META-ANALYSIS OF THE EFFECT SIZES OF COMPUTER ASSISTED INSTRUCTION STUDIES IN SCIENCE EDUCATION

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Abstract

Computers have been in use in facilitating teaching and learning in Nigerian institutions of learning over the years. The study investigated the magnitude of the effects of Computer Assisted Instruction on secondary students' performance in sciences through meta-analysis of the effect sizes of the studies done in Science Education Department, Federal University of Technology Minna. Descriptive survey design precisely using Meta-analysis was adopted in the study. The population of the study consisted of 545 projects conducted in science education department F.U.T. Minna for the years 2006-2015. 78 research reports were selected using purposeful sampling technique considering only CAI studies. The results revealed that the average effect size of Biology across the years was 0.46 (46%), Chemistry was 0.05 (5%), Geography was 0.48(48%), Mathematics was 0.40 (40%) and Physics was 0.57 (57%) across the years. The average effect size of the five basic science subjects was 0.52(52%) which is a large effect size. The study found out that there was no significant difference among the effect sizes based on nature of subjects and there was no significant difference among the effect sizes based on the years of the studies. It was recommended among others that use of CAI should be encouraged in schools as it enhances teaching and learning especially in science subjects. Effect sizes should always be reported in experimental studies to display the quantum of effects of treatments for decision making.

Keywords: Meta-analysis, Computer assisted instruction, Effect size, Achievement

Introduction

Science and Technology are the bedrocks of any structural and physical development in the contemporary world. Apart from the improvements in the standard of living, science and technology have facilitated the development of the developing countries by leading to the improvement of their needs and desire to compete with the developed world in all spheres of life, education inclusive (Brown, 2010).The role of science and technology in making the earth more comfortable for living cannot be overemphasized. One of the objectives of education as prescribed in the National Policy on Education FRN (2004) is to build a self-reliant nation through the greatest use of technological breakthrough. It is obvious that technology over the years has changed the pattern of human life, particularly with the advent and use of computers in education. Computer is a general purpose machine commonly consisting of digital circuitry that accepts (inputs), stores, manipulates and generates (outputs) data as numbers, text graphics, voice, video files or electrical signals, in accordance with instructions called a programme (Pritchard, 2005). When computers are used in presenting learning contents to learners in a class, it is termed to be Computer Assisted Instruction (CAI).

Computer Assisted Instruction is an interactive process and usually involves learning individually as it involves an interaction between learner and computer programmes at ones pace and scheduled time (Curtis, 2013).For decades, CAI have been in use for learning instruction in various institutions of learning with positive feedback. Such studies were collated and reported in the literature using a method of analysis called meta-analysis.

Meta-analysis uses the effect size to summarize results so that each findings is expressed as a standard unit (Coolidge, 2006). Meta-analysis has the capacity to synthesize results from individual studies, provide a means of identifying moderate variables and means to generate a definitive answer to complex issues at it brings together disparate research findings from primary studies and reconcile them (Gay, Mills, & Airasian, 2009). An effect size gives a direct measure of the impact of an intervention in terms of how much difference is found between groups or parts in time relative to the standard deviation of the difference. Effect size is simply defined as numerical way of expressing the strength or magnitude of a reported relation (Gay, Mills & Airasian, 2009). Effect sizes are usually expressed in decimal number. In few occasions, effect sizes appear to be greater than one, but they usually run from 0.00 to 1.00. Positive effect sizes denote that experimental groups did better, while negative effect sizes indicate that control groups dii better.Where the result is 0.00, it simply implies that none of the groups is better, that is to say both the experimental and control groups are equal. The result of a study expressed as an effect size can be more meaningful and more interpretable than whether or not the result is statiscally significant.

Several researches investigated the effectiveness of CAI in teaching and learning at all levels of education over the years. Researchers collated such studies for better inferences. For example, Li and Ma (2010) analyzed 85 independent effect sizes from 46 studies. A positive correlation was found between using computer technology as a learning tool to teach mathematics as opposed to a presentation tool. Tekbiyik and Akdeniz (2010) reported a meta-analysis to determine the overall effectiveness of Computer Assisted Instruction on students' academic achievement in science education from 2001 to 2007 in Turkey. This effect size was interpreted as an average student's achievement moved from the 50th percentile to the 87th percentile in science learning when Computer Assisted Instruction was used. In another report, Larwin (2011) reported meta-analysis of the effectiveness of CAI on students' achievement in postsecondary statistics education in 40 years. The results suggest that the typical average student moved from the 50th percentile to the 73rd percentile when technology was used as part of the curriculum. In a more complex study, Yesilyurt (2010) conducted a meta-analysis of CAI in science and mathematics in Turkey with the total Effect Size E++ = 3.8262 and critical significance level $p < 0.0001$. The results revealed that Computer Assisted Instruction was quite more effective than traditional teaching.

Generally, the use of meta-analysis of effect size has tremendously influence the inferences been made on the effectiveness of CAI on academic achievement and other important traits as reported in several literature.

Since the advent of computers in the early 19th century, they have been in use for several purposes including learning where most often than not, is tagged as Computer Assisted Instruction (CAI). For quite long time, researches were embarked upon as to validate several CAI packages in teaching and learning in schools with several favourable results. There were numerous studies ranging from the use of powerpoints to the use of dev eloped computer packages in different subjects using projectors in the classroom instruction. Many results revealed positive impact of computers on academic achievement with significant effects across subjects (Bello, Wasagu & Kamay,2016; Gambari, 2010; Yaki, 2011; Yusuf & Afolabi, 2010; & Dafo, Usman & Sadiq, 2015). The question is, how rich or to what extent

were those effects? It is obvious that most of the locally based researches do not report effect sizes of the experiments particularly at undergraduate levels. To the best of the researchers' knowledge, no study was carried out to determine the effect sizes of CAI studies in the department. This underscores the need to explore this type of investigation to help reveal the strength of the CAI studies done in the department to serve as an eye opener for other researchers within and outside the locale.

Aims and Objectives of the Study

The Aim of the study was to analyze the effect sizes of Computer Assisted Instruction(CAI) studies in the department of Science Education, Federal University Of Technology Minna between 2006-215. Specifically, the study sought to determine the:

(i) effect size of CAI in Biology across the years
(ii) effect size of CAI in Chemistry across the years.
(iii) effect sizes of CAI in Physics across the years.
(iv) effect size of CAI in Geography across the years.
(v) effect size of CAI in Mathematics across the years.
(vi) effect sizes of CAI in science subjects across the years.
(vii) difference among the effect sizes of CAIs across the science subjects.
(viii) difference among the effect sizes of CAIs across the years.

Research Questions

The following research questions were formulated to guide the studies:-

(i) What is the effect size of Biology CAI studies from 2006-2015?
(ii) What is the effect size of Chemistry CAI studies from 2006-2015?
(iii) What is the effect size of Physics CAI studies from 2006-2015?
(iv) What is the effect size of Geography CAI studies from 2006-2015?
(v) What is the effect size of Mathematics CAI studies from 2006-2015?
(vi) What is the average effect size of the CAI studies in science subjects from 2006-2015 in Science Education Department in Futminna?
(vii) Is there any difference among mean effect sizes of the studies across the science subjects?
(viii) Is there any difference among mean effect sizes of the studies across the years?

Research Hypotheses

The following null hypotheses were formulated:

HO_1: There is no significant difference among the effect sizes of CAI studies across the science subjects from 2006-2015

HO_2: There is no significant difference among the effect sizes of the CAI studies across the years from 2006-2015

Methodology

The study adopted ex-post- factor design. The population of the study comprises 545 CAI studies conducted In the Science Education Department, Federal University of Technology Minna from 2006 to 2015. Purposive sampling technique was used to select 78 previously basic science CAI studies in the department, which include 19 Biology, 2 chemistry, 9 Geography, 26 Mathematics and 26 Physics. Purposive sampling technique is used where randomization is not viable, and when certain characteristic is targeted in the population (Gay, Mills & Airasian,2009). Access to the data for the study was obtained from the Head of the Department and CAI research reports were sorted out from all the projects, theses and dissertations in the departmental library within 2006-2015 and were coded logically. Results of the posttest of each of these research reports were collated and used in calculating their effect sizes manually across the subjects using mean and standard deviation, effect size

formulas as follows :- (t – value : g = $t \times \sqrt{\frac{1}{N_E}+\frac{1}{N_C}}$, for t-test results , for ANOVA : $W^2 = \frac{SSB-(K-1)MSW}{SST+MSW}$, for mean and standard deviation: $g = \frac{\bar{X}_E-\bar{X}_C}{s_p}$, and $S_p = \frac{(N_e-1)\,S_E^2+(N_C-1)\,S_C^2}{(N_e+N_c-2)}$; to establish the effect sizes. Analysis of Variance was used in testing the null hypotheses with the aid of Statistical package for Social Sciences (SPSS) version 22.

Results

Research Question One

What is the average effect size of Biology CAI studies from 2006-2015?

Table 1: Average Effect size of Biology CAI Studies from 2006-2015

S/N	CODE	Year	Effect size
1	011	2010	0.03
2	007	2014	0.81
3	061	2014	0.17
4	014	2014	0.70
5	015	2014	0.04
6	018	2014	4.10
7	020	2014	0.20
8	035	2014	0.03
9	036	2014	0.05
10	037	2014	0.05
11	038	2014	0.32
12	044	2014	0.06
13	050	2015	0.04
14	051	2015	0.75
15	052	2015	0.04
16	054	2015	0.04
17	055	2015	0.02
18	058	2015	0.04
19	003	2015	1.30
Total			**8.79**
Average			**0.46**

Table 1 shows the effect sizes of Biology CAI studies across the years. The effect sizes range from 0.02 to 4.10 and an average effect size of 0.46 (46%) which can be interpreted as a large effect size. This indicates that the use of CAI in teaching Biology has been effective

Research Question Two

What is the average effect size of Chemistry CAI studies from 2006-2015?

Table 2: Average effect size of chemistry CAI studies from 2006-2015

S/N	**Code**	**Year**	**Effect Size**
1	041	2014	0.03
2	065	2014	0.07
Total			**0.10**
Average			**0.05**

Table 2 reports the effect sizes of chemistry CAI studies across the years. The effect sizes reported ranges from 0.03-0.07 and an average of 0.05 (5%).By interpretation, this is but a small effect size.This indicates that the use of CAI in teaching chemistry has not been effective

Research Question Three
What is the average effect size of Geography CAI studies from 2006-2015?

Table 3: Average effect size of geography CAI studies from 2006-2015

S/N	Code	Year	Effect Size
1	016	2014	0.04
2	023	2014	0.04
3	027	2014	0.08
4	034	2014	0.06
5	039	2014	3.50
6	053	2015	0.03
7	056	2015	0.04
8	071	2011	0.50
9	084	2008	0.05
Total			**4.34**
Average			**0.48**

Table 3 reports the effect size of Geography CAI studies across the years. The effect size reported ranges from 0.03-3.50 and an average of 0.48 (48%).This signifies a large effect size. It clearly indicates that the use of CAI in teaching Geography has been effective

Research Question Four
What is the average effect size of Mathematics CAI studies from 2006-2015?

Table 4: Average effect size of mathematics CAI studies from 2006-2015

S/N	Code	Year	Effect Size
1	001	2006	0.07
2	008	2014	3.02
3	009	2006	0.05
4	010	2009	0.04
5	013	2014	0.69
6	019	2014	1.17
7	021	2015	1.30
8	033	2014	0.06
9	042	2014	0.02
10	043	2014	0.40
11	045	2014	0.05
12	046	2014	0.02
13	047	2014	0.03
14	048	2014	0.03
15	059	2015	0.06
16	063	2008	1.84
17	064	2009	0.64
18	066	2010	0.04
19	067	2010	0.03
20	068	2011	0.05

21	069	2011	0.62
22	070	2011	0.03
23	073	2011	0.06
24	075	2012	0.04
25	080	2012	0.03
26	081	2012	0.07
Total			**10.46**
Average			**0.40**

Table 4 shows the effect size of Mathematics across the years and the effect sizes reported range from 0.02-3.02 and an average of 0.40 (40%). This is interpreted as large effect size. By implication, it is clear that the use of CAI teaching Mathematics has been effective.

Research Question Five

What is the average effect size of Physics CAI studies ?

Table 5: Average effect size of physics CAI studies from 2006-2015

S/N	Physics Code	Year	Effect Size
1	004	2010	4.38
2	072	2011	0.09
3	074	2011	0.82
4	076	2012	0.77
5	077	2012	0.04
6	079	2012	0.07
7	082	2012	0.04
8	083	2012	0.04
9	005	2013	1.13
10	024	2014	0.05
11	025	2014	0.04
12	026	2014	0.06
13	028	2014	0.06
14	029	2014	0.14
15	030	2014	0.04
16	031	2014	1.54
17	032	2014	2.23
18	060	2014	0.06
19	062	2014	0.49
20	040	2014	0.04
21	049	2014	0.40
22	057	2015	0.05
Total=			**12.58**
Average			**0.57**

Table 5 shows the effect sizes of physics CAI studies across the years. The effect sizes reported ranges from 0.04-4.38 and an average of 0.57 (57%) which is also interpreted as a large effect size. This is an evident that CAI has been effective in teaching Physics as a science subject.

Research Question Six
What is the effect size of CAI on the Five Basic Science Subjects?

Table 6: Average effect size of the five CAI science subjects

S/N	Subject	Number Of Studies	Total Effect Size
1	Biology	19	8.90
2	Chemistry	2	0.05
3	Geography	9	4.38
4	Mathematics	26	10.43
5	Physics	22	16.85
Total		**78**	**40.61**
Average			**0.52**

Table 6 reports the grand average effect size over the years of the five basic science subjects. The average effect size obtained was 0.52 (52%) which can be regarded as a large effect size. This simply indicates that the use of CAI has been favourable in teaching the five basic sciences.

HO_1: There is no significant difference among the effect sizes of CAI studies from 2006-2015 across the science subjects.

Table 7: ANOVA of the difference in the mean effect sizes of cai across the subjects

	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	3.56	8	.445	.471	.873*
Within Groups	71.008	75	.947		
Total	74.571	83			

*= Not significant at 0.05

Table 7 shows ANOVA results of the difference in the mean effect sizes based on the subject f (8,75) = 0.471, P> 0.05. Therefore, the null hypothesis is accepted. It implies that there is no significant difference among the effect sizes across the subjects.

HO_2: There is no significant difference among the effect sizes of the CAI studies across the years from 2006-2015

Table 8: ANOVA of the difference in the mean effect sizes across the years

	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	3.446	8	.431	.454	.884*
Within Groups	71.126	75	.948		
Total	74.571	83			

*=Not significant at 0.05

Table 8 provides ANOVA results of the difference in the mean effect sizes base on the subject f(8,75) = 0.431, P> 0.05,. Therefore, the null hypothesis is accepted. This indicates that there is no significant difference among the effect sizes of the studies across the years.

Discussion

The aim of this study was to determine the effect sizes of CAI studies from 2006-2015 in the department of Science Education, Federal University of Technology, Minna, Nigeria. Results for the research question one shows that the effect sizes of Biology CAI studies 0.46 (46%) which can be interpreted as a large effect size. This indicates that the use of CAI in teaching Biology has been effective. This is in line with the findings of Tekbiyik and Akdeniz (2010) who obtained a large average effect size of 1.12 from 82 CAI studies in science education (Biology inclusive). The subjects moved from 50^{th} to 85^{th} percentile after using CAI.

The results for the research question two indicated average effect size of chemistry CAI studies across the years to be 0.05 (5%). By interpretation, this is but a small effect size. Although the number of the chemistry CAI studies was too small for the analysis (i.e. only two studies),so this could have contributed in getting the small effect size obtained. The result is parallel to that obtained by Tekbiyik and Akdeniz (2010), Yesilyurt (2010) and Liao (2007) who obtained large effect sizes in the meta-analysis of the CAI studies in sciences and Mathematics.

The results of the research question three indicated a large average effect size for Geography CAI studies across the years, 0.48 (48%).This also supports the previous meta-analysis such as Tekbiyik and Akdeniz (2010), Yesilyurt (2010), and Liao (2007) who got a large effect sizes in their analyses of CAI studies. This also clearly indicates that the use of CAI in teaching Geography has been positive.

Research question four yielded an average effect size of 0.40 (40%) in Mathematics CAI studies across the years. As usual, the coraborates that of Tekbiyik and Akdeniz (2010), Yesilyurt (2010), and Liao (2007) who obtained large effect sizes.

The results for the research question five shows an average effect size of 0.57 (57%) for physics CAI studies across the years. This is an evident that CAI has been effective in teaching Physics as a science subject. This in line with the finding of Yesilyurt (2010) who got average effect size of 3.83 in physics CAI studies.It also corroborates those of Haas (2005), Tekbiyik and Akdeniz (2010), Yesilyurt (2010), and Liao (2007) who got a large effect sizes in their analyses of CAI studies in sciences.

Table 6 reports the grand average effect size over the years of the five basic science subjects. The average effect size obtained was 0.52 (52%) which can be regarded as a large effect size. This simply indicates that the use of CAI has been favourable in teaching the five basic sciences. The findings are supported by all the cited studies like Tekbiyik and Akdeniz (2010), Yesilyurt (2010) and Liao (2007).

The null hypothesis one was accepted as there was no significant difference among the effect sizes across the five basic science subjects. This was also in support of the results of who found no significant difference in Biology CAI studies. Thus, nature of a subject is not determinant of a large effect size according to the results of this study.

Also the null hypothesis two was accepted as the results indicated that there was no significant difference among the effect sizes of the studies across the years. So years have nothing to do with the effect sizes of the CAI studies, even though there was little variations in the effect sizes of each year of studies. The results indicated in significant difference across the year

Conclusion

It is obvious from the findings of this study, that the use of CAI is an effective medium of teaching and learning of science subjects, and meta-analytically, the differences in students' performance amongst the experimental and control groups proved to be substantial as most of the results revealed higher performance when CAI was used as revealed by the large effect sizes obtained.

Recommendations

The following recommendations were made based on the findings:-

(i) The use of CAI should be encouraged in schools as it enhances teaching and learning especially in science subjects as established by the effect sizes of this study.

(ii) Meta-analysis should be encouraged on CAI studies and other relevant studies in other tertiary institutions as to have comprehensive information on certain variables and their relationship

(iii) CAI packages should be improved for publications so that secondary schools and also tertiary institutions can access them for teaching and learning activities.

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APPENDIX

EFFECT SIZE FORMULAS

(1) For mean and standard deviation

$$g = \frac{\bar{X}_E \quad \bar{X}_C}{S_p}$$

g =effect size

$\bar{X}_E$ = Mean of the experimental group

$\bar{X}_C$ = Mean of the control group

S_P = pooled standard deviation

The pooled standard deviations is calculated using the following formula:

$$S_p = \frac{(N_e - 1)\, S_E^2 + (N_C - 1)\; S_C^2}{(N_s + N_2 - 2)}$$

S_p = pooled standard deviation

N_e = no of subjects in experimental group

N_C = no of subjects in control groups

S_E = standard deviation of the experimental group

S_C – standard deviation of the control group (Hdges & Olkin, 1985)

N.B. (for mean & standard deviation)

Cohen d = $\frac{Mean\ differences}{Standard\ deviation}$

Interpretation

$0 \longrightarrow 0.20$ = weak effect size
$0.21 \longrightarrow 0.50$ = modest effect size
$0.51 \longrightarrow 1.00$ = moderate effect size
> 1.00 = strong effect size (Cohen, 1988)

(2) For t-test statistics

(a) $\propto = \frac{\sqrt{t^2}}{t^2+df}$

r^2 = percentage of variance explained (effect size)
t^2 = t-value squared
df = degree of freedom (Gravelter & Wallnau, 2005)

(b) t – value : g = $t \times \sqrt{\frac{1}{N_E}+\frac{1}{N_C}}$

g = effect size
N_E = number of subjects in the experimental group
N_C = number of subjects in the control group (Tekbiyik & Akdeniz, 2010)

Interpretation

0.100 = small
0.243 = medium
0.371 = large (Coolidge, 2006)
$0.01 < r^2 < 0.09$ = small effect
$0.09 < r^2 < 0.25$ = medium
$r^2 > 0.25$ = large
(Cohen, 1988, Gravelter & Wallnau, 2005)

(3) For ANOVA

(a) $W^2 = \frac{SSB-(K-1)MSW}{SST+MSW}$

W^2 = omega squared (effect size)
SSB = sum of squares between
SST = sum of square total
MSW = mean squared within

(b) $\eta^2 = \frac{SS\ between\ treatments}{SStotal}$

η^2 = eta squared (effect size)
SSbt = sum of squares between treatments
SS_{tt} = total sum of squares

Interpretation

$W^2 > .15$ = large effect
$W^2 > .06$ = medium effect
$W^2 > .01$ = small effect (Coolidge, 2006)