Are They Effective?

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What is CAI?

Drill and practice software, generally called Computer-Assisted Instruction (CAI), has been used in education for over 30 years. From simple mathematics tutorials, these programs expanded their reach to a variety of academic and vocational subjects, and to all levels of the educational structure, from elementary grades to higher education. They are also frequently used for job skill development and military training. The program functions as an automated tutor. The topic to be taught is divided into modules of increasing complexity. The students work at their own time and pace, starting with the basic modules. At the end of each module, the students must complete an evaluation. If they answer correctly a determined percentage of questions, they can move to a more advanced module. Otherwise, they may repeat the module until they have mastered the targeted concept or skill (some programs offer remedial modules).

CAI utilizes the capacity of computer technologies to: provide immediate feedback, perform repetitive tasks with equal precision, and store large amounts of data. The program enables the students to practice the skills or concepts as many times as necessary until mastery is achieved. The students can work at home or elsewhere in out-of-school hours, saving classroom time for more complex and creative activities. Moreover, the students can work on their own, without the pressure from their more advanced peers. The programs are designed to provide encouragement through supportive statements when the students respond to the questions correctly, or sympathetic expressions and a chance to correct when the answers are wrong. Many programs have an information management system that keeps a history of the students’ activity, including the number of attempts to pass each module, the types of errors made or the time spent on each question. Teachers can use this history to develop an individualized plan that fits each student’s needs. Most recent CAI software integrates features that encourage activities beyond the simple drill-and-practice, such as simulations, graphing and even modeling.

What does evaluation say about CAI?

Evaluations of computer tutorials tend to be inconsistent, ranging from “significantly improved” to “no statistical significance found.” Cotton (2000) reviews 35 studies related to the use of CAI conducted throughout the 1980s, when the programs were popular. Overall, results were encouraging. When compared to students receiving only traditional, teacher-direct instruction, students who had the teacher instruction supplemented by CAI were found to learn faster – sometimes as much as 40 percent faster – and had better retention rates (measured through higher scores in delayed tests). They also improved their attitudes toward school and their potential as learners. CAI students had better attendance rates, showed higher motivation and cooperated better with peers.

Kulik (1994) reviewed approximately 550 individual studies conducted between 1978 and 1991 using a meta-analysis technique. His findings are similar to Cotton’s: on average, students who use CAI learn faster and retain more than students who had only traditional instruction. In addition, they develop more positive attitudes toward school. Evaluators for the Carnegie Learning’s Cognitive Tutor, a tutorial software for mathematics, compared public school students in two U.S.A. cities: a group used the Tutorial and a comparison group received only traditional instruction. Student achievement was compared using national standardized tests. On average, students who used the Algebra I Tutor performed 85 percent better on assessments of complex mathematical problem solving and thinking, and 14 percent better on standardized assessments of basic mathematical skills than their peers who did not use the program. Students who had completed the three-course sequence (Algebra I, Geometry and Algebra II) performed on average 30 percent
better on the Third International Mathematics and Science Study (TIMSS) assessment, and 227 percent better on real-world problem solving assessments. A smaller study compared two groups of students attending a calculus course: one group used computer tutorials to enhance the lessons, and the other received only teacher-direct instruction. When the groups were compared, the students who used the software showed improved understanding of key concepts (Cooley, 1999). In contrast, a review of six years of qualitative and quantitative studies on the use of computer tutorials for science teaching questioned the reliability of CAI results. According to this study, advancement through the program levels did not ensure that the student had mastered the concepts, nor the lack of advancement reflected that mastery had not been achieved (Hativa, 1994).

Rather than asking whether CAI improves student’s academic achievement in general, more recent studies are focusing on the behavior of specific types of tutorials, groups of students and types of skills. Wheeler & Regian (1999) looked at the use of a computer tutorial to teach word problem solving to ninth-grade students. The study compares 639 students divided into three groups: a group received traditional instruction, a second group received instruction plus a simple word problem computer tutorial, and the third group received instruction plus a word problem software containing active instruction. The research found that students using the active tutorial improved significantly more than the other two groups. Although improvement occurred in both abstract and concrete reasoning, the gains in the abstract reasoning were not as large as the gains in the concrete subtest. González & Birch (2000) compared three different tutorial approaches to introducing elementary statistics concepts to college students. The approaches included traditional paper-and-pencil tutorial, basic tutorial software, and multimedia software. In the post-test, students using tutorials showed a better comprehension of statistics than those who did not use tutorials. Those using the basic tutorial program also finished the tests much faster. The use of computer tutorial to provide or reinforce basic concepts in complex subjects is also the topic of a study by Washington, Parmianpour & Fraser (1999). The authors utilized the tutorial in an introductory college class on biomechanics and verified a significant improvement in basic concepts for students using the tutorial, although differences in final grades between control and treatment groups were not significant.

What should we conclude?

It is clearly tempting to say that “more research is necessary,” the self-protective statement so common among researchers. No one will err by requiring more research on anything, but research is a too vague word for a field with so many intervening variables. The term CAI is not universal and may indicate programs other than drill and practice tutorials. Likewise, tutorials may receive different labels. Evaluations of CAI programs may be comparing quite different approaches, particularly because many studies do not describe the software used. Some tutorials are limited to basic memorization and reinforcement activities, while others can be quite sophisticated, emphasizing higher-order thinking skills activities. For instance, the Mathematical Abstract Reasoning Tutor, MARTHA, is a computer tutorial that focuses on abstract reasoning on mathematics, including modeling (Wheeler & Regian, 1999).

The quality of the programs also varies. Not all drill-and-practice software have undergone research and testing to ensure efficacy, and many are not regularly updated. Researchers who use standardized tests to assess the impact of tutorials must assess the relationship between what is taught in the program and what is required in the test. Washington et al (1999) comment that the content of the tutorial used in their study corresponded only minimally to the material required for the midterm and final exams. In this case, the treatment and control groups were being compared with a measure that did not reflect the treatment.

Which skills seem to respond better to tutorials and for whom tutorials work better, or do not work at all, are two questions that merit further attention. Burchfield & Gifford (1995) tested the efficacy of tutorial software to teach integrated science process skills (control variables, define operationally, formulate hypotheses, interpret data, experiment and formulate models). The tutorial did not show significant improvement in the targeted skills, but students using the program scored much better than a control group on measures related to ability to graph and interpret data. Cotton’s review indicates that CAI programs are particularly useful for students who require structured content and flexible learning time, such as children and youth with disabilities and those struggling academically. For this group, the software is a patient tutor that is never angry or frustrated, never embarrasses the child in front of others, and never forgets to say a word of praise or encouragement (Cotton, 2000). Yet, this effect may be relevant only in the case of younger users and may have no significance for college students (Burchfield & Gifford, 1999).

Should we adopt computer tutorials?

If planning to buy computer tutorials, teachers and educators should carefully examine the programs focusing on:

- **Program objectives** – the tutorial’s objectives must correspond and complement the educational goals defined by the teacher;
- **Purpose for use** – CAI is a tool, not a replacement for a well-planned learning experience; research suggests...
that the program is more effective when used to reinforce or clarify topics that were discussed in class;

- **Potential use** – how frequently will the program be used? Where? Does it take from classroom time or complement it? Does the school have a place where students can use the program outside classroom time?

- **Content quality** – is the content correct and updated? Is the level of difficulty appropriate for the students? How well is the content integrated with the curriculum and the lesson plan?

- **Presentation quality** – uninteresting software will not motivate the students, while a fancy software with weak content will not help;

- **Program requirements** – before buying the tutorial, it is important to examine hardware requirements, particularly memory requirements;

- **Cost-effectiveness** – a more expensive program does not necessarily mean a better one; the software should be evaluated against educational objectives and potential benefits.

Research suggests that computer tutorials improve basic skills in mathematics and science for students in all grade levels, from elementary to undergraduate school. However, they are not a panacea that will ensure successful learning for all students in all situations, but simply a tool that can be effectively employed to boost students’ academic achievement and interest. As any tool, the final success of the project will depend on how well it is used.

### References


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1 A summary of the evaluation is found at [www.carnegielearning.com/k12/mathematics/research/whitepapers](http://www.carnegielearning.com/k12/mathematics/research/whitepapers); the evaluators are part of the Carnegie Learning organization.

2 The authors recognize that hardware limitations hurt the efficiency of the multimedia module.

3 This review did not look into the effectiveness of CAI for skill training and graduate studies.