CHAPTER I

INTRODUCTION

This chapter begins with a description of learning theories that can support the use of computers in teaching and learning. It is followed by a description of the development of computer use in education. The ensuing sections discuss issues of relevance, significance, and effectiveness of computer-assisted instruction (CAI) as it relates to technical education and training. The need for this study is also explained. The chapter proceeds with a description of the problem that provided the impetus for this study, as well as the study purpose, limitations, delimitations, and definitions.

Learning, Educational Technology, and CAI

Since the turn of this century, psychological theorists have sought to explain how learning occurs. The resulting learning theories were initially applied in traditional classrooms where teaching aids were limited to chalk and chalkboards. In these classrooms, very often the teacher served as the "sage on the stage" in the teaching and learning process. As radio, television, and motion pictures become available, technology was gradually introduced into education with the belief that it might enhance the teaching and learning process. One such technology, the overhead projector, became a common sight in classrooms. The introduction of technology into education spurred efforts to try to match learning theories with various uses of technology in order to produce the best learning. Spencer (1988) named Edward Thorndike, Ivan Pavlov, and John Watson as the major theorists whose early work strongly affected the development of educational technology throughout most of this century. Simonson and Thompson (1997) also named

the first two, and included B. F. Skinner as being most influential in providing theories that supported computer use in education.

Thorndike's connectionism theory states that learning consists of a series of connections between the problems of a particular situation and previous accomplishments. Complex ideas should be broken down into prerequisite concepts, and positive reinforcement should be applied as these concepts are learned so that they can be applied to more complex, higher-level learning activities (Simonson & Thompson, 1997). Simonson and Thompson noted that Thorndike's theory provided the foundations for many changes in education, such as the specific goals of education, one of which is the ability to read at a certain level. It also promoted the measurement of educational outcomes.

Ivan Pavlov discovered that any neutral stimulus, when paired with an original unconditioned stimulus that is associated to a natural response, could replace the original stimulus and become a conditioned stimulus that produces that response (Spencer, 1988). However, this conditioned stimulus is gradually weakened and subjected to extinction without the continuous presence of the unconditioned stimulus. Pavlov's method became known as classical conditioning. It follows that higher-order conditioning can be built from complex chains of stimuli that control behaviors (Simonson & Thompson, 1997). Classical conditioning provided a foundation for computer-based instructional design in that learning should be organized from very simple to very complex events. Pavlov's theory had a significant impact on the development of learning theory, and was noted by Spencer (1988) as having paved the way for the behavioral science movement that was founded by John Watson.

Watson approached psychology in terms of stimulus and response. He emphasized that psychology should not dwell into the issues of memory and mind, and that attention should only be paid to observable changes in behavior (Chambers & Sprecher, 1983). This brand of psychology hinges on the argument that (a) humans and animals adjust to their environment through hereditary and habit; and (b) certain stimuli lead organisms to make responses, and it is possible to predict a stimulus, given the response and vice-versa (Spencer, 1988). Through stimulus-response (S-R) relationships, Watson conducted various successful conditioning and de-conditioning experiments that provided support for his theory.

B. F. Skinner introduced radical changes to the stimulus-response theory. He proposed that the stimulus can be eliminated from S-R, leaving only the response followed by reinforcement (Chambers & Sprecher, 1988). Thus, while acknowledging the applicability of Pavlov's classical conditioning, Skinner introduced a second kind of learning, termed operant conditioning. Simonson and Thompson (1997) explained that operant conditioning involves the use of reinforcement to promote the desirable changes in behavior, and this reinforcement occurs following the desired actions. They illustrate an example where activities in a computer-assisted instruction lesson would praise students for correct answers. Cues would be given to students to maximize the likelihood of correct answers. These cues would gradually be removed so that in later exercises, students could work on their own. The students are said to be conditioned by the computerized reinforcement so that eventually, they could proceed without any cues.

Paradigm Shift in Learning Theories

The aforementioned theories remained dominant until the 1970s. Since then, alternative theoretical perspectives have surfaced. These new theories soon accumulated enough support to shift the paradigm of educational psychology from the behaviorist to the cognitivist perspective, one that considers learners' internal processes during learning. Among the main cognitive theorists are Jerome Bruner, Jean Piaget, and Seymour Papert. According to Simonson and Thompson (1997), cognitive theorists believe that instruction must be based on students' existing state of mental organization, or schema. The way knowledge is internally structured has effect on how new learning will occur. This implies that computer-based instruction needs to be organized and delivered in a way that complements the cognitive structure and level of sophistication of the learner. Simonson and Thompson added that while behaviorists are more concerned with the outcomes of instruction, cognitivists are more concerned with the content and context of instruction.

Although the theories described above have many differences, some common ground among them does exist. Techniques supported by all the theories that are applicable in computer-based instruction include feedback, assessment of learners, and individualized instruction.

Along with the increasing use of computers in education comes a growing body of CAI research that is based on learning theories. Findings from this research are being used to produce improved CAI. Consequently, contemporary CAI is very different from the early applications of computers in education. Early attempts at using computers in the teaching and learning process proceeded in the same manner that television, radio, and motion pictures were used in education. Like every new wave of technology, computers

were greeted with great enthusiasm. Soon, it was realized that merely using computers will not in itself improve teaching and learning. The computer, like other aspects of educational technology, is just a tool. It is the way computers are used that makes the difference. As mentioned earlier, research on computer use has helped to uncover appropriate ways of using computers in teaching and learning. For a better understanding of the way research has changed the use of computers in education, it is important to understand how computer use in education has developed.

The Development of Computer Use in Education

The history of computers in education goes back about thirty years, beginning with mainframes in the 1960s, and evolving into minicomputers in the early 1970s and microcomputers in the late 1970s (Simonson & Thompson, 1997). One of the earliest applications of computers in education was PLATO, which started as a government-funded project at the University of Illinois in 1960. PLATO eventually enabled computer-based instruction to integrate text and graphics, and provided one of the first programming environments for instructors to develop CAI (Alessi & Trollip, 1991). Other early examples include the Computer Curriculum Corporation at Stanford, MYCIN, GUIDON, and Papert's work with LOGO at MIT (Simonson & Thompson, 1997).

In the early days of computer use in education, many computer-assisted instruction lessons resembled books in which the screen is displayed with text only. Users' only interaction with the computer was by pressing a key to advance through the program (Steinberg, 1990). Such programs have been dubbed as "electronic page turners." Nevertheless, Steinberg observed that while many of the early computer-

assisted instruction lessons resembled flashcard-like drills, an increasing number of lessons presented complex drills and many have gone beyond drills and provide an opportunity to acquire concepts and to develop critical thinking and problem-solving skills.

Great strides have been made in terms of computer use in education. Computers are now ubiquitous in the classroom. Forcier (1996) classified current computer uses in education into management, instruction and learning, and educational research. In instruction and learning, further sub-categories include computer literacy, computer-assisted instruction, and computer-managed instruction. Computer-assisted instruction occurs when the learning situation involves the direct instructional interaction between computer and student. Within computer-assisted instruction, computer applications are divided into drill and practice, tutorial, simulation, and multimedia instruction. In reality however, the applications are predominantly one type but encompass elements of other types.

From the classroom to the world of work, computers are part of the rapid technological advancement. Rapid progress in electronics and computers call for today's workers to deal with complex systems comprised of various inter-connected components. More effective training methods are needed so that workers are well prepared for contemporary workplaces.

Relevance of CAI in Technical Education and Training

Technological advancement in contemporary workplaces requires workers to possess new skills. Johnson, Flesher, Ferej, and Jehn (1992) noted that workers can no longer rely on perceptual and physical abilities but must also rely on abstract thinking

skills. Citing the case of troubleshooting as one that "requires technicians to use their knowledge, skills and experience to effectively interact with a complex technical system that is behaving in some unusual way" (p.1), Johnson et al. believed that such skills can be developed through properly designed computer-assisted instruction. In searching for evidence of their belief, the authors compared the effectiveness of troubleshooting between a computer-assisted group and a control group that was taught in the laboratory. They found that the computer-assisted group became more effective troubleshooters than the control group.

Computer-assisted instruction also provides the opportunity to conduct training that can be safe and cost-saving. For example, when training workers for work in a hazardous chemical factory or a nuclear plant, it would be dangerous to intentionally create leaks in the plant and train workers to contain the leaks. In military training, it would be desirable to have some training on a computer-simulated tank or fighter jet before personnel are allowed to operate a multi-million dollar vehicle. In the airline business, this concept has long been used to train pilots through flight simulators. CAI would also be useful when there is a high student-instructor ratio, real equipment is unavailable, and there is a need for recurrent training.

<div align="center">Significance of the CAI Effectiveness Issue</div>

Numerous studies have investigated the effectiveness of computer-assisted or automated instruction in technical education and training (e.g., Lajoie & Lesgold, 1989; Livergood, 1994). Some of these studies were conducted on the theoretical premise that it is possible for automated instructional systems to emulate the desirable characteristics of human tutors in one-on-one instruction (Regian & Shute, 1992). Regian and Shute

believe that it is even possible for automated instruction to be more effective than human tutors in some aspects like being persistent and constantly motivated. Spencer (1988) cited Fosnot (1984) as suggesting that for most of its history, educational technology has attempted to justify the assumption that both the processes and products of technology can help improve instructional effectiveness. These efforts are worthwhile for a number of reasons. First, the vast amount of expenditures invested integrating computers into instruction must be justified. If it can be shown that computers do in fact produce greater gains in some measure of learning as compared to traditional classroom teaching, then there is evidence that those investments are fruitful, and the use of computers in education and training should be continued. Second, traditional classroom teaching and computer-assisted instruction differ in many ways such as modes of communication and instructor-learner interaction (Steinberg, 1990). Both methods have unique features but either one may be used to provide instruction for a particular learning experience. This raises the question of which is the more effective method for that learning experience. One way to answer this question would be to compare the two methods by measuring the respective gains in learning. Hence, there have been numerous studies of computerized instruction's effectiveness.

<center>Research on CAI Effectiveness</center>

Many studies that sought to ascertain the effectiveness of computer-assisted instruction in technical education and training have used experimental or quasi-experimental designs to compare computer-assisted instruction with more traditional methods of instruction. However, the results are mixed, and no single study can conclusively show whether computer-assisted instruction is generally effective in

<center>8</center>

technical education and training. As Kulik, Kulik, and Shwalb (1986) implied, when there is a need to draw general conclusions, it is necessary to take into account the results from a variety of settings under different circumstances and to apply tools of research synthesis to the results of the individual studies. Such a tool is meta-analysis. It is widely used in both education and medical research to combine, in quantitative terms, the results of many studies into a single metric, called effect size (Fletcher, 1997). Effect size is a standard score that is calculated by dividing the difference between the means of two comparison groups by the standard deviation of either the control group or the combined distributions. For example, if a group that received computer-based coaching on the Scholastic Aptitude Test (SAT) obtained an average score of 550, and a group that received conventional teaching averaged 500, the effect size for the computer-based treatment would be 0.5, since the standard deviation on the SAT is 100 (Kulik, 1994).

Meta-analyses focusing on computer-assisted instruction had been conducted at various levels of education (e.g., Kulik et al., 1986; Ouyang, 1993). However, previous computer applications in education "has been confined to drill and practice while little effort has been directed to the support of higher level of thinking skills" (Johnson et al., 1992, p.2). Additionally, since many workplaces have placed greater emphasis on employees' higher-order thinking, studies utilizing computer applications that demand such thinking need to be examined to determine their overall effectiveness. This calls for a meta-analysis focusing more specifically in the field of technical education and training. Such an analysis was conducted in Fletcher's (1992) effectiveness study of interactive courseware. Fletcher's quantitative review includes studies that had been conducted in industrial and military training. Since then, other studies have been

conducted. Therefore, it is desirable to conduct a meta-analysis that can systematically analyze CAI studies focusing on higher-order thinking, both in the civilian and military settings.

<center>Statement of the Problem</center>

Attempts to apply the best methods of technical education and training include the use of computers to aid students in the learning process, both in the civilian and military sectors. On one hand, computer-assisted instruction (CAI) has great potential for improving instruction, but on the other hand it can provide poor instruction at great cost (Alessi & Trollip, 1991). Such concern has led researchers to study CAI in education and training in terms of effectiveness as compared to the more traditional methods. Several meta-analyses have been conducted in an attempt to ascertain the overall effectiveness of CAI at various levels of education and training (e.g., Fletcher, 1992; Kulik et al. 1986). However, little is known about the elements of higher order thinking and problem solving skills that are so important in the current workplace. Previous meta-analyses have shown CAI to be more effective at the elementary level (Kulik, Kulik, & Bangert-Drowns, 1985) and preschool level (Fletcher-Flinn & Gravatt, 1995), where repetitive, drill-type instruction prevails. However, for instruction that aims to foster higher order thinking and problem solving skills, individual studies that examined such effectiveness produced mixed results and the overall effectiveness of such CAI is unclear. Furthermore, advancements in computer technology have enabled CAI to incorporate text, visual effects, sound, and motion. To provide a contemporary view of the overall effectiveness of CAI in technical education and training, studies that used these newer computer technologies need to be quantitatively examined.

<center>10</center>

Purpose of the Study

The purpose of this study was to quantitatively analyze a group of studies that individually 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. Additionally, it was determined how CAI effectiveness is related to various features of the individual studies.

The following research questions related to higher order learning in technical education and training were 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 identified?

3. What differences in CAI effectiveness exist between categories in each of the identified study features?

Limitations

This study has the following limitations:

1.   The meta-analysis was limited to primary studies that could be obtained from the National Technical Information Service (NTIS) database, Educational Resources Information Center database (ERIC), Dissertation Abstracts International (DAI), and Defense Technical Information Center database (DTIC).

2.   Only primary studies from the above databases that are were retrievable from university libraries were considered. Any generalization of this study beyond these sources should be made with caution.

<center>Delimitations</center>

1.   Only studies focusing on higher order learning, including problem solving were included.

2.   Only studies reporting students' achievement in some form of learning were included.

3.   Only studies comparing achievement between a group that was taught in a computer-assisted manner and a group that was taught in the traditional manner were included.

4.   Primary studies for the meta-analysis were selected from those that involved technical education and training in secondary, postsecondary, university, and military settings.

5.   Primary studies that did not contain adequate data for calculating effect sizes were not used.

<center>Definitions</center>

<u>Computer-Assisted Instruction (CAI)</u>

The use of a computer to provide course content instruction in the form of drill and practice, tutorials, and simulations. The term is used synonymously with CBL (Computer-Based Learning), CBI (Computer-Based Instruction), and CAL (Computer-Assisted Learning) (Chambers & Sprecher, 1983).

<u>Drill and Practice</u>

A type of CAI design that provides practice and reinforcement of previously introduced concepts. Representative of a repetitive, or "flash card" approach to learning in which rote memory is emphasized (Chambers & Sprecher, 1983).

<center>12</center>

<u>Effectiveness of CAI</u>

For purposes of this study, the effectiveness of CAI is measured relative to traditional instruction. This measure is given by the effect size. Positive effect size shows CAI is more effective and vice versa.

<u>Effect Size</u>

A standardized score that is obtained by subtracting the control (traditional instruction) group mean from the treatment (CAI) group mean and dividing the difference by either the standard deviation of the control group or the pooled standard deviation.

<u>Higher Order Learning</u>

A learning condition that requires students to build upon fundamental knowledge and comprehension in a content area. The instructional focus may include and must go beyond recall or recognition of factual knowledge and comprehension such that students may take multiple paths in solving real-world problems and/or making complex decisions where no unique solution path exists. Higher order learning develops cognitive architecture that unifies students' learning experiences.

<u>Intelligent Computer-Assisted Instruction (ICAI)</u>

A type of CAI founded on three kinds of knowledge and problem-solving expertise programmed in a sophisticated instructional environment. The three kinds of knowledge are expert knowledge, student knowledge, and diagnostic knowledge. ICAI is comprised of three modules -- the expert module, the student module, and the tutorial module. The expert module contains the domain knowledge. The student module diagnoses student knowledge. The tutorial module identifies which deficiencies in

knowledge to focus on and selects strategies to present that knowledge. ICAI is also

known as Intelligent Tutoring Systems. (Burns & Capps, 1988)

Meta-Analysis

Cooper and Hedges (1994) defined meta-analysis as the statistical analysis of a

collection of analysis results from individual studies for the purpose of integrating the

findings. In comparing meta-analysis to the narrative literature review, Whitley (1997)

added that the former is a quantitative synthesis of a set of studies that integrates the

results of their statistical analyses, while the latter uses qualitative techniques to integrate

a body of research.

Primary Studies

Studies that are selected for a meta-analysis.

Simulation

A type of CAI lesson design where the computer models a real world or fictional

situation in which the student plays a role and interacts with the computer (Chambers &

Sprecher, 1983).

Tutorial

A type of CAI lesson design in which question and answer, dialog type learning

in the traditional tutor mode is emphasized (Chambers & Sprecher, 1983).

Summary

Sound learning principles can provide support for the effective use of CAI. These principles are increasingly being applied in CAI from the classroom to the workplace. Concurrent with this increase in application, much research has been conducted that examined the effectiveness of CAI as compared to traditional instruction. CAI effectiveness research in technical education and training has not produced conclusive results. As such, there is a need for a quantitative analysis in order to determine the degree of overall effectiveness of CAI in this field. There is also a need to determine the influence of features of the numerous studies on the effects of CAI. This study undertakes the aforementioned tasks through the meta-analysis approach.