A Meta-Analysis on the Effects of Computer-Assisted Instruction on Students' Learning Achievement in Taiwan

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Abstract—**The application of computer-assisted instruction (CAI) in Taiwan had gone for a long time. This study was performed to synthesize existing research comparing the effects of CAI versus (traditional instruction) TI on students' achievement in Taiwan. In spite of claims regarding the potential benefits of using CAI in education, research results comparing the effects of CAI and traditional instruction in Taiwan are conflicting. Some studies all reported significant gains for CAI over traditional instruction. However, some studies had found no significant differences between CAI and traditional instruction. Meta-analysis was a statistical process whereby the findings of several studies, focusing on a common problem or topic, are pooled in an effort to draw inferences as to the meaning of a collective body of research. In an effort to lend data to this debate, this study provides the first meta-analysis of CAI verse traditional instruction in Taiwanese schools. The results from this study suggest that the effects of CAI in instruction are positive over traditional teaching in Taiwan. Students' learning achievement in language subject area was significant different from mathematics subject area, but learning achievement in sociology, science, and computer subject area were insignificant different from mathematics subject area. Students' learning achievement with multimedia type CAI was significant different from with web-based type CAI, and students' learning achievement with web-based type CAI was better than with multimedia type CAI.**

Keywords- computer-assisted instruction, learning achievement, meta-analysis

I. INTRODUCTION

The application of computer-assisted instruction (CAI) in Taiwan had gone for a long time. Early CAI experiments were accepted on mainframe computers in several universities but had not been considered successful. Then, Taiwanese government was embarking on efforts to develop authoring systems to facilitate CAI in language, to train teachers in the design and use of CAI, to develop CAI and to evaluate it. In 1984, the National CAI Project was established, with emphasis being placed on a computer designed specifically for CAI in language. Furthermore, a 6-year project for CAI in the schools was instituted. The specific objectives of this plan were to increase teachers and students knowledge of CAI, to train teachers in the development of CAI courseware, to develop and distribute a CAI authoring tool, and to institute and maintain a national database of courseware accessible to all teachers. After 1991, based on the development of Microsoft Windows operating system, the multimedia CAI courseware became viable and popular in many schools. Teachers and students started to use multimedia CAI software in their classrooms as supplements of traditional instruction. The National Science Council (NSC) also granted hundreds of research based projects to develop the multimedia CAI courseware and evaluate their effectiveness in instruction. In addition, The National Information Infrastructure (NII) project started in 1996 which facilitated three nationwide network systems and made web-based CAI possible [1].

Since 2001, for the NII was more mature and Internet also became more popular, web-based learning occurred not only in schools but also in businesses and homes. Some universities even provided virtual classrooms or e-learning to facilitate web-based distance learning. In general, the development of CAI in Taiwan has undertaken from the development of traditional courseware for mainframe computers from multimedia CAI to the web-based CAI.

In spite of claims regarding the potential benefits of using CAI in education, research results comparing the effects of CAI and traditional instruction in Taiwan are conflicting. Fong [2], Chiu [3], Shao [4], Chang [5], Tsai [6], Yu [7], Wu [8], Chiu [9], Yu [10], Lin [11], Fan [12], Chen [13], Chang [14], Lai [15], Hsu [16], Li [17], Chuang [18], Yao [19], Ko [20], Tsai [21], Lu [22], Wu [23], Hung [24], Liu [25], Tasi [26], Chang [27], Wu [28], Hu [29], Yeh [30], Hsieh [31], and Yu [32] all reported significant gains for CAI over traditional instruction. However, Liu [33], Chen [34], and Lai [35] had found no significant differences between CAI and traditional instruction.

Meta-analysis was a statistical process whereby the findings of several studies, focusing on a common problem or topic, are pooled in an effort to draw inferences as to the meaning of a collective body of research [36]. Early meta-

analysis studies of CAI were published prior to the microcomputer revolution, since 1970. In an effort to lend data to this debate, this study provides the first meta-analysis of CAI verse traditional instruction in Taiwanese schools.

A. *Computer-assisted instruction and Traditional instruction*

The purpose of this study was to synthesize and analyze the research on effects of two instructional approaches. It was important to define these approaches to ensure proper selection of appropriate studies.

Computer-assisted instruction (CAI) is classes using computer-assisted instruction or computer-assisted learning software as replacement of or supplement to traditional instruction to teach students. Traditional instruction (TI) is classes using traditional instruction to teach students. A traditional course requires face-to-face instruction that comes from lectures and activities via teacher's dictating and expressions in a real classroom. Course materials are delivered in a form of book and other written resources.

II. MATERIALS AND METHOD

The research methodology implicated in this study was the meta-analytic approach which was similar to that suggested by Higgins, Thompson, Deeks, and Altman [37]. Their approach requires a reviewer to locate studies through objective and replicable searches, code the studies for salient features, describe outcomes on a common scale, and use statistical methods to relate study features to outcomes. This approach requires the reviewer to use objective procedures for locating studies, use quantitative techniques to describe study features and outcomes, and use statistical methods to summarize overall findings and explore relationships between study features and outcomes. The research framework of this study was as Figure I.

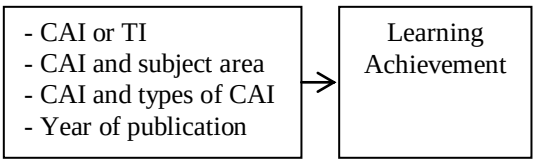

Figure I. Research framework of this study

A. *Research Data*

These studies considered for use in this meta-analysis came from Taiwan Theses and Dissertations Knowledge Value-Added System. 34 theses were located through this search procedure.

Several criteria were established for inclusion of studies in the present analysis as:

1. The study had to compare the effects of CAI and TI on students' learning achievement.
2. The study had to provide quantitative results from both CAI and TI classes.
3. The study had to use Taiwan students as subjects.
4. The study could be obtained with full-text.

Taiwan Theses and Dissertations Knowledge Value-Added System was the project entrusted to Taiwanese National Central Library (NCL) by the Department of Higher Education of The Ministry of Education in Taiwan. As recalling to the past efforts of theses and dissertations related information gathering, NCL started editing and printing of Catalog of Theses and Dissertations in Taiwan in 1970. Taiwanese NCL has implemented the specific plan of theses and dissertations abstracts nationwide since 1994 by establishing abstracts files of theses and dissertations and launched web version of on-line search system which got very good feedback about positive value by various fields in 1987. In 1998, it also established theses and dissertations abstracts online system with the financial support by The Ministry of Education in Taiwan. Taiwanese NCL held the opening ceremony of National Theses and Dissertations Abstract File Building Plan which set up another new milestone on formal internet service of theses and dissertations. After 2000, Taiwanese NCL added functions of uploading of full text electronic theses and dissertations and online printing of authorization papers in addition to above mentioned National Theses and Dissertations Abstract File Building Plan. Thus Taiwanese NCL integrated the existing collaborative production and sharing of on-line database of National Theses and Dissertations information network [39].

B. *Data Analysis*

Meta-analysis was originally created by Glass, McGaw, and Smith [38]. In relating it to existing analyses, it could be classified research analysis into primary analysis, secondary analysis, and meta-analysis. Primary analysis is the original analysis of raw data. Secondary analysis uses alternative analytical techniques to analyze the same data to answer the same research questions, or uses the same techniques to answer different questions from the same data. A meta-analysis encompasses results of studies that are already conducted. It did not use the term to refer to the analysis of a planned series of investigations. Purpose of a meta-analysis was not simply to summarize a whole body of literature with a single effect size or overall significance level. It also tried to determine how study features influence effect sizes.

The effectiveness of CAI in technical education and training was determined by the overall effect of the treatment. Meta-analytic procedures were applied to calculate the size of this effect. As the meta-analysis progressed, and results unfolded, studies were grouped according to their common study features, and the various categories within the features were identified. Since a meta-analysis synthesizes the statistical results from many different studies, it is not necessary to define the independent variable in very specific terms. For this meta-analysis, it was sufficient to state the independent variable as the teaching method in technical education and training, which could be either computer-assisted instruction or traditional instruction. For the same reason, it was adequate to begin the meta-analysis by defining the dependent variable as student learning or achievement in learning resulting from technical

education and training, as measured by some test or tests. The meta-analysis would be applied with Stata 13 computer software in this study.

C. Outcome Measures

The learning outcomes measured in these 34 theses was learning achievement, as indicated on researcher-developed achievement tests at the end of the campus program. A meta-analysis was performed to synthesize existing research comparing the effects of CAI and TI on students' learning achievement in Taiwan. For statistical analysis, outcomes from a variety of different studies with a variety of different instruments had to be expressed on a common scale. The transformation used for this purpose was the one recommended by Higgins, Thompson, Deeks, and Altman [37]. For reduce measurements to a common scale, each outcome was coded as a standardized mean difference (SMD) that was CAI group's learning outcome (treatment group) minus TI group's the learning outcome (control group).

D. Variables Studied

Four variables were coded for each study in the present theses, and they include year of publication, subject area, sample size, and the type of CAI. Year of publication was coded because it was important to know how effects were related to sources of information over time. Subject area was coded so that potential different effects for subjects with different background could be detected. Sample size was coded so that effects related to characteristics of research procedures could be detected. Type of CAI was coded because it is critical to know how effects are related to the nature and design of the primary research.

E. Coder Reliability

For get more reliable outcomes from coding, three research assistants coded these studies (theses). Each of the three research assistants coded one third of the studies on each of the independent variables. To check for accuracy, the researcher coded each of the studies independently. In addition, the different codes on each of the studies between research assistants were discussed. The final agreement had to be met after discussion.

III. RESULTS

These studies considered for application in meta-analysis got from Taiwan Theses and Dissertations Knowledge Value-Added System, and 34 theses were obtained through this search method. The summarize of these 34 theses in this study was as Table I. They all be published after 2000. Most of them (55.88%) with the sample size between 51 and 100. 17 theses (50.00%) were focus on the subject area in mathematics. 24 theses (70.59%) involved multimedia type of CAI.

TABLE I. SUMMARIZE OF THESE 34 THESES IN THIS STUDY

Variables		N	%
Year of publication	2000	1	2.94
	2001	1	2.94
	2002	9	26.47
	2003	4	11.76
	2004	2	5.88
	2005	1	2.94
	2006	3	8.82
	2007	3	8.82
	2008	2	5.88
	2010	2	5.88
	2011	1	2.94
	2012	4	11.76
	2013	1	2.94
Sample size	1-50	8	23.53
	51-100	19	55.88
	101-500	7	20.59
Subject area	Mathematics	17	50.00
	Language	5	14.71
	Sociology	1	2.94
	Science	9	26.47
	Computer	2	5.88
Type of CAI	Multimedia	24	70.59
	Web-based	10	29.41
Total		34	100.00

A. The Effects of Students' Learning Achievement

34 theses with the effect of CAI versus TI on students' learning achievement in Taiwan in this study were as Figure II (with fixed effects analysis) and Figure III (with random effects analysis). The number of comparisons and the study-weighted SMD were reported as Figure II and Figure III. Either fixed effects analysis or random effects analysis, 31 (91.18%) of the study-weighted SMD were positive and favored the CAI group, while 3 (8.82%) of them were negative and favored the TI group. With fixed effects analysis, the range of the study-weighted SMD was from -1.44 to 7.92. The overall grand mean for all 34 study-weighted SMD was 1.28 ($p < 0.001$), suggesting that the learning achievement of CAI group was better than TI group. I-squared of 0.98 reflects the great heterogeneity across studies. With random effects analysis, the range of the study-weighted SMD was from -1.44 to 7.92. The overall grand mean for all 34 study-weighted SMD was 2.29 ($p < 0.001$), suggesting that the learning achievement of CAI group was better than TI group. I-squared of 0.98 reflects the great heterogeneity across studies.

The SMD for the 34 theses were presented as a forest plot in Figure IV. The diagram shows that despite several large effects, most of the SMD were small to I-squared in magnitude. About 29 (85.29%) of them lie between -5 and 5, while less than 10% of the SMD had absolute value greater than 5. The funnel plot in this study was as Figure IV.

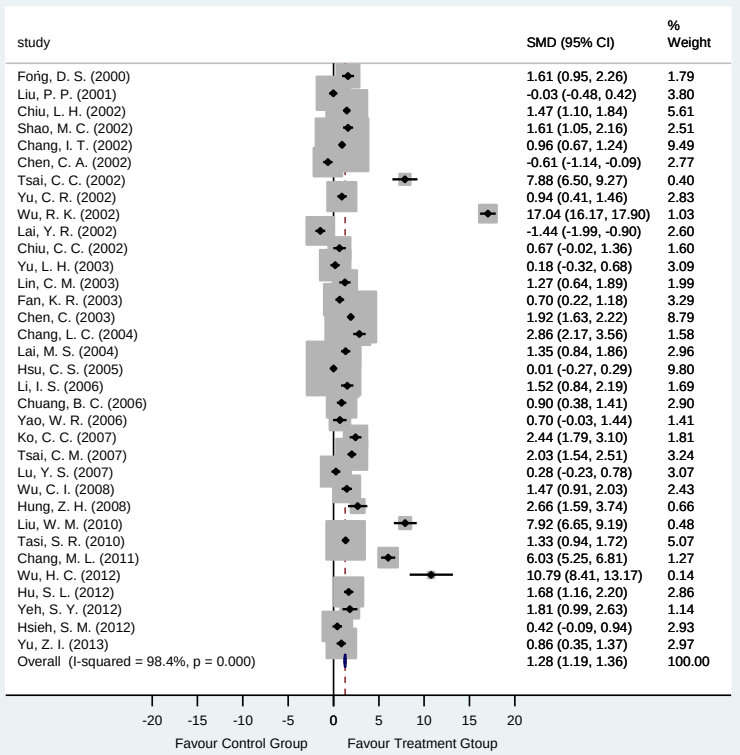

Figure II. The forest plot of these 34 theses in this study with the weights were from fixed effects analysis.

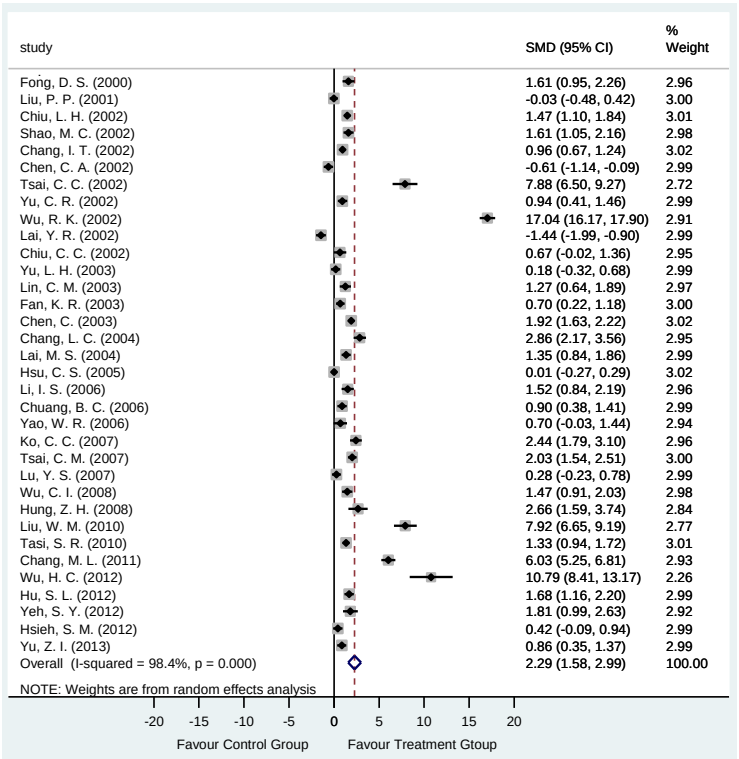

Figure III. The forest plot of these 34 theses in this study with the weights were from random effects analysis.

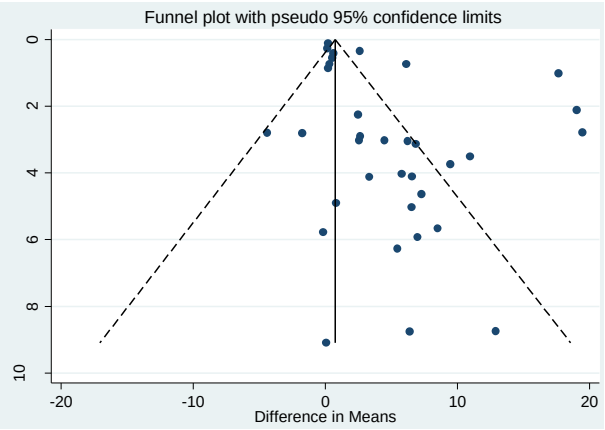

Figure IV. The funnel plot in this study.

B. *Subject Area and Students' Learning Achievement*

CAI studies conducted to measure students' achievement tend to focus on specific subject areas. The result of meta-regression on students' learning achievement with subject area was as Table II. The subject area in this study included mathematics, language, sociology, science, and computer. Studies included in the present meta-analysis were spread over a wide range of subject areas. 17 studies (50.00%) examined the effects of CAI for mathematics course. 5 studies (14.71%) concentrated on the language course. Another studies (35.29%) concentrated on the sociology, science, and computer courses.

Based on mathematics subject area, it could be find that students' learning achievement in language subject area was significant different from mathematics subject area (t-value=2.35; p-value<0.05), but learning achievement in sociology, science, and computer subject area were insignificant different from mathematics subject area. Besides, learning achievement in language subject area (10.98) was better than mathematics, sociology, science, and computer subject area (4.39).

TABLE II. THE RESULT OF META-REGRESSSION FOR SUBJECT AREA

	Coef	SE	t-value	95% Conf. Interval
Language	6.59	2.80	2.35*	0.86 ~ 12.32
Sociology	2.17	5.95	0.36	-10.01 ~ 14.35
Science	-1.67	2.40	-0.69	-6.59 ~ 3.25
Computer	-2.39	3.95	-0.61	-10.46 ~ 5.678
Intercept	4.39	1.46	3.00*	1.40 ~ 7.38

*: P-value<0.05

C. *Type of CAI and Students' Learning Achievement*

The types of CAI in this study included multimedia type CAI and web-based type CAI. The result of meta-regression on students' learning achievement with the types of CAI was as Table III. Two types of CAI were coded for the 34 studies included, among them 24 (70.59%) and 10 (29.41%) studies were coded as multimedia and web-based, respectively.

Based on the multimedia type CAI, it could be find that students' learning achievement with multimedia type CAI was significant different from with web-based type CAI (t-value=2.33; p-value<0.05). Besides, students' learning achievement with web-based type CAI (8.46) was better than with multimedia type CAI (3.43).

TABLE III. THE RESULT OF META-REGRESSION FOR THE TYPES OF CAI

	Coef	SE	t-value	95% Conf. Interval
Web-based	5.03	2.16	2.33*	0.62 ~ 9.43
Intercept	3.43	1.19	2.88*	1.00 ~ 5.86

*: P-value<0.05

D. *Year of Publication and Students' Learning Achievement*

The publication year of these 34 theses publication were from 2000 to 2013 (Table I). The year of publication in this study was based on 2000, and it would be coded from 0 to 13. The result of meta-regression on students' learning achievement with the year of publication was as Table IV.

Based on the publication year at 2000, it could be find that the different of learning achieve between with CAI and with TI was increase. The different of learning achieve between with CAI and with TI was 5.32 (t-value=2.07; p-value <0.05) each year.

TABLE IV. THE RESULT OF META-REGRESSION FOR THE YEAR OF PUBLICATION

	Coef	SE	t-value	95% Conf. Interval
Year of publication	5.32	.26	2.07*	.01 ~ 1.06
Intercept	2.18	1.75	1.24	-1.39 ~ 5.74

*: P-value<0.05

IV. DISCUSSION AND CONCLUSION

The results of this meta-analysis indicate that CAI has moderately positive effects on students' achievement over TI in Taiwan. The results from this study suggest that the effects of CAI in instruction are positive over traditional teaching in Taiwan. Although many educators devote tremendous efforts with great expectation that technology will dramatically increase students' academic achievement, the results of this study provide to classroom teachers an accumulated research-based evidence for positive outcomes by using technology in instruction.

CAI studies conducted to measure students' achievement tend to focus on specific subject areas. Studies included in the present meta-analysis were spread over a wide range of subject areas. Significant differences on SMD were found among subject areas, the various subjects examined seem to suggest that CAI has the potential to implement in different subject areas. Language subject area showed the effects of CAI may more helpful over other subject areas (mathematics, sociology, science, and computer). The SMD for studies coded as mathematics, sociology, science, and computer courses were

almost identical, suggesting they were equally effective on students' achievement. This result clearly displays the process of development of CAI in Taiwan: from traditional CAI (multimedia CAI) to e-learning (web-based CAI). The higher SMD associated with web-based CAI than multimedia CAI. Web-based CAI was more helpful than multimedia CAI in students' learning achievement. The different of learning achieve between with CAI and with TI was increase. So, the help of CAI in learning achieve progress with information technology.

CAI has been presented to have positive effects on the students' learning achievement in many studies. This study also exposed learning benefits from CAI experiences for students in a country with Chinese culture such as Taiwan.

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