strategies had small mean effect on students' achievement in integrated science.

Research Question two: What is the mean effect of instructional methods/strategies (IMS) on students' achievement scores in overall science subjects?

From table 2 above, the mean effect size overall of (IMS) on students' achievement scores in science subjects was 2.75. It indicates that the IMS had small mean effect size.

Hypothesis One: The effect sizes of instructional Methods/Strategies on students' achievement do not differ significantly across the five (5) science subjects (Biology, Chemistry, Mathematics, Physics and Integrated science).

Table 3: Summary of One-way Analysis of Variance (ANOVA) of instructional methods/strategies on students' achievement scores by effect size

		Sum of Square	Df	Mean Square	F	Sig.
Effect size	Between groups	7.299	3	2.433	1.441	.246
	Within groups	62.457	37	1.688		
	Total	**69.7**	**40**			

The data presented in Table 3 shows that the value of F is 1.44. This value is greater than 0.05 showing that the mean effect of instructional methods/strategies (IMS) on students' achievement scores across the five (5) science subjects between the groups does not differ significantly. Therefore, the null hypothesis of no significant difference is upheld.

Discussion of Findings

The study shows that the mean effect size of instructional methods/strategies on students' achievement in biology was moderate (3.20). It implied that the IMS employed moderately changed the students' achievement in biology. The finding appears to be consistent with Jeyne (2003), though the study was not on IMS. It revealed that the achievement scores of children with highly involved parents in schooling activities was higher than those with less involved parents with average effect of about 0.5-0.6 which is equivalent to 3.00. The finding is also in agreement with that of Redfield and Rousseau (1981), who reported that the average effect size of use of higher-level questions was moderate (0.73) which is equivalent to 3.00 according to rating scale.

The mean effect sizes of instructional methods/strategies on students' achievement in chemistry, mathematics, physics and integrated science were small with 2.14, 2.67, 2.00 and 2.87 respectively. It showed that the IMS employed in chemistry, mathematics, physics and integrated science had small change in students' achievement scores. The result is in line with the findings of Cohen, Kulik and Kulik (1982) who found the average effect size for academic outcomes of tutoring on students' achievement to be 0.03 which is equivalent to 2.00 according to the rating scale.

The mean effect size overall of instructional methods/strategies (IMS) on students achievement was small (2.75). The implication is that the IMS employed had small change on students' achievement scores in the overall science subjects. The finding is also in agreement with that of Wise and Okey (1983) who found the main overall effect size of various science teaching strategies on achievement to be 0.34. It implies that the various teaching strategies employed in teaching sciences did not improve the academic achievement of the students so much. The main overall effect size was small (0.34) which is equivalent to 2.00 according to the rating scale.

The study shows that there was no significant difference on the mean effect sizes of instructional methods/strategies (IMS) on students' achievement across the five (5) science subjects. Thus, the value of F is 1.44 which is greater than 0.05. Therefore, the null hypothesis of no significant difference was upheld. This is contrary to the findings of Johnson and Stanne (2000), though the study was on cooperative learning methods; it reported that cooperative learning methods produce significantly higher achievement.

Educational Implication of the Study

The study shows that the mean effect size of instructional methods/strategies (IMS) on students' achievement in biology was moderate. By implication therefore, the IMS could be employed by the teachers to improve students' achievement in science related disciplines in our schools.

Though the study revealed that there was no significant difference on the mean effect sizes of IMS on students' achievement across the five (5) science subjects, the effect size of IMS on students' achievement in biology was moderate. It implies that the science teachers could therefore effectively employ the IMS in teaching and learning of other science subjects.

Conclusion

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

The study shows that the mean effect size of instructional methods/strategies (IMS) on students' achievement in biology was moderate, the mean effect sizes of IMS on students' achievement in chemistry, mathematics, physics and integrated science were small, the overall mean effect size was small and there was no significant difference between the mean effect sizes across the five (5) science subjects.

Recommendations

Based on the findings of this study, the following recommendations were made:

- Researchers conducting experimental studies should include the effect sizes of their studies in their analyses to aid in finding out the impact of a given treatment or the overall effectiveness of intervention.

- Researchers should endeavour to report the mean gains and standard deviations of their studies in order to help for further analysis.

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