A meta-analytical investigation of the influence of computer assisted instruction on achievement in science

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Contents

Abstract

This meta-analysis was performed to determine the overall effectiveness of computer assisted instruction on students' academic achievement in science education from 2001 to 2007 in Turkey. The study reported the results of 65 effect sizes (ES) included in 52 studies. Grand mean for 65 ESs was found to be 1.12. This effect size can be 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 addition, two variables (grade level of subjects and

instruction method of comparison group) had a statistically significant impact on the mean of ES.

Keywords: Computer assisted instruction, Meta-analysis, Science education

Introduction

Using computers in science education has become popular in Turkey as well as in other countries. Since science has many theoretical and abstract concepts, which are difficult to understand by students, students need some visual materials in order to learn these theoretical and abstract concepts. The importance of computer assisted instruction (CAI) has increased in schools. CAI is a method that uses computers in a learning media and strengthens students' motivation and educational processes. It gives opportunities to both students and teachers to learn and teach more quickly and to combine active learning with computer technology (Akçay et. al., 2006). Collette and Collette (1989) explained that using a computer increases motivation and desire during lectures and laboratory work in the process of learning (Akçay et. al., 2006). There are a lot of important reasons to use a computer in science education. They can provide text, graphs, audio, video, pictures, animation and simulation in the same media to students. Simulations foster learning and help students to see different aspects of a subject and generalize about it (Akpinar & Ergin, 2007). Some studies showed that CAI was more effective than the other methods in increasing students' interest in science lessons (Geban, Askar & Özkan, 1992; Hounshell & Hill, 1989).

Many primary studies that investigate phenomenon directly have been carried out in determining the effect of CAI on students (Özmen, 2008; Akçay et. al., 2006; Tas, Köse & Çepni, 2006; Karamustafaoglu, Aydin & Özmen, 2005). Evaluation of these studies plays an important role at certain characteristics by gathering them together for determination of the effectiveness of CAI. Meta-analysis is an effective review method used for evaluating similar studies.

Meta-analysis refers to the critical review and integration of the findings of separate studies. In a meta-analysis, the researcher compares outcomes across several studies using quantitative methods. The goal is to summarize the findings and characteristics of different studies (Göçmen, 2005). The method focuses on a common problem or topic and pools findings of several studies in an effort to draw inferences as to the meaning of a collective body of research (Hannafin et al., 1996).

Basically meta-analysis helps researchers to translate results from different studies to a common metric and statistically explore the relations between the characteristics and findings of the studies.

During the past three decades, a large number of meta-analyses have systematically examined the effects of technology on student outcomes. Kulik and his associates have reported several studies focused on the effectiveness of computer based education in elementary and secondary schools, colleges and adult education (Kulik & Kulik, 1986; Kulik & Kulik, 1991; Kulik, Kulik & Schwalb, 1986; Kulik, Kulik & Bangert-Drowns, 1985; Kulik, Kulik & Cohen, 1980). In these studies, positive outcomes were found on students in favour of computer assisted instruction.

In the last decade, meta-analysis studies on CAI have increased in various areas. The first study during this period examined the effectiveness of CAI on the academic achievement of secondary students (Christmann, Lucking, & Badgett, 1997). In another study, Christmann, Badgett and Lucking (1997) focused on microcomputer-based CAI within differing subject areas. Whitley (1997) investigated gender differences in computer-related attitudes and behavior. Moreover, Cavanaugh (2001) examined the effectiveness of interactive distance education. Recent meta-analyses investigated the effectiveness of CAI programs in supporting beginning readers (Blok, Oostdam, Otter & Overmaat, 2002) and the effects of CAI versus traditional instruction on students' achievement in Taiwan (Liao, 2007).

Even though there are a lot of studies on the effect of CAI on students' academic achievement, there are few in science education (Bayraktar, 2001-2002; Christmann & Badgett, 1999). Bayraktar (2001-2002) investigated how effective CAI was on student achievement in secondary and college science education when compared to traditional instruction. She found the overall effect size as 0.273 from 42 studies yielding 108 effect sizes between the years 1970 and 1999. The results of the study also indicated that some study characteristics, such as student-to-computer ratio, CAI mode, and duration of treatment were significantly related to the effectiveness of CAI. Christmann and Badgett (1999) examined the effects of CAI on students' achievement in differing science and demographic areas. They combined 11 studies on CAI in science. Schroeder et. al., (2007) studied a meta-analysis of U.S. research published from 1980 to 2004 on the effect of specific science teaching strategies on student achievement. The major implication of their research is that they have generated empirical evidence supporting the

effectiveness of alternative teaching strategies in science. Moreover, Tekbiyik, Birinci Konur and Pirasa (2008), investigated effects of computer assisted instruction on students' attitudes towards science courses in Turkey meta-analytically. In the study the arithmetic mean for 23 ESs included 17 studies was found to be 0.68.

Although, studies were started towards computer assisted education in Turkey in 1984, the first great project, called the Project of Computer Assisted Education, was put into practice by the National Ministry of Education. 7,541 teachers were trained in computer assisted education at the project.

During the 1990–1991 academic years, the National Ministry of Education bought 12,000 computers and attempted CAI in elementary and secondary schools (Alyaz & Gürsoy, 2002). The use of educational professional software for CAI started during the 1990s in Turkey when big software production companies brought their programs to Turkey, and the computerization process was accelerated (Özmen, 2008).

Schools and teachers have been constantly supported until the 2000s to encourage using CAI. Using computers has become widespread in schools and research on the effectiveness of CAI has increased after 2000. Several studies have been conducted in order to determine the effects of computer assisted instruction in science education, like all other subject areas. There have not been any studies providing insight on the effectiveness of CAI and evaluating the process of its development in Turkey yet.

Aim of the Study

The aim of the study is to meta-analytically determine the overall effectiveness of CAI on Turkish students' academic achievement in science education from the year 2001 to 2007. In order to reach this aim following research questions were formulated:

1. What is the effectiveness of CAI on students' academic achievement in science in terms of effect sizes (ESs) calculated from primary studies?

2. Are there any significant relationships between the effectiveness of CAI and the variables such as grade level, subject area and instruction methods of comparison group, publication year, type of publication and sample size?

Method

In the present study, data was analyzed using a meta-analysis technique that is a secondary statistical analysis using primary research. Our approach is similar to Kulik et al. (1985) and Glass, McGaw and Smith's (1981); firstly we located objective and replicable studies from reliable sources. Then, we coded these studies for prominent properties and created a common scale by outcomes of studies. Finally we performed statistical methods on the studies' outcomes and calculated effect sizes.

Data Sources

In order to gather the studies included in meta-analysis, various sources were used in the study. Three type studies were brought together for the meta-analysis: journal articles, dissertations/theses and conference papers. The Social Science Citation Index (SSCI) journals, Turkish Academic Network and Information Center Social Science Database, national printed journals, Academic Search Complete, Education Research Complete and ERIC databases were searched for journal articles. The Council of Turkish Higher Education Thesis Center was scanned to get the dissertations/theses. The conference papers were collected from the papers of prominent conference of science education, educational technologies and educational sciences in Turkey. So, 52 studies were used in the meta-analysis.

Inclusion Criteria

The following criteria was established for choosing studies included in the meta-analysis.

1. Studies had to compare the effects of computer assisted instruction and others (traditional instruction, laboratory based, etc.) on students' cognitive achievement.

2. Studies had to be in science subject area (Physics, Chemistry and Biology).

3. Studies had to include an experimental method with a experimental and a control group. Studies with no comparison group were not used in the analysis.

4. Studies had to report quantitative results.

5. Studies had to include Turkish students as subjects.

6. Studies had to report means, standard deviations and number of subjects of experimental and control groups separately (If these were not reported, F or t values had to exist).

7. Studies had to have been published between 2001-2007 years.

Coding

Studies were chosen to use in the meta-analysis. Then, a coding paper was prepared for the coding process. Two researchers' coded variables and quantitative data needed to calculate effect sizes to the paper for each study separately. The researchers compared the coding papers for coding reliability. Agreement was obtained 0.90 between the coding papers. The different codings were discussed by the researchers.

Variables

Six variables were coded for each study:

1. Publication year
2. Type of publication (journal article, dissertation/thesis or conference paper)

3. Grade level (elementary, secondary or university)

4. Subject area (physics, chemistry, biology)

5. Instruction method of comparison group (traditional, laboratory based…)

6. Sample size

Calculation of Effect Sizes

Although there are several approaches to calculate an effect size, Hedge's g, also known Hunter and Schmidt's d (Hunter & Schmidt, 1990), was used in this analysis.

$$g = \overline{X}_E - \overline{X}_C / S_P$$ (Hedges & Olkin, 1985)

Here, g is effect size (ES), $\overline{X}_E$ is the mean for experimental group, $\overline{X}_C$ is the mean for control group and is pooled standard deviation of two groups.

$$S_P = \sqrt{(N_E - 1)S_E^2 + (N_C - 1)S_C^2 / (N_E + N_C - 2)}$$

N_E, N_C are the number of subject of experimental and control groups respectively and S_E, S_C are the standard deviation of experimental and control groups respectively. If means and standard deviations of groups were not reported, t and F values were used to calculate the ESs:

For *t* value: $g = t \times \sqrt{1/N_E + 1/N_C}$ and for F value: $g = \sqrt{F} \times \sqrt{1/N_E + 1/N_C}$

The SPSS package program was used to compute the ESs and variability measurement. Each variable was evaluated as a factor in an analysis of variance (ANOVA) to investigate whether there were significant differences within each variable on the ESs.

Results

As can be seen from Table I, the study reported the results of 65 effect sizes included in 52 studies, since some studies performed multiple comparisons within

the same study. The overall number of subjects was 3,902 in 52 studies. Although 63 (97%) of the 65 effect sizes in the present analysis were positive and favored the CAI, only 2 (3%) were negative and favored traditional instruction.

Table 1. *Publishing year, number of comparisons and effect sizes of each primary study*

Authors of the studies	Year	Number of ES	ES
Akçay, et al.	2006	2	1.58
			0.66
Akçay, Tüysüz & Feyzioğlu	2003	4	1.32
			3.41
			1.98
			3.31
Akgün	2005	1	0.53
Akpınar & Ergin	2007	1	1.44
Akpınar, Aktamış, Günay & Ergin	2005	1	0.83
Ardac and Dilek	2002	2	0.67
			-0.78
Arıkan, et al.	2006	1	1.59
Ayas, Yılmaz & Tekin	2001	1	1.17
Aydoğdu	2006	1	0.47
Aykanat, Doğru & Kalender	2005	1	1.77
Başaran	2005	1	0.03
Bayrak, Kanlı & İngeç	2007	1	0.20
Çavaş	2005	1	0.63
Çekbaş, et al.	2003	1	0.22
Çepni, Taş & Köse	2006	1	0.64
Çömek & Bayram	2004	1	1.20
Demirer	2006	1	0.71
Feyzioğlu & Akçay	2006	1	0.14
Gönen & Kocakaya	2005	1	0.79
Gönen, Kocakaya & İnan	2006	1	0.79
Güler & Sağlam	2002	1	0.05
Gündüz	2005	1	0.48
Güney, Özmen & Kenan	2007	1	1.68
İlbi	2006	1	0.17
Kara	2005	2	1.36
			2.45
Kara, Gürses & Özkan	2006	2	0.94
			0.76
Kara & Yeşilyurt	2006	2	1.85
			1.18

Karamustafaoğlu, Aydın & Özmen	2005	1	0.96
Katırcıoğlu & Kazancı	2003	2	0.50
			0.84
Kıyıcı & Yumuşak	2005	1	2.31
Korkmaz	2006	2	3.23
			1.82
Morgil, et al.	2003	1	1.39
Ocak & Ocak	2002	2	2.68
			0.09
Oğur	2006	1	0.87
Olgun	2006	1	0.47
Özdener, Karagöz & Bayrak	2005	1	0.06
Özmen	2008	1	2.26
Özmen	2007	1	0.76
Özmen & Kolomuç	2004	1	0.24
Pektaş, Türkmen & Solak	2006	1	0.71
Saka & Yılmaz	2005	1	1.46
Salgut	2007	1	0.73
Sarıçayır	2007	2	2.13
			-0.25
Sevim	2006	1	0.65
Sılay, Gök & Oğur	2004	1	2.79
Şengel, Özden & Geban	2002	1	0.88
Taş, Köse & Çepni	2006	1	0.65
Tekmen	2006	1	2.02
Topçu & Pamuk	2006	1	0.17
Yakar	2005	2	1.86
			2.15
Yenice, et al.	2003	1	1.04
Zaman	2006	1	1.77
Grand Mean Of ESs			**1.12**
Grand Median Of ESs (Stnd. Dev.)			**0.87 (0.88)**

The range of the ESs was from -0.78 to 3.41. The grand mean effect size for 65 ESs was 1.12. This mean can be interpreted as a large ES. Nevertheless a grand median and standard deviation for all ESs were 0.87 and 0.88 respectively.

Table 2 shows the F values and descriptive statistics for the six variables. Two variables (grade level of subjects and instruction method of comparison group) indicated statistically significant effects at a 95% confidence level. In order to

determine the source of these effects, Scheffe's post hoc test was performed for each of these variables.

Table 2. *Descriptive statistics and the results of ANOVA for the variables*

Variables	N	%	Mean of ESs	SD	F	p
Publishing year						
2001-2003	16	24.6	1.17	1.17	0.313	0.732
2004-2005	18	27.7	1.22	0.84		
2006-2007	31	47.7	1.03	0.74		
Type of publication						
Dissertation/thesis	17	26.2	1.25	0.93	0.298	0.744
Journal article	34	52.3	1.09	0.92		
Conference paper	14	21.5	1.01	0.74		
Grade level of subjects						
Elementary (4th-8th grade)	25	38.5	1.43	0.98	3.264*	0.045
Secondary (9th-12th grade)	21	32.3	0.79	0.76		
University	19	29.2	1.06	0.77		
Subject area						
Physics	20	30.8	1.21	0.88	0.183	0.833
Chemistry	22	33.8	1.11	1.04		
Biology	23	35.4	1.05	0.73		
Instruction method of comparison group						
Traditional	55	84.6	1.25	0.89	2.989*	0.038
Laboratory Based	5	7.7	0.31	0.40		
Constructivist (7E)	3	4.6	0.77	0.03		
Others	2	3.1	0.15	0.02		
Sample size						
1-40	17	26.2	1.31	0.97	0.916	0.405
41-60	19	29.2	0.92	0.73		
More than 61	29	44.6	1.13	0.92		

*$p < 0.05$

Discussion

In the present study, the grand mean for 65 ESs included 52 studies was 1,12. This effect size can be interpreted as an average student exposed to CAI exceeds the academic achievement of 87% of the students who were thought using other methods. In other words, the typical student's achievement moved from the 50th percentile to the 87th percentile in science education when CAI was used.

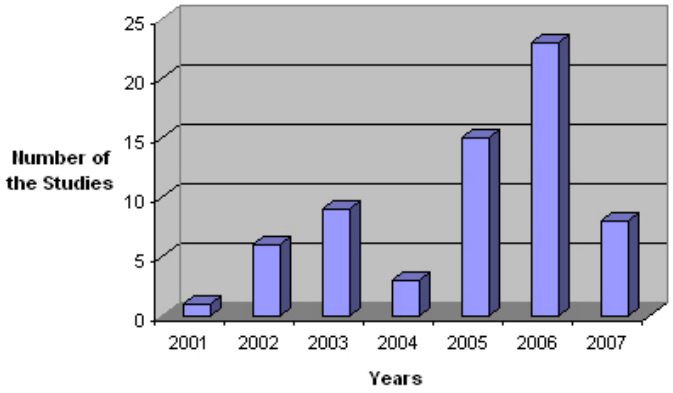
This finding is consistent with Bayraktar's (2001-2002) study. The author found an overall effect size of 0.273 was calculated from 42 studies in secondary and college science education in the United States between 1970 and 1999. Similarly, in an earlier study, Christmann and Badget (1999) reported an effect size of 0.266 standard deviations when they synthesized the results of 11 studies comparing the effectiveness of CAI and traditional instruction in science. Liao (2007) also calculated positive effect size (ES=0.55) from 52 studies including all disciplines not only science, which favored CAI in Taiwan. The present study has larger effect size than these earlier studies.

This mean can also be interpreted as a large ES, since an effect is said to be medium when ES=0.5 and large when ES=0.8 (Cohen, 1977). It is an important result, with not only a large level grand mean effect size, but also 97% of all ESs favored of CAI.

Six variables were investigated for each study in the meta-analysis. For the publication year variable, there was no significant difference of the mean ES. For the years variable, approximation of the mean ES values can be seen in Table 2. Firstly, we aimed to investigate the range of 2000-2007 years. Since we have not met any studies reported in 2000, the range of the studies was defined as 2001-2007.

The relationship between number of studies and years was a remarkable result in the study (Figure 1). It could be said that number of the studies of computer assisted science education have increased almost constantly from 2001 to 2006 in Turkey. A decreasing of number of the studies reported in 2007 is illusive, because the period of data collection was from March to August of 2007; and at the end of 2007, studies will amount to more than in 2006 will be reported. These results reveal that the number of the studies on CAI will seemingly increase in the future in Turkey.

Figure 1. *Relationship between number of studies and years*



Another variable was type of publication. In the study, 52.3% of studies were located from journals, 26.2% of studies were located from dissertation/theses and 21.5% of studies were located from conference papers. However dissertation/thesis has larger mean ES than the others; there is a small difference among journal articles, dissertation/thesis and conference papers of mean ES in Turkey. Liao (2007) in Taiwan and Bayraktar (2001-2002) in United States found similar results.

The present meta-analysis detected significant differences in effectiveness for different grade levels. The results indicated that the most effective grade level was elementary (4th-8th) in Turkish computer assisted science instruction, followed by the university level. The most ineffective was the secondary (9th-12th) level. The ineffectiveness of the ES at secondary level (9th-12th) is probably due to the fact that these graders have to study very hard for a nationwide university entrance examination in Turkey, and using computer assisted instruction may not be a sensible approach for this aim. Liao (2007) also found the smallest ES at high school (10th-12th) and interpreted it because of nationwide college-entrance-examination. Bayraktar (2001-2002) did not find differences between secondary and college levels on CAI in science.

However, significant difference among the ES of subject areas was not pointed out in the study; the largest mean effect was found for physics then chemistry and biology. Literature shows that CAI is more effective in physics than in other subjects. Christmann and Badget (1999), by synthesizing the results of 11 studies, concluded that CAI is most effective in general science (ES=0.707), followed by physics (ES=0.280), chemistry (ES=0.085) and biology (ES=0.042). Bayraktar (2001-2002) calculated the mean ES for physics, general science, biology and chemistry respectively as 0.555, 0.335, 0.167, and 0.108. It is generally known that

physics has many theoretical and abstract concepts that are difficult to understand by students. It can be said that CAI in physics courses is more effective than the other subject areas of science owing to this property of physics.

For the instruction method, the mean comparison of studies with traditional instruction group was significantly higher than studies in which the comparison groups were laboratory based, constructivist (7E) and others. In other words, CAI is more effective than traditional instruction compared to the other instruction methods in Turkish science education.

The last variable sample size was investigated in present meta-analysis. Although no significant difference was found among the mean ES on sample sizes, the largest mean ES was associated with studies with small sample size (1–40). This result can be interpreted as CAI on students' achievement is more effective for a small sample size in Turkey.

Conclusions and Implications

CAI has been shown to have positive and large effects on the academic achievement of students in science education in Turkey. In addition, the results remarkably indicated that the most effective grade level was elementary and CAI is more effective than traditional instruction compared to the other instruction methods. The largest mean effect was found for physics as to chemistry and biology and it is associated with in small sample size.

The results of this study suggested that a number of the studies of computer assisted instruction have increased, especially after the year 2000. This is the first study providing the overall effectiveness of CAI in science education in Turkey. This study has eliminated the contradiction about effectiveness of CAI versus traditional instruction on students' achievement. The results indicated that CAI has been shown to have positive effects on the academic achievement of students in Turkey as well as in USA and Taiwan (Liao, 2007; Bayraktar, 2001-2002; Bangert-Drowns et al., 1985; Kulik et al., 1985). In addition, the study mentioned that CAI could be used at the elementary level rather than other levels without doubt.

After this analysis it is recommended to educational researchers for further research, that not only primary research, but also meta-analysis, should point the out the

factors of effectiveness for students' achievement using computer assisted science education. The results from further reports must be used in classes.

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