WHERE'S THE PROOF?
A REVIEW OF LITERATURE ON EFFECTIVENESS OF INFORMATION TECHNOLOGY IN EDUCATION

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Abstract – *Often heard at engineering educational conferences is the plea, "where's the proof that use of information technology really works?" No single study can produce convincing evidence because in learning-teaching experiments there exist many confounding factors even in the best-designed study. Only sifting through the great amount of information can one find the patterns. Our review summarizes the research findings on computer assisted instruction over the past fifteen years. Many of the studies are themselves reviews and meta-analyses, which cover hundreds of studies, over approximately 2,180 studies either directly or indirectly. Our interest is to gather hard, statistical evidence about use of information technology for better learning, time on tasks, costs, and learner/teacher attitudes. Research strongly supports the use of technology as a catalyst for improving the learning environment. Educational technology has been shown to stimulate more interactive teaching, effective grouping of students, and cooperative learning. A few studies, which estimated the cost effectiveness, reported time saving of about 30%. At first, professors can be expected to struggle with the change brought about by technology. However, they will adopt, adapt, and eventually learn to use technology effortlessly and creatively.*

INTRODUCTION

With great hyperbole and hope, the zealots have convinced many organizations to invest heavily in information technologies. Sooner or later, the doubters had to step forward and demand compelling evidence that these investments could be justified. This challenge is in fact, healthy in limiting unwise use, commitments and investments in technologies prematurely. Our interest is to gather hard, statistical evidence about use of information technology for better learning, time on tasks, costs, and learner/teacher attitudes and other measurable parameters.

DEFINITIONS

The following definitions are not universal, but are generally understood in the literature [6], [21], [23].

Computer Assisted Instruction (CAI) – The computer provides

a) Drill and practice exercises but not new material
b) Tutorial instruction that includes new material.

Computer-managed Instruction (CMI) – The computer evaluates student test performance, guides students to appropriate instructional resources, and keeps records of student progress.

Computer-enriched Instruction (CEI) - The computer

a) Serves as a problem-solving tool
b) Generates data at the student's request to illustrate relationships in models of social or physical reality, or
c) Executes programs developed by the student.

Computer-Based Education (CBE)

a) In drill-and-practice applications, the teacher presents lessons to pupils by conventional means, and the computer provides practice exercises as a follow-up.
b) In the tutorial mode, the computer both presents the concepts and provides practice exercises on them.
c) In the dialogue mode, the computer presents lessons and practice, and the student is free to construct natural language responses, ask questions in unrestricted mode, and almost completely control the sequence of learning events.

Resource Based Education (RBE)

a) Guided Discovery, which involves structuring the content, setting short-term goals for students, providing a range of learning resources (e.g., videotapes, books, flowsheets, diagrams, computer aided learning packages, software tools, self-paced laboratories, tutorials lectures etc.) and then individually assessing student progress with appropriate feedback.
b) Conversational learning, which provides students with greater freedom in the choice of learning resource and the order in which content is covered. Especially suited to project work and the capabilities of advanced students, this strategy requires the teacher to adopt the role of learning consultant.

APPROACH

Our review summarizes the research findings on information technologies over the past fifteen years. The areas are summarized from thirty-five studies covering elementary, secondary level, higher education contexts, and health professions. Many of the studies are themselves reviews and meta-analyses, which cover hundreds of studies, over approximately 2,180 studies either directly or indirectly.

The review papers, which we summarized, used these methods:

1. Locate studies of an issue through objective and replicable searches
2. Code the studies for salient features
3. Code the study outcomes on a common scale and
4. Use statistical methods to relate study features to outcomes

The studies considered for our analysis came from two major sources.

1. Literature searches.
   - Searches were conducted using five databases.
     Educational Resources Information Center (ERIC)
     Dissertations Abstracts International (DAI)
     National Technical Information Service (NTIS)
     MEDLINE
     Government Printing Office (GPO)
1. Bibliographic searches.
   - Retrieved by branching from bibliographies in the documents located through reviews and computer searches.

All studies had to meet four basic criteria for inclusion into our data set.

1. The studies had to take place in actual classrooms or appropriate learning environment.
2. The studies had to provide quantitative results on an outcome variable measured in the same way with both a technology-taught or assisted and a conventionally instructed group.
3. The studies had to be free from such crippling methodological flaws as:
   Substantial differences in aptitude of treatment and control groups.
   Target "teaching" of the criterion test to one of the comparison groups, and
   Significant differential rates of subject attrition from the groups being compared.
4. The studies had to be retrievable by Interlibrary Loan or from the ERIC, NTIS or University Microfilm International (UMF).

FINDINGS

Our study covered a range of student types and subject matter but excluded disability related learning/teaching studies.

1. Mathematics (Interactive algebra I, II & III at college level and for Grades 1-12)
2. Science (Grades 1-12)
3. Social science (Grades 7-12)
4. Microprocessor systems and interfacing (EE 362, Electrical and Computer Engineering students)
5. Language arts (Reading and writing) (Grades 1-12)
6. Combined subjects
7. Vocational training
8. Information processing, communication and presentation skills (Grades 4-6).
9. Surgical nursing (Undergraduate level)
10. Dental study (Undergraduate and advanced level)
11. Pharmaceutical and allied health occupation education (Undergraduate level)

The various technologies used included the following:

1. CAI (Computer-Assisted Instruction),
   CBI (Computer-Based Instruction),
   CEI (Computer-Enriched Instruction),
   and CMI (Computer-Managed Instruction)
2. Interactive multimedia instruction (Video, sound etc.)
3. Video Jockey (VJ) multimedia testbed system [13]
   VJ uses write-once laser videodisc and auto-locatable videocassette playback units that are controlled via networked computers, with multiple channels of audio and video signals available to classrooms and lab facilities via an in-house cable-TV network. The user interface software provides a hierarchical search path through still frames, animation sequences, and full-motion video segments stored in the multimedia database.
4. Microcomputers
5. Multimedia reference material (online resources) and video tapes
6. Internet/World Wide Web (WWW)

The instructional outcome measured most often was student learning, as indicated on achievement examinations given at the end of the program of instruction. Other outcome variables measured in the studies were:

1. Performance on a follow-up or retention examination given after some time, usually 2 to 10 weeks except in one case, where the retention examination was conducted after 2-6 months [20] after the completion of the program of instruction,
2. Attitude toward computers or instruction or subject/course content or school
3. Course completion rate
4. Amount of time needed for instruction or preparation
5. Amount of time needed for student learning
6. Cost effectiveness

For statistical analysis, outcomes were often expressed on a common scale of measurement, which is an effect size (ES). Effect Size is defined as the difference between the mean scores of two groups divided by the standard deviation of the control group. For studies that reported means and standard deviations for both experimental and control groups, ES could be calculated directly from the measurements provided. According to Kulik and Kulik [6], an ES of 0.3 in the average study is considered "a moderate but significant effect". The average ES of 0.3 means that in a typical study, the performance of experimental students was 0.30 standard deviations higher than the performance of the control students.

The various findings summarized from the review papers are as follows. Not all references can be included in this brief paper.

Computer Assisted Instruction (CAI) in a paper, which reviewed 16 papers, raised the student examination scores moderately by 0.42 standard deviation units, i.e. CAI placed the average student using it at the 66^{th} percentile of the control group distribution [5]. The average effect size was 0.63 when CAI was used in *Health professions education*, which is a review of 118 papers [10]. The results in a single paper support the use of CAI in Nursing education for teaching surgical nursing topics and permitting an increase in the student faculty ratio with no loss in quality [12]. The cost-effective ratio of CAI in a single study is 0.40-twice the estimated effect of peer tutoring [7].

Mediated learning [2] for *Interactive Mathematics* (IM) for more than 12,000 *entry level college students* improved pass rates on average of 15% over traditional course pass rates. Retention rates increased in more than 75% of the campuses using IM. Ten percent of the campuses using Mediated learning reached retention rates of 100%. Mean final examination test scores increased as much as 0.50 to 0.75 standard deviation units and course completion rates as much as 40 percent over traditionally taught classes. Both of these are single papers [3]. An average time saving of 31% was reported in a review of 188 studies. The average cost ratio was 0.36 [18].

Mean achievement effect or mean effect size (Represents the overall treatment effectiveness across studies. Each effect size is weighed by using reciprocal of its variance. Studies with greater sample size receive more weight) for *Interactive Video* (IV) was 0.530 in a meta-analysis of 367 papers, which is similar to that of CAI [14].

Using *Interactive Multimedia* for 47,000 *trainees with no technical skills*, retention enhancement of 60% is achieved. In addition, net annual savings of $198,000/year and 30% learning time reduction are reported in a single paper [16].

Online communications (Internet or wide-area networks such as CompuServe, AOL, or Prodigy) used for information processing, communications, and presentation skills can help improve the learning skills of students. The study included 500-600, *fourth to sixth grade students* in 14 experimental classes and 14 control classes. The average of mean scores of all the described skills above is 11.73 for experimental group and 9.92 for control group, with a difference of 1.81 between them [4].

Types of *individualized instruction* [11] assessed in a meta-analysis of 500 papers were self-instruction (SI), programmed instruction (PI), and computer based instruction (CBI) raised the performance of students approximately one third of a standard deviation unit in *dental education*. The average student in the individualized group scored at the 64th percentile of the students in the conventional group. Only four comparative studies of CBI in dental education settings were found. Three of the four CBI studies in the meta-analysis showed large achievement effects. The mean effect size was 0.59 for CBI, 0.36 for PI and 0.32 for SI. The differences among the types of individualized instruction were not statistically significant. On an average, Individualized courses needed only three-quarters (0.77) of the time needed for conventional instruction.

Using *computer software* in a single paper [15], motivational mean (contribution of technological media for motivational attributes, e.g., notions of curiosity or exploration of novelty, challenge, free choice and illusion of self-determination) increased from 7.58 to 8.57 and educational mean (contribution of technology for educational attributes, e.g., subject matter) changed from 7.58 to 7.97. The sample consisted of 38 *Mathematics, sixth-grade* students. Student reports identified a broader range of motivational characteristics in the computer lesson than in the classroom settings.

Computer Based Instruction (CBI) programs in a review of 254 papers raised health study student examination scores by 0.30 standard deviations in the average study, a moderate but significant effect [6]. CBI also produced small but positive changes in student attitudes toward teaching and computers, and reduced substantially the amount of time needed for instruction. The average student receiving CBI in *health professions education* scored at 66th percentile of the students in the conventional group. In this paper reviewing 65 papers, CBI raised the performance of the students approximately by 0.40 of a standard deviation unit [9].

The overall effect size for a third grade was 0.48 and for a fifth grade 0.31 when *computers* were used in *elementary education.* Gains were roughly 0.50 and 0.33 standard deviations respectively more than the control group's gains over a four month period. The program was found to be cost effective as well in this review of 51 papers [19].

CAI and Computer Managed Instruction (*CMI*) were generally effective in *secondary schools*, raising the student examination scores by 0.4 standard deviations. Computer Enriched Instruction (*CEI*) raised examination scores by 0.07 standard deviations. Computer Based Education (*CBE*) also has stronger effects in studies when focused on disadvantaged students. CBE had positive effects on student attitudes. The subjects tested are *mathematics, science, language arts and reading.* The study reviewed 500 papers [21].

The average effect of *CAI* program in a review of 32 papers in *elementary schools* was to increase in pupil achievement scores of 0.47 standard deviations, or from 50th to the 68th percentile [20]. The average effect of *CMI* was an increase in scores of only 0.07 standard deviations. The subjects tested are *mathematics, science, language arts and reading.*

The perceived level of competition, i.e. competition for grades was much higher in *Resource Based Education* (RBE) in *chemical engineering* students (52-75%) than in conventional units (34-37%). The mean ratings in the competition for grades were 2.2 for the conventional, and ranged from 2.7-3.0 for RBE. The study group comprised 31 students [23].

Using Multimedia, final-class GPA of *electrical and computer engineering* students, in *microprocessor and* *systems interfacing* subject improved from 2.58 to 2.97. Seventy percent of the students felt the performance improvement using multimedia, 25% felt otherwise and 5% of the students were not sure. The experiments were run on a class ranging from 40-50 students [13].

Extended *Microcomputer-Based laboratory* (MBL) has been shown effective in improving *middle-school students'* graphing skills. The tests are conducted in *physics* class on 18-20 students. The mean standardized ability tests (SAT/ACT) score was 1049 for standard MBL and 1014 for control group. Real-time graphing improved about 90% of the graphing skills of the students with respect to the control group [17].

Corporate *Computer Based Training* (CBT) (training includes a five day classroom program during each of the first four years in the firm) has improved the mean score on final tests from 13.4 to 15.6. Timesaving were about four person years for 1000 *participants* in a 3-day program [8].

Well-designed *hypertext* has great potential for giving novice users (29 c*ollege students* enrolled in *introductory psychology*) enhanced functionality at little cost to the user. The scores based on question-answers were higher for the experimental group, with a mean of 1.38 than for the paper group with 1.23. This difference was marginally significant [22].

CONCLUSION

Research strongly supports the use of technology as a catalyst for improving the learning environment [24]. Educational technology has been shown to stimulate more interactive teaching, effective grouping of students, and cooperative learning. The doubters with somewhat open minds and, of course, the Luddites are asking difficult but fair questions. Can you prove that learning is better? Is this cost effective? How can we support the needed infrastructures? Can you give me a compelling reason to use a new technology or teaching method? No single, published study can answer even one of the questions. This broad overview does provide convincing evidence that information technologies can enhance learning when the pedagogy is sound, and when there is good match of technology, techniques and objectives. The question of cost effectiveness has to be answered before adapting to the technology mediated learning. A few studies, which estimated the cost effectiveness, reported time saving of about 30%.

There are surprisingly few studies reporting neutral or negative results. According to McNeil B. and Nelson K. [14], published journals articles reported a significantly higher mean effect size than dissertations, theses, and government reports. The attitudes of students using CBI and conventional studies in health professions education are compared. Two out of three studies showed positive effects favoring conventional studies, in case of attitudes toward the subject, but none of the differences were statistically significant. Also in case of attitudes toward computers, three of four studies favored conventional students, the only statistically significant study is the fourth one, which favored CBI [9]. The paucity of negative results may be a reluctance to publish them. It hardly seems possible that all use of information technology results in improvements.

At first, professors can be expected to struggle with the change brought about by technology. However, they will adopt, adapt, and eventually learn to use technology effortlessly and creatively.

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