# Education and Training Technology in the Military

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PERSPECTIVE

# Education and Training Technology in the Military

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The United States Department of Defense (DOD) has contributed to the development of various education and training technologies, two of which are computer-assisted instruction and simulation-based instruction. DOD investment in computer-assisted instruction has continued from the 1950s to the present. Its contributions have ranged from drill and practice to computers capable of generating instructional interactions on demand and in real time. DOD investment in instructional simulation began with pilot trainers but evolved to include computer-controlled simulators serving a wide range of purposes, including simulators that are networked for collective education and the training of crews, teams, and units. Past and continuing contributions of the DOD in areas such as effectiveness, cost-effectiveness, instructional efficiency, and collaborative collective activity are worthy of attention.

Military organizations rely on education and training to prepare individuals and groups of individuals to perform extremely difficult tasks at high levels of proficiency under stressful conditions. Both education and training are needed: training to provide the knowledge and skills needed to perform military tasks and jobs, and education to help military personnel at all levels decide when and how to apply the knowledge and skills that they acquire through training (*1*).

Accordingly, the U.S. Department of Defense (DOD) provides training and education for the 2.1 million members of its active and reserve armed forces, 700,000 civilian employees, and 85,000 dependent children. This enterprise has been accompanied since the 1960s by an investment of $150 to 250 million each year on research and development in education, training, training devices, and training simulators.

For military organizations, both education and training are means to an end. Efficiency (time and resources expended) and effectiveness (production of human competence) are critical. Military organizations have historically turned to technology to maximize the efficiency and effectiveness of all their activities, training and education included. Two examples of instructional technologies whose development have been substantially stimulated by the DOD are computer-assisted instruction (CAI) and simulation-based instruction.

## Computer-Assisted Instruction

The contributions of the DOD to the development of computers have been well noted. They range from the first vacuum tube–driven calculators to the Internet. Perhaps less well known are its contributions to the development and use of computers for instruction, which began in the 1950s (*2*–*4*) and have continued to the present (Fig. 1). Many DOD techniques and technologies developed in these areas are open and nonclassified and have found their way into both private and other public sectors. After reviewing contributions to CAI from all sectors, the Congressional Office of Technology Assessment concluded that "The military has been a major, and occasionally, the major player in advancing the state-of-the-art … without [military research and development] … it is unlikely that the electronic revolution in education would have progressed as far and as fast as it has" (*5*).

One early example was PLATO (Programmed Logic for Automated Teaching Operations), which was specifically designed for the development and presentation of instruction (*6*). PLATO was one of several projects at the University of Illinois Coordinated Science Laboratory that were supported by all three military departments in the 1950s. A prominent feature of the PLATO system was its plasma panel, which allowed digitized graphics (with some primitive animation) to be displayed along with text during its "teaching operations." Hardware aside, the major impact of PLATO was in encouraging individuals to develop and use CAI through its authoring language, TUTOR.

The other major CAI development efforts of the time took different approaches. The Institute for Mathematical Studies in the Social Sciences at Stanford University concentrated on CAI curriculum structure and strategies, and the MITRE Corporation working with the University of Texas (and later Brigham Young University), developed Time-Shared Interactive Computer-Controlled Television (TICCIT), an entire computer system designed to implement formal principles of instructional design. All three of these efforts received support from the DOD throughout the 1960s. Many techniques and capabilities that they developed found their way into K–16 education (*4*, *7*, *8*).

The effectiveness of CAI was recognized by the 1970s (*9*, *10*). However, costs posed major impediments to its widespread adoption. Researchers found the costs of computer technology itself and the costs of anticipating responses to all possible learner states and interactions to be problems.

Moore's Law, that which posits, roughly, a doubling of computer capabilities every 18 months, appears to be solving the first problem. The second problem led the DOD to support the development of intelligent CAI (ICAI) (*11*). This support was partially motivated by developments in artificial intelligence but especially by the promise of reducing production costs by enabling computers themselves to generate instructional interactions on demand and in a near-conversational manner. Development of the mixed-initiative instructional dialogue capabilities envisioned by Uttal (*12*) and Carbonell (*13*) was key to this approach. Work on ICAI—today generally called intelligent tutoring systems—has continued in both military and private sectors (*11*, *14*, *15*).

With time, a growing body of data permitted the application of meta-analytic techniques to assess CAI effectiveness. Among other findings from comparisons of CAI with standard classroom learning in military, academic, and industry sectors were reductions of 24 to 54% in the time taken to learn (*11*). Technology costs aside, a 30% reduction in the time needed to learn would save the DOD 15 to 25% of the $4 to 5 billion it spends annually for specialized skill training (from novice to journeyman).

Today, much CAI developed for the military emphasizes portability, which reduces costs by allowing digital learning objects (anything from entire courses to course modules to raw media, such as video and audio clips) to operate across a variety of computer systems. It enables instructional materials developed, for example, by the active forces to be reused without reprogramming by reserve and specialized training commands. It also allows both instruction and performance aiding to be distributed on demand, to locations from classrooms to the field, on computer platforms ranging from desktop to handheld devices.

Efforts to increase both the portability and reusability of learning objects and capabilities for on-demand instruction integrated with performance aiding have cumulated in the DOD Advanced Distributed Learning (ADL) initiative (*16*). ADL is intended to take advantage of the distribution capabilities of the global information infrastructure (today's World Wide Web). It has joined with industry and academia to develop the Sharable Content Object Reference Model (SCORM). This model has been adopted globally by academic, industrial, and military organizations to satisfy criteria for the portability, durability, and reusability of digital learning objects. In cooperation with the Corporation for National Research Initiatives, the ADL initiative also developed the Content Object Resolution, Discovery, Registry/Repository

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Architecture (CORDRA), which permits digital objects to be located globally while allowing their developers to retain control over access to them.

## Simulation

The military has been developing simulation for many years as an instructional technique to represent the visual, auditory, haptic, and occasionally olfactory sensations of the operational world. CAI concentrates on teaching, whereas simulation concentrates on learning through interactions with authentic "real world" experiences. Military research on simulation effectiveness, techniques, and costs may supply much of the empirical assessment that educational researchers have suggested is absent from these experience-based "situated" approaches (*17*).

Simulation reduces costs while increasing safety, visibility of events, and reproducibility of actions. It is often included in CAI to train individuals in operating, maintaining, and deploying equipment. Other applications, such as training for complex tasks and collective operations, use simulation as the primary instructional approach to enhance application, analysis, and evaluation of facts, concepts, and procedures already acquired by individuals.

*Simulation for complex tasks*. Today's technology-infused military operations have spawned what Wulfeck and Wetzel-Smith (*18*, *19*) have called "incredibly complex tasks." Such tasks are cognitively demanding and increasingly common in today's military operations. CAI is very good at producing journeymen from novices, but these tasks require higher levels of mastery, involving analysis, evaluation, and creativity defined by common hierarchies of learning [for example, (*20*)]. Training for these tasks must compress years of experience into intense instructional interactions with a comprehensive range of realistic situations. Simulation is viewed as essential for preparing large numbers of individuals, many with limited success in traditional academic settings, to perform these tasks. Examples include learning how to apply sophisticated knowledge of oceanography in using advanced sonar to detect submarines (*18*, *19*), how to apply electronics in maintaining complex avionics equipment (*21*), and how to apply operational procedures and tactics in making collaborative decisions in confused time-pressured environments (*22*).

The best early example of an incredibly complex task may be the operation of aircraft. Military pilots must process numerous multimodal stimuli arriving from equally numerous sources, interpret and prioritize attention among them, pursue an integrated plan of action while performing difficult and interdependent manual control movements, navigate and direct the aircraft, adjust for the transport and launch of weapons, and avoid lethal attacks arriving anytime from anywhere in three-dimensional space (*23*). Preparing individuals to perform these tasks has, since the beginning of manned flight, relied on simulation (*24*).

Early versions used human instructors to control simulators and simulations. Increasingly, instructor-generated stimuli and responses were replaced with those produced by mechanical, electrical, and finally electronic devices (Fig. 2).


**Fig. 1.** U.S. Marine using a tactical training simulation embedded in CAI. [Image made by Amela Sadagic, MOVES Institute, Naval Postgraduate School (NPS)]

Most of these military simulation capabilities have been adopted elsewhere (*25*).

*Simulation training for collectives*. Today, military use of simulation has incorporated computer-networking techniques to link simulators and simulations together to enable members of collectives—crews, teams, and units—to train together. This approach remains important for training aircrews (*26*) but has expanded well beyond aviation applications.

Most operations-oriented training focuses on collectives. In their review of collectives in industry and business, Cannon-Bowers, Oser, and Flanagan reported a clear "consensus … that work groups are the cornerstone of modern American industry" (*27*). A review by the National Research Council (*28*) suggested that what the military is learning about training teams is widely applicable elsewhere. Until recently, however, the use of technology-based simulation for collective training was rarely found outside of military organizations.

**Fig. 2.** An Apache attack helicopter pilot engaged in a simulated mission using a Longbow Crew Trainer located in a combat zone. [U.S. Army photo/Sgt. Brandon Little. Image provided courtesy of the U.S. Department of Defense Office of Public Affairs through the Digital Video and Imagery Distribution System]


**Fig. 3.** U.S. Air Force A-10 pilots training with British ground troops 3700 miles away on the tactics, techniques, and procedures of close air support. [U.S. Air Force photo/Staff Sgt. Joe Laws. Image provided courtesy of the U.S. Department of Defense Office of Public Affairs through the Digital Video and Imagery Distribution System.]

Since the 1980s, the U.S. military has categorized collective simulation training into three categories: live, constructive, and virtual (*29*). These three approaches complement one another; each provides unique capabilities for developing human performance beyond the basic knowledge and skills provided by individual training.

Live-simulation participants employ real-world materiel on exercise ranges instrumented to record all relevant events. Technologies such as eye-safe laser transmitters and receivers provide opportunities for free play, tactical creativity, and participant motivation. Events are recorded in extensive detail for later analyses, which can be facilitated by experts but is primarily expected to come from the participants themselves (*30*).

Constructive simulation is more academic. It is best exemplified by computerized war games. Participants establish scenarios, parameters, and command decisions. They then use computers to play out missions and use the consequences of their decisions to support the development of tactics, techniques, and procedures.

Virtual simulation occupies the middle ground between live and constructive simulation (Fig. 3). It employs human-controlled simulators networked together to collaborate or otherwise engage each other on common electronically generated terrain (*31*, *32*). The simulators may be physically located anywhere because they are modular and share a common model of the situation and its virtual terrain; a tank crew in a tank simulator in Germany can receive air support from aircraft simulators in Nevada when they are being attacked on the electronic terrain by helicopter simulators located in Alabama. Virtual simulation provides more realistic experience and feedback than constructive simulation but with less cost and time than live simulation.

Civilian applications of virtual networked simulation for education may include globally dispersed groups engaging collaboratively in scientific experiments, problem solving, or decisionmaking using otherwise unaffordable equipment, visiting otherwise inaccessible locations for field research, or guided by otherwise unavailable experts.

*Simulation fidelity*. One perennial issue for military and civilian simulation-based instruction alike is the amount of realism, or "fidelity," that is needed. Optimal choices key on the careful explication of instructional objectives and their subsequent use in selecting levels of simulation fidelity (*33*). Development of techniques to trade off the costs of fidelity against instructional effectiveness is a particular concern and contribution of military research. Simulation effectiveness may be judged by the transfer of what is learned in instruction to what is done in practical operations. Quantitative attempts to deal with this issue have used transfer effectiveness ratios to balance the cost of simulator time to the cost of using real equipment (*34*). "Isoperformance" curves have also been developed to help instruction designers identify points at which different combinations of training inputs produce equivalent performance output with minimal costs (*35*).

### Conclusion

Military organizations have their own perspectives and emphases, but the techniques and technologies that they have developed in the following areas, among others, continue to be of interest and value beyond the military.

*Training technology.* After reviewing the issue of tailoring instruction to the needs of each learner, Scriven (*36*) concluded that it was both an educational imperative and an economic impossibility. Continued DOD interest in developing CAI arises from an expectation that computer technology will make this imperative affordable (*11*). The results from the 1960s on have been instructional technologies that adjust the pace, sequence, and difficulty of tasks so that learning is accelerated, allowing learners to focus on what they need to learn rather than what they already know.

*Instructional efficiency.* Military organizations, which assume responsibility for individuals from enlistment through retirement, have concentrated on the development of techniques and principles that increase instructional efficiency and assess the cost-effectiveness of alternate approaches.

*Collective performance.* Instructional technology for crews, teams, and units is a particular concern of military organizations. Techniques for developing shared mental models, conducting group assessments, encouraging collaboration, and measuring the competence, productivity, and readiness of collectives should be of value to all sectors.

*Research and development.* The military continues to invest substantially in research and development for instructional technology. Some of its instructional technology programs, particularly those in skill-training areas, have been transferred to specific civilian applications. However, its open nonproprietary development of techniques, technologies, and capabilities in nonclassified areas, particularly those of CAI and simulation, has influenced instructional practice in all sectors.

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PERSPECTIVE

# Technology and Testing

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Large-scale testing of educational outcomes benefits already from technological applications that address logistics such as development, administration, and scoring of tests, as well as reporting of results. Innovative applications of technology also provide rich, authentic tasks that challenge the sorts of integrated knowledge, critical thinking, and problem solving seldom well addressed in paper-based tests. Such tasks can be used on both large-scale and classroom-based assessments. Balanced assessment systems can be developed that integrate curriculum-embedded, benchmark, and summative assessments across classroom, district, state, national, and international levels. We discuss here the potential of technology to launch a new era of integrated, learning-centered assessment systems.

A new generation of technology-enabled assessments offers the potential for transforming what, how, when, where, and why testing occurs. Powered by the ever-increasing capabilities of technology, these 21st-century approaches to assessment expand the potential for tests to both probe and promote a broad spectrum of human learning, including the types of knowledge and competence advocated in various recent policy reports on education and the