

CHAPTER V

SUMMARY, CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

This chapter presents a summary of the research problem, purpose, methodology and procedures, and findings of the study. Conclusions, discussion, and recommendations for practice and future research are also presented.

Summary

Rapid technological advancements in contemporary workplaces require higher order thinking from employees. In preparing students for these workplaces, instructors and trainers in the field of technical education and training have an important role to play. They must provide opportunities for students to engage in higher order learning. In doing so, appropriate learning theories and pedagogical principles should be applied. With the increasing availability and accessibility of microcomputers, instruction that combines sound learning principles with the functionality of computers forms a potentially effective teaching method called computer-assisted instruction (CAI). Along with this development came a proliferation of studies that compared CAI with more traditional instruction in terms of their effectiveness. In these studies, achievement of students taught through CAI was compared with those taught through traditional instruction. Such studies have also been conducted in the field of technical education and training. However, results from these studies were equivocal. To reach a conclusive statement on the effectiveness issue, several meta-analyses have been performed. Results of these meta-analyses generally favored CAI.

The results of CAI research over the years and the increasing power of computers have contributed to the development of much improved CAI that can engage students in

higher order thinking in technical education and training. In the same manner that older CAI was investigated, the effectiveness of newer CAI was compared with traditional instruction. Some studies showed that CAI was more effective than traditional instruction (e.g., Gott, 1995; Parchman et al., 1997) while others showed no difference (e.g., Shute & Gawlick-Grendel, 1996; Yuill, 1991).

Purpose of the Study

One purpose of this study was to quantitatively analyze individual studies that have investigated the effectiveness of CAI in technical education and training as compared to traditional instruction, with the intent of determining the overall effectiveness of CAI in this field. The focus was on higher order learning. A second purpose was to determine the difference in CAI effectiveness of studies grouped into different categories.

Research Questions

The following research questions related to higher order thinking in technical education and training had been formulated to guide this meta-analysis.

1. What is the overall effectiveness of CAI on achievement as compared to traditional instruction?

2. What are the study features and corresponding categories on which differences in CAI effectiveness can be investigated?

3. Is there a difference in effectiveness between the following types of CAI: (a) CAI, and (b) intelligent CAI?

4. Is there a difference in effectiveness between the following nature of CAI treatment: (a) CAI that replaced traditional instruction, and (b) CAI that supplemented traditional instruction?

5. Is there a difference in effectiveness between CAI studies that grouped subjects according to (a) random assignment, (b) intact groups, and (c) other types of subject assignments that were not random or intact groups?

6. Is there a difference in effectiveness between CAI that was implemented at the following educational levels: (a) secondary / postsecondary, (b) university, and (c) adult military?

7. Is there a difference in effectiveness between CAI that was implemented in the following settings: (a) civilian, and (b) military?

Methodology and Procedures

The methodology used in this study was meta-analysis. It is the statistical analysis of a collection of analysis results from individual studies for integrating the findings (Cooper & Hedges, 1994). Studies were located, identified, and collected for analysis through computer and manual procedures. Several criteria were followed in locating studies for this meta-analysis:

1. Studies must involve instruction in the field of technical education and training, which include those conducted in the military.

2. Studies must be retrievable from university libraries.

3. A comparison was made in the studies between a group of students that received computer assisted instruction with another group that was taught in the traditional manner, and student learning in both groups was measured in some form.

Computer searches were performed in locating suitable studies. A published search from NTIS was also used to locate studies. Study abstracts obtained were read to eliminate studies that were not within the focus of this meta-analysis. Based on information from these abstracts, studies that met the given criteria were gathered through university library services. It should be noted that due to certain restrictions, accessing military studies took two months to complete. The 70 studies gathered for analysis were conducted between 1967 and 1997. Studies published or conducted between 1987 and 1997 were examined first to include: (a) primary studies that were not used in previous meta-analyses, (b) primary studies that used newer computer technology, and (c) an adequate number of studies to begin the meta-analysis. Subsequent data screening resulted in 21 usable studies. These studies were next examined for soundness of experimental design. All were found acceptable for subsequent analysis.

Effect Sizes of Studies

The effect size chosen as a basis for comparison across studies was the standardized mean difference. Effect sizes were calculated from (a) posttest effect size only, (b) the difference between posttest effect size and pretest effect size, (c) t-statistic, and (d) F-statistic from ANCOVA tables.

Findings

The final set of 21 studies yielded 28 effect sizes. The number of subjects from these studies totaled 2969. All the studies focused on higher order learning and were conducted in either the civilian or military sectors.

Overall Effectiveness

The overall effect size of computer-assisted instruction in technical education and training was 0.35. In terms of effectiveness of instruction, students receiving CAI outperformed students receiving traditional instruction by 0.35 standard deviations. An interpretation of this value is if the same performance measure was applied for both groups, the “average” students taught in the traditional manner who scored at the 50% level would have scored at the 64% level if taught through CAI.

CAI Type and Effectiveness

There was a significant difference in effectiveness between Intelligent CAI ($\underline{M} = 0.65$, $\underline{SD} = 0.54$) and CAI ($\underline{M} = 0.27$, $\underline{SD} = 0.39$), $t(25) = 2.1$, $p < .05$. Intelligent CAI was significantly more effective than CAI.

Nature of Treatment and Effectiveness

There was no significant difference in effectiveness between CAI applied as a replacement to traditional instruction ($\underline{M} = 0.32$, $\underline{SD} = 0.44$) and CAI applied as a supplement to traditional instruction ($\underline{M} = 0.49$, $\underline{SD} = 0.52$), $t(25) = 0.89$, $p > .1$.

Type of Subject Assignment and Effectiveness

Subject assignment into groups were categorized into three types: (a) random assignment, (b) intact groups, and (c) subject assignments other than the preceding two types. There were no significant differences in effectiveness between random assignment ($\underline{M} = 0.23$, $\underline{SD} = 0.31$), intact groups ($\underline{M} = 0.40$, $\underline{SD} = 0.51$), and other arrangements ($\underline{M} = 0.34$, $\underline{SD} = 0.38$), $F(2, 18) = 0.37$, $p > .1$.

Educational Level and CAI Effectiveness

Three educational levels were considered: (a) secondary / postsecondary ($M = 0.11$, $SD = 0.25$), (b) university ($M = 0.45$, $SD = 0.55$), and (c) adult military training ($M = 0.44$, $SD = 0.41$). There were no significant differences in CAI effectiveness between the three levels of education, $F(2, 23) = 0.88$, $p > .1$.

Setting and CAI Effectiveness

Studies from military and civilian settings were analyzed using a t-test to determine whether there was a significant difference in effectiveness between CAI in the military ($M = 0.44$, $SD = 0.41$), and civilian ($M = 0.37$, $SD = 0.50$) settings. It was discovered that the difference was not significant, $t(26) = 0.35$, $p > .1$.

Conclusions

Computer-assisted instruction that involved higher order learning in technical education and training was more effective than traditional instruction. The degree of this effectiveness was represented by an effect size of 0.35. Based on the classification of effect sizes, this magnitude is considered “small to medium”. On average, students in the CAI class would outperform their colleagues taught in the traditional manner by 0.35 standard deviation, indicating an improvement for the average student from the 50th to the 64th percentile. This result is comparable to several other meta-analyses of CAI effectiveness in technical training. Fletcher (1990) found an overall effect size for military training to be 0.39, indicating an improvement in the average student performance from the 50th percentile to the 65th percentile for the computer-based group. Kulik et al. (1986) found a slightly higher overall effect size of 0.42 from 18 studies in technical training that were conducted between 1964 and 1979 implying a 50th

to the 66th percentile gain by the average student. The moderate magnitude of the overall effect size in this study also seems to agree with the observation that CAI program developers “have apparently been less successful in teaching the higher order skills emphasized at higher educational levels” (Kulik & Kulik, 1991, p. 76).

Intelligent computer-assisted instruction (ICAI) was significantly more effective than non-intelligent computer-assisted instruction for higher order learning in technical education and training. This finding provides support for the benefits of using ICAI in teaching higher order subject matter and higher order skills. The literature review did not discover previous studies that compared ICAI with conventional CAI, therefore preventing any direct comparisons. However, a different basis of categorization of CAI types was found in the literature. Cohen and Dacanay (1992), Kulik et al. (1986), and Kulik and Kulik (1991) classified CAI into three types: (a) Computer-Assisted Instruction (CAI), (b) Computer-Enriched Instruction (CEI), and (c) Computer-Managed Instruction (CMI). They defined CAI as drill and practice, and tutorial; CEI as simulation and calculating tools; and CMI as programs that keep student records, guide students, and record students’ progress. None of the researchers who used this categorization in their meta-analyses found any significant difference between CAI, CEI, and CMI.

Although the mean achievement for supplemental CAI is higher than the mean achievement for replacement CAI, the difference is not significant. This non-significance may be due to the amount or proportion of additional instruction in supplemental CAI in relation to the traditional instruction received by the experimental and control groups. Some supplemental CAI studies provided only five hours of additional computerized instruction. Perhaps, a minimum amount of supplemental CAI must be provided before a

significant difference can be achieved. In addition, while the supplemental CAI is being provided, students in the control group may have used the time to review the lesson by themselves and therefore were able to perform as well as the experimental group.

There were no significant differences in CAI effectiveness between the various types of subject assignment into experimental and control groups. A non-significant difference was also found by Fletcher-Flinn and Gravatt (1995), who categorized subject assignment into random, non-random, repeated measurements, and “not categorized” (p. 229). Agreement on this result was also found in meta-analyses by Kulik et al. (1986), and Kulik and Kulik (1991). Therefore, types of subject assignments other than random assignment can continue to be used in CAI effectiveness studies.

Three educational levels were considered: (a) secondary / postsecondary, (b) university, and (c) adult military training. There was no significant difference in the CAI effectiveness at the three different levels of education. This finding is in agreement with that of Fletcher-Flinn and Gravatt (1995), who compared CAI effectiveness for adult training, tertiary, and secondary. However, Liao and Bright (1991) found that CAI effectiveness was significantly lower at the high school level than at the college level. Roblyer et al. (1988) also found higher effect sizes at the college level. Thus, for the present study, educational level appears to make little if any contribution to a better understanding of CAI’s effectiveness.

Studies were categorized into either military or civilian settings. There was no significant difference in effectiveness between CAI implemented in the military and civilian settings. Although Fletcher (1990) conducted a meta-analysis of the effectiveness of computer-controlled interactive videodisc instruction at the higher education, industrial

training, and military training levels, he did not report whether the obtained effect sizes were significantly different. Therefore no comparison could be made between Fletcher's study and the finding of this study.

Discussion

Given the small difference in learning achievement between computer-assisted instruction and traditional instruction, is it worth to implement CAI? The answer to this question must be tied to the cost of implementing CAI in terms of cost-effectiveness and cost-efficiency. One way of determining cost-effectiveness is by comparing the costs of CAI and traditional instruction to accomplish a given level of achievement. The least expensive method that produces the prescribed level of achievement is the more cost-effective method. Apart from effectiveness, the question of efficiency is also important when comparing CAI and traditional instruction. The amount of effort and time required to implement CAI as compared to traditional instruction needs to be justified too. Also important is the amount of savings in training time by using the different teaching methods. However, for training that involve safety of trainees and equipment, high costs of CAI may be less difficult to justify. If the safety or life of a person using real equipment for training (e.g., aircraft) is in danger, the choice of CAI over conventional training is obvious.

A critical element of this meta-analysis was the identification of suitable studies from abstracts accessed through computer searches. Although combinations of keywords are powerful, the searches may have missed a certain number of pertinent studies. Such a problem is not unique to this study. Difficulties with locating and accessing studies will be an ever present limitation in meta-analyses.

The results of this research were also dependent on the studies selected. Several factors related to the reporting of studies might have affected the results. Unreported data presented a problem in this meta-analysis. Attempts to retrieve these data from study authors proved futile. In certain studies, data were available but not in a form that was suitable for the calculation of effect sizes. Authors of studies are strongly encouraged to include summary statistics such as means, standard deviations, and t and F values in their reports and articles so that these statistics may be used for future meta-analyses.

Recommendations

Recommendations for Practice

As shown by this meta-analysis, computer-assisted instruction has great potential for use in higher order learning. Personnel in the field of technical education and training should not disregard the demands of contemporary and future workplaces. When teaching higher order thinking to students, various means should be used, including computer-assisted instruction. Areas where the computer would have an advantage over real equipment at providing opportunities for students to learn complex skills should be given top priority.

It was shown from studies used in this meta-analysis that the effectiveness of computer-assisted instruction was frequently investigated in teaching diagnostic problem solving including troubleshooting. The use of computer-assisted instruction is well suited to the teaching of diagnostic problem solving because of the practice opportunities provided by the computer that are difficult to obtain through real equipment. One type of computer-assisted instruction that has shown promise in teaching diagnostic problem solving was Intelligent CAI. Most of the Intelligent CAI programs for troubleshooting

have been implemented in the military. To take full advantage of this educational technology, ICAI technology should be diffused into the civilian sector. Joint efforts are needed between the military and civilian sectors to make this technology diffusion possible. Students at the postsecondary level who seek immediate employment upon graduation should be the initial targets for this cooperation. A successful example of such cooperation was shown in the diffusion of the Internet from the military to the civilian sector.

A barrier to the implementation of computer-assisted instruction in the civilian sector is the lack of expertise among instructors to develop these programs. Purchasing commercial software may not be the best solution since it may not suit the learning experience that was targeted. However, authoring programs that allow instructors to use windows-based menus to design CAI programs are now available. Given the proper training, instructors can develop sophisticated CAI programs that meet their needs.

The preceding is concerned with software aspects of CAI. Also of paramount importance are the learning principles underlying CAI programs. Efforts must continue developing CAI programs that apply such techniques as Cognitive Task Analysis, especially for highly specialized skills (e.g., troubleshooting complex equipment).

Recommendations for Future Research

Meta-analysis has been shown to be useful in integrating findings from the literature on a particular topic. However, researchers who use meta-analysis should be selective when including studies for their analysis. It is better to include fewer studies that address the same topic than to use a large number of studies having different foci.

Although random assignment is central to sound experimental designs, it is not easy to implement in practice. Class schedules, time constraints, and availability of equipment are barriers to the use of random assignment. However, researchers can be encouraged by the findings of this study and other studies. The use of intact classes can be a reasonable alternative to random assignment, provided preexisting differences between groups are accounted for through statistical analysis.

Inadequacy of data is a major problem for research that uses meta-analysis. Authors of studies should note that results of their studies may be shared with the research community at large, and should thus make every effort to ensure that summary statistics are reported.

Another area that should be investigated is from a more comprehensive frame of reference i.e., cost-effectiveness. Schools and other educational institutions are constrained by financial budgets. The effectiveness of CAI may not be enough to persuade these educational entities to implement CAI. They need information such as the CAI cost per student that will be needed to increase achievement by a certain amount.