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Research Foundations for the Advanced Distributed Learning Initiative

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Executive Summary

The Advanced Distributed Learning (ADL) Initiative was established by the Office of the Undersecretary of Defense for Personnel and Readiness (OUSD(P&R)) in 1997. Its purpose was to assist the military Services in making "learning" (education, training, and performance/decision aiding) available on-demand, anytime and anywhere.

"Learning" in ADL is used as a catch-all designator for education, training, and performance/decision aiding. "Distributed" in ADL signifies learning that can be provided in classrooms with a teacher present, in the field linking together widely dispersed instructors and students, or standing alone with no instructor other than the computer itself. "Advanced" in ADL implies affordable, interactive, adaptive, on-demand instruction delivered using computer technology so that it is available anytime, anywhere.

Empirical research, available as early as the 1960s, suggested the feasibility of ADL and its goals. It has shown that:

- Individualized, tutorial 'learning' (including individualized performance/decision aiding) can be provided affordably by technology-based learning.
- Technology-based learning can be more effective and can produce greater return on investment than conventional instructional approaches across many instructional objectives and subject matters.
- Technology-base learning allows education, training, performance aiding, and decision aiding to be delivered on platforms ranging from hand-held devices, to desk-top computers, to capabilities embedded in operational equipment.

Statistical findings from this research may be summarized by a "Rule of Thirds." It states that application of technology-based learning can reduce the cost of instruction by about one-third. Additionally it can either reduce instructional time to reach instructional goals by about one-third, or increase the skills and knowledge acquired by about one-third while holding instructional time constant.

The long-term vision for ADL is an extrapolation from such developments as portable, increasingly accessible computing, the global information infrastructure, modular object-oriented architectures, and natural language processing. The march toward devices that might be described as personal learning associates seems inevitable. These devices will act as personal accessories. They will respond on demand to requests for education, training, and performance aiding by assembling relevant objects from the global infrastructure and engaging the user in guided conversations to enhance the knowledge and skills and/or problem solving capabilities of individuals and/or groups of dispersed individuals whose devices are wirelessly linked together.

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Research Foundations for the Advanced Distributed Learning (ADL) Initiative

A. The Requirement

About 1.1 million U.S. forces are dispersed across the Continental United States and an additional 1.4 million forces are spread across 50 foreign countries. Individuals in these forces need to be capable of independent thought and action. They also need to be able to continue their training and career growth when they are far removed from military schoolhouses, expert mentors, or others in their own career specialties.

Additional complications arise from the rapid growth in the amount and complexity of information that individuals at all levels must integrate and prioritize. The trend has produced an increasing demand for what Wulfeck and Wetzel-Smith (2008) and Wetzel-Smith and Wulfeck (2010) have described as "incredibly complex tasks." Today, about 15% of military tasks are abstract, multidimensional, non-linear, dynamic, and inter-dependent. The dynamic nature of these tasks and the evolving operational environment require that individuals receive up-to-date training and performance assistance.

Finally, the difficulty of all military tasks is exacerbated by the dispersal of units and the individuals serving within these units. Human decisions and actions must be coordinated within and across teams whose members may be globally dispersed in other nations, immersed in other cultures, and serving at widely varied command levels. The ability to communicate, coordinate, and perform tasks under these conditions may not guarantee success, but the consequences of its absence are severe.

These operational conditions have created an imperative to ensure that "learning"—education, training, and task, job, and decision aiding—is rapidly available on demand, anytime and anywhere, to uniformed and civilian individuals and teams at all levels of responsibility.

B. The Technical Opportunity: A Third Revolution in Learning

In response to this requirement, ADL is riding and contributing to a third revolutionary wave in learning. The first revolution in learning occurred about 5,000 years ago, with the invention of writing—the use of graphic tokens to represent syllables of sound. Before the invention of writing, learning activity appears to have been conducted as a tutorial conversation between a learner and a sage, or at least someone who had the knowledge and skill the learner sought to acquire. With writing, a learner could access knowledge and skill without this face-to-face interaction. Writing allowed the content of ideas and instruction to transcend time and place.

The second revolution in learning occurred with the invention of books printed from moveable type—first in China around 1000 A.D. and then in Europe in the mid-1400s (Kilgour, 1998). With books, the dissemination of knowledge and skills through writing became scalable. Once content was produced, it could be made widely available and became increasingly inexpensive as printing technology developed. However, with writing and printing, the dissemination of content was passive. It lacked the tutorial interactivity that had been the foundation of learning for the previous 100,000 years or so of human existence.

Enter computer technology, with its ability to adapt rapidly, in real time, to the changing demands, needs, and circumstances of learners and learning. Computer technology allows not just content, but also instructional strategies, techniques, and interactions to become inexpensively ubiquitous and available on demand—anytime, anywhere. It may be fomenting a third revolution in learning. ADL is a response and a contributor to this third revolutionary possibility.

"Learning" in ADL is used as a catch-all designator for education, training, and performance/decision aiding. "Distributed" in ADL is not just another word for distance. It signifies learning that can be provided in classrooms with a teacher present, in the field linking together widely dispersed instructors and students, or standing alone with no instructor other than the computer itself. "Advanced" in ADL implies affordable, interactive, adaptive, on-demand instruction using computer technology so that it can be delivered anytime, anywhere.

The ADL purpose, from its inception, has been to ensure access to the highest quality education, training, and performance/decision aiding tailored to individual needs and delivered cost effectively and anytime/anywhere.

C. Evidence: Research and Development (R&D) Foundations

What evidence suggests that computer technology might be effecting this third revolution? What have we learned from research on computer uses in instruction? Some key findings can be summarized as follows:

- Although individualized learning tailored to the needs of individual students has long been viewed as an imperative, it has also been viewed as unaffordable (Scriven, 1975). With few exceptions, we cannot afford one instructor for every student—an Aristotle for every Alexander. Computer technology can make this imperative affordable. A core argument for ADL, then, is not for technology but for making individualization affordable.

- The instructional technologies targeted by ADL have been found to be more effective than typical classroom instruction across many instructional objectives and subject matters.
- ADL is generally less costly, offering greater return on investment (ROI) than current instructional approaches, especially when many widely dispersed students must be served.
- ADL allows education, training, and performance/decision aiding and problem solving to be delivered from the same knowledge bases on platforms ranging from hand-held devices, to large desktop computers, to capabilities embedded in operational equipment.

These arguments have been made for the computer-assisted approaches used by ADL for the last 40–50 years (e.g., Alpert and Bitzer (1970), Atkinson (1968), Coulson (1962), Galanter (1959), and Suppes (1966)). They have been repeatedly validated by empirical research and practical experience. Statistical findings from this work have been summarized by a "Rule of Thirds" (Fletcher, 1997, 2004). This rule states that application of the technologies on which ADL is based reduces the cost of instruction by about one-third. In addition, the application of these technologies can either reduce instructional time to reach instructional goals by about one-third or increase the skills and knowledge acquired by about one-third while holding instructional time constant.

The following sections discuss more specifically the R&D behind these arguments and the Rule of Thirds.

D. Individualization: Tutorial Instruction

The argument for ADL technology begins with an issue that arises independently from applications of technology. It concerns the effectiveness of classroom instruction, involving one instructor for 20–30 (or more) students, compared to individual tutoring, involving one instructor for each student. Empirical results from comparisons of this sort are shown in Figure 1, adapted from Bloom (1984).

Bloom combined findings from three empirical studies that compared tutoring with one-on-many classroom instruction. The result of such comparisons showed the tutored students to have learned more, and the result is not surprising. The surprise is the size of the difference. Overall, as Figure 1 suggests, the difference was found to be two standard deviations. It suggests that one-on-one tutoring, with instructional time held constant, can raise the performance of mid-level 50th percentile students roughly to that of 98th percentile students. These and similar empirical findings suggest that differences between one-on-one tutoring and typical classroom instruction are not only likely but very large.

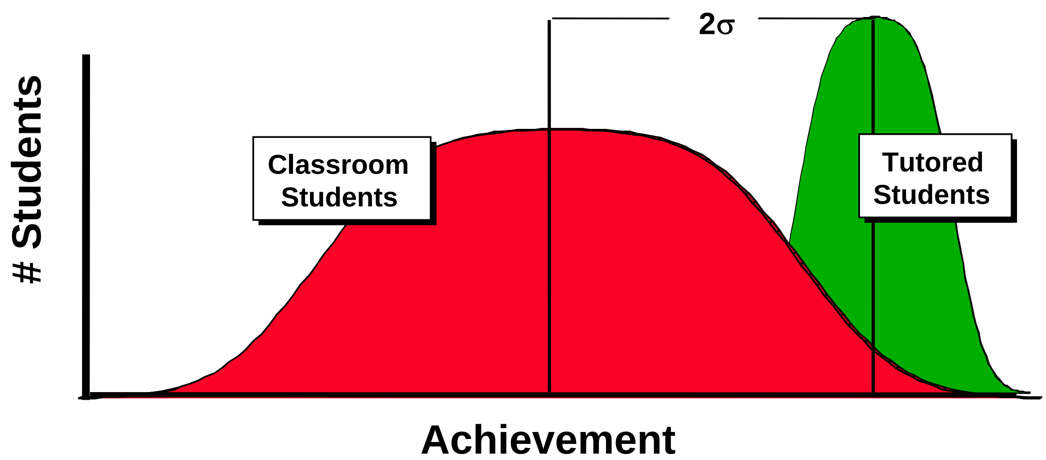

Figure 1. Individual Tutoring Compared to Classroom Instruction

Most importantly for training applications, the shapes of these distributions support Corno and Snow's (1986) suggestion that the individualization provided by tutorial instruction helps guarantee that all learners reach some basic level of competency.

What accounts for the success of one-on-one tutoring? The research summarized below suggests that it is primarily due to (1) the ability of tutors and their students to engage in many more interactions per unit of time than is possible in a classroom and (2) the ability of tutors to tailor pace, sequencing, and content to the needs, capabilities, goals, interests, and values of individual students.

1. Interactivity

With regard to the first tutorial capability (the intensity of instructional interaction), Graesser and Person (1994) reported the following:

- Average number of questions by a teacher of a class in a classroom hour: 3
- Average number of questions asked by a tutor and answered by a student during a tutorial hour: 120–145
- Average number of questions asked by any one student during a classroom hour: 0.11
- Average number of questions asked by a student and answered by a tutor during a tutorial hour: 20–30.

These data show great differences in interactivity and intensity between tutorial and classroom instruction. This level of interactivity, by itself, may account for a substantial portion of the success of tutorial over classroom instruction.

Is this level of interactivity found in instruction using ADL technology? Early studies of computer-assisted instruction in reading and arithmetic found that students in grades K–6 were answering 8–10 individually selected and assessed questions each minute (Fletcher and Atkinson, 1972; Fletcher and Suppes, 1972). This level of interactivity extrapolates to 480–600 such questions an hour if students were to sustain this level of interaction for 60 minutes.

2. Tailoring Pace, Sequencing, and Content

With regard to the second tutorial capability (tailoring the session content), tutors adjust the content and sequence of instruction to the needs of their students. All these adjustments relate to pace—the rate or speed with which students are allowed to proceed through instructional material.

Many classroom instructors have been struck by the differences in the pace with which their students learn. Their observations are confirmed by research. For instance, consider some findings on the time it takes for different students to reach the same instructional objectives:

- Ratio of time needed by fastest and slowest students to reach mathematics objectives: 4 to 1 (Suppes, Fletcher, and Zanotti, 1975; 1976)
- Overall ratio of time needed by fastest 10% and slowest 10% of K–8 students to reach objectives in a variety of subjects: 5 to 1 (Gettinger, 1984)
- Ratio of time needed by fastest and slowest undergraduates in a major research university to learn a programming language: 7 to 1 (Private communication, Corbett, 1998).

The differences in the speed with which students learn are not surprising, but, as with tutoring, the magnitudes of the differences are surprising. Although the speed with which different students reach instructional objectives is not independent of ability, research has found that it is most directly keyed to prior knowledge (Dochy, Segers, and Buehl, 1999; Tobias, 1989). Students in military education and training bring with them a wide variety of backgrounds and life experiences—often much wider than those found among K–12 students. Adjusting the pace of instruction to their individual needs may be especially important for them.

The challenge this diversity presents to classroom instructors is daunting. Typically, the instructors focus on some of their students and leave the others to fend for themselves. This pattern is especially true in training settings where the primary task is to enable as many learners as possible to cross a specific threshold of knowledge and skill. Technology alleviates this difficulty because it allows each learner to proceed as rapidly or as slowly as needed. Learners can skip what they already know and concentrate on what they need to learn.

The degree to which individualization of sequence and content matters is to some extent addressed by studies comparing individualized branching with fixed-content, linear sequencing. Two of the early studies were performed by Fowler (1980) and Verano

(1987). Both of these researchers used computer-controlled videodisc instruction in their experiments. Fowler compared branched presentations with linear instruction in which precisely the same materials were held to a fixed-content, linear sequence. She reported an effect size of 0.72 (roughly, an improvement from the 50th to 76th percentile) in the ability to operate and locate faults on a movie projector. Verano also compared an interactive, adaptive, branching approach with a strictly linear approach for presenting instructional material in beginning Spanish. He reported an effect size of 2.16 (roughly, an improvement from the 50th to 98th percentile) in end-of-course knowledge. These two studies, among others, suggest that individualization of sequence and content matters—perhaps a great deal.

E. Technology-Assisted Learning

1. Time Savings

One of the most stable findings in the comparisons of technology-based instruction and conventional instruction (which uses lecture, text, and experience with equipment (e.g., in the laboratory)) concerns instruction time savings. Table 1 presents these findings.

Table 1. Percent Time Savings for Technology-Based Instruction

Study (Reference)	Number of Studies Reviewed	Average Time Saved (Percent)
Orlansky and String (1977) (Military Training)	13	54
Fletcher (1991) (Higher Education)	8	31
Kulik (1994) (Higher Education)	17	34
Kulik (1994) (Adult Education)	15	24

As the table shows, Orlansky and String (1977) reported that reductions in time to reach instructional objectives averaged about 54% in 13 assessments of technology-based military training. Fletcher (1991) reported an average time reduction of 31% in 8 assessments of IMI applied in higher education. Kulik reported average time reductions of 34% in 17 assessments of technology used in higher education and 24% in 15 assessments of adult education (Kulik, 1994). Each of these reviews covered different sets of evaluation studies that compared technology-based instruction and conventional classroom instruction involving lecture, texts, and perhaps laboratory examples. Overall, it seems reasonable to expect that technology-based instruction will reduce by about 30% the time students take to reach a variety of objectives.

2. Costs

An example of the cost benefits of this reduction in time to learn can be seen in residential, specialized skill training. The DoD spends about $6.5 billion a year on this training, which is the "schoolhouse" training individuals receive after Basic, or initial accession, training. It qualifies individuals for the many technical jobs (e.g., wheeled vehicle mechanics, radar operators, avionics technicians, medical technicians, and so forth) needed to perform military operations. It does not include the costs of aircraft pilot training, officer education, or training provided in military units.

Extrapolated from an earlier analysis by Angier, Fletcher, and Horowitz (1991), Figure 2 shows the annual reductions in costs that would result if instruction time were reduced by 30% for 20, 40, 60, and 80% of military personnel who complete residential, specialized skill training each year. For instance, if the DoD reduced by 30% the time to train 20% of the personnel undergoing specialized skill training, it would save about $428 million per year. If it were to do so for 60% of these personnel, it would save about $1,284 million per year—or about 20% of the funds allocated for specialized skill training. Specialized skill training is particularly amenable to the use of ADL technologies. Use of these technologies by 60% of specialized skill trainees is not an unreasonable expectation.

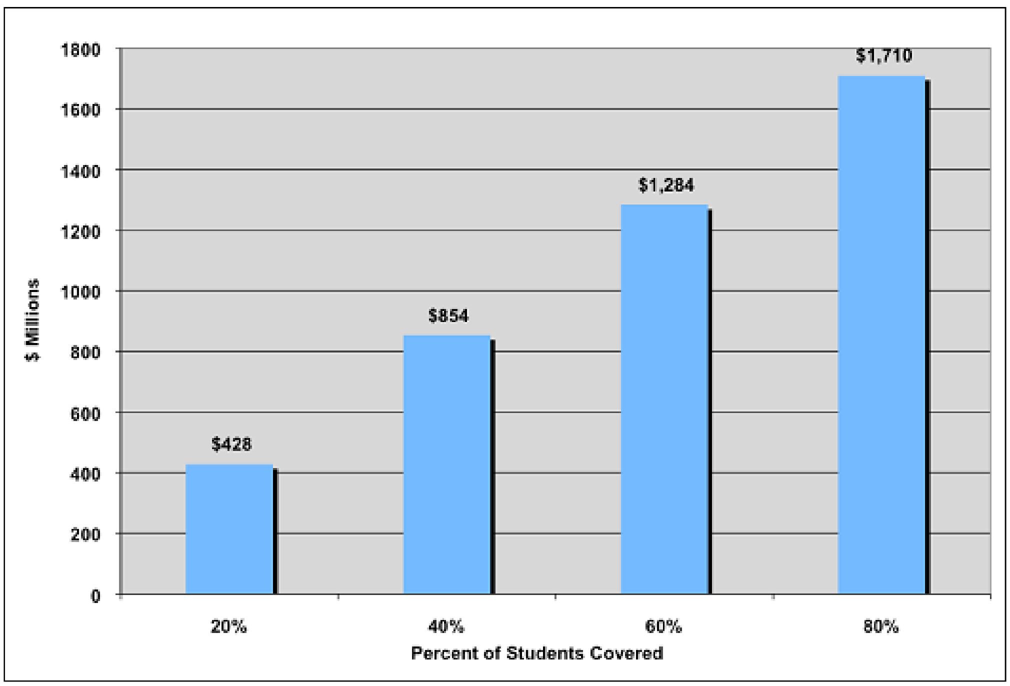

Figure 2. Cost Savings ($ 2008) in Specialized Skill Training Assuming a 30% Reduction in Training Time

Saving 30% of training time may be a conservative target. Commercial enterprises that develop technology-based instruction for the DoD regularly base their bids on the expectation that they can reduce instructional time by 50%. Noja (1987) has reported time savings as high as 80% with the use of technology-based instruction in training operators and maintenance technicians for the Italian Air Force.

Two other sources of cost savings with ADL technologies are not considered in the Figure 2 data. First, the cost models used to generate the data in Figure 2 assume reductions in training time in residential settings but do not take into account using ADL technologies to distribute some of that training to operational units—thereby reducing change of station or temporary duty costs. Second, ADL technologies can be used to simulate expensive equipment, operational environments, and interpersonal situations—thereby not just reducing costs, but also increasing safety, enhancing visualization, and allowing time to be sped up or slowed down as needed for the training.

Perhaps more importantly for military applications, ADL technologies can prepare individuals more quickly for operational duty. In this way, these technologies act as force multipliers by increasing readiness and operational effectiveness without increasing personnel costs.

a. Instructional Effectiveness

Research data suggest that savings from using ADL technologies do not come at the expense of instructional effectiveness. Empirical findings report the opposite. Figure 3 shows effect sizes from several reviews of studies that compared conventional instruction with technology-based instruction.

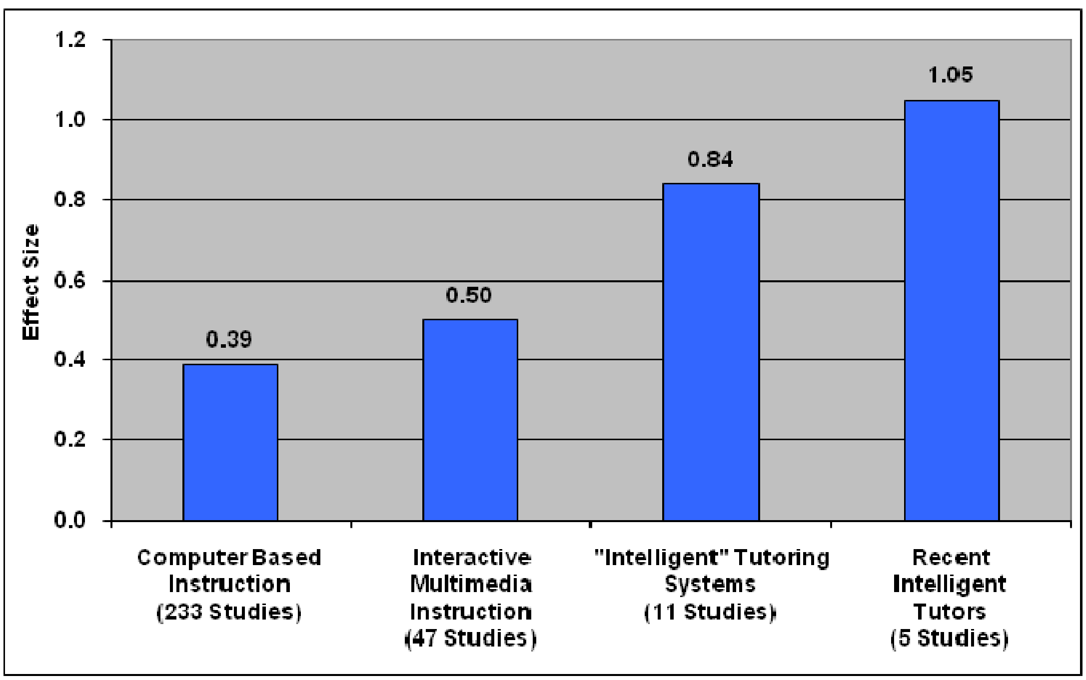

Figure 3. Some Effect Sizes for Studies Comparing Technology-Based Instruction With More Conventional Approaches

In Figure 3, computer-based instruction (CBI) summarizes the results from 233 studies that involved a straightforward application of computer presentations using text, graphics, and some animation, as well as some degree of individualized interaction. The effect size of 0.39 standard deviations suggests, roughly, an improvement of 50^{th} percentile students to the performance levels of 65^{th} percentile students.

Interactive multimedia instruction (IMI) involves more elaborate interactions adding audio, animation, and video and generally taking advantage of the multimedia effect (Fletcher and Tobias, 2005; Mayer, 2005). These added capabilities evidently increase achievement. They show an average effect size of 0.50, which suggests an improvement of 50^{th} percentile students to the performance levels of 69^{th} percentile students.

Intelligent tutoring systems (ITSs) involve a capability that has been developing since the late 1960s (e.g., Carbonell, 1970; Sleeman and Brown, 1982). In this approach, an attempt is made to directly mimic the one-on-one dialogue that occurs in tutorial interactions. A key goal of these systems is to generate computer presentations and responses in real time and on demand as needed or requested by learners. Instructional designers do not need to anticipate and pre-store them. This approach is computationally more sophisticated and more expensive to produce than standard computer-based instruction. However, its cost can be justified by the increase in average effect size to 0.84 standard deviations, which suggests, roughly, an improvement of 50^{th} percentile students to the performance levels of 80^{th} percentile students. As will be discussed later, ROI is much more sensitive to scaling and delivery costs of instruction than to the initial costs to design and develop it.

A selected group of ITSs ("Recent Intelligent Tutors") was considered just to see how far these systems are progressing. The average effect size of 1.05 standard deviations for these applications is promising. It represents, roughly, an improvement of 50^{th} percentile students to the performance levels of 85^{th} percentile students.

The extensive tailoring of instruction that generative, ITSs provide to meet the needs of individual students can only be expected to increase. Such systems may raise the bar—well past Bloom's 2-Sigma challenge—for the ultimate effectiveness of ADL-based instruction.

b. Student Attitudes

Student attitudes toward instruction can affect its effectiveness and efficiency. Many evaluations of technology-based instruction simply ask students if they prefer it to more conventional classroom approaches. Greiner (1991) reviewed these evaluations and found overall that 70–80% of students who were polled preferred technology-based approaches to other approaches. When students reported that they did not prefer the technology-based approaches, the reasons were usually because of implementation or technical problems with the technology and not the instructional approach itself.

McKinnon, Nolan, and Sinclair (2000) completed a thorough 3-year study of student attitudes toward the use of technology-based learning and productivity tools such as spreadsheets, databases, graphics, desktop publishing, and statistical processing. The attitudes of the students toward technology use slackened as the novelty of using the technology wore off. However, their attitudes remained positive and significantly more positive than those of students who did not have access to the technology throughout the 3 years of the study.

c. ROI

Knowing that we can use ADL technologies to reduce learning time, particularly time to learn journeyman skills such as remembering, understanding, and applying facts, simple concepts, and straight-forward procedures, what might an investment in these technologies return?

One way to answer this question is by applying the findings presented earlier in Figure 2, which only considered savings. Using the analysis underlying that figure, we can wrap in both the savings and the costs to achieve them using an ROI model. This model simply reduces to the ratio of the net return (savings in this case) to the costs as shown in the following

$$\frac{Savings - Costs}{Costs}.$$

We can begin by assuming (conservatively) a 30% reduction in training time achieved through the use of ADL technologies by (conservatively) 40% of residential specialized training students. From Figure 2 and the analysis on which it is based (Angier, Fletcher, and Horowitz, 1991), these assumptions suggest annual savings of $854 million. Given this result, the next step is to determine the costs to design, develop, and deliver ADL instruction to 40% of residential specialized skill training students.

Using ADL technology, how much would it cost to render the training needed by 40% of specialized skill students? According to the last published Military Manpower Training Report (2002), the average Specialized Training course length across all four Services was about 57 training days.[1] If that number were reduced by 30%, the training

[1] The 2002 Military Manpower Training Report is the last such report issued by the OUSD(P&R). Changes in specialized skill training since 2002 are assumed to have been small. This present analysis uses training and manpower data from the 2002 report but uses 2008 cost data for personnel and ADL course development and delivery.

course length would amount to about 40 days. Military personnel in training billets may be required to perform additional duties, but, assuming 8 hours a day in course training amounts to about 320 hours of training. About 357,700 officers and enlisted personnel completed Specialized Training in FY 2002. Forty percent of that number amounts to 143,080 learners. In effect then, 320 hours of ADL training would have to be produced and then delivered to 143,080 learners.

Estimates to produce an hour of computer-assisted training vary widely and depend on the content, instructional strategy, and pay and allowances for subject matter experts, "authors," and computer programmer/analysts. One source of estimates comes from the Joint Knowledge Development and Distribution Capability (JKDDC), which is producing Web-based individual training programs for joint assignments and operations. As of May 2008, JKDDC had produced over 200 courses, with more than 65,000 course completions (Camacho, 2009). In the first quarter of FY 2008, the costs for JKDDC to develop an hour of instruction were about $14,000, and the costs to deliver it were about $4.

We might then assume that it would cost about $4.48 million to produce 320 hours of ADL specialized skill training and an additional $183.14 million to deliver it to 143,080 students. The investment for the first year of this training would cost about $187.62 million.

Developing and delivering technology-based instruction to 40% of Specialized Skill students (about 143,080 students) would require 30% fewer hours to complete their training—a savings of about 136 hours for each student. Assuming a composite of $42 per hour in pay and allowances (Military Personnel Composite Standard Pay, 2009), this use of technology-based instruction would amount to (42 × 143,080 × 136) = $817.27 million. Plugging these data and assumptions into an ROI calculation yields

$$\frac{\$817.27M - \$187.62M}{\$187.62M} = 3.36 \; .$$

Under these assumptions, an investment in ADL technology will return about $3.36 for every dollar invested.

After the first year, the costs to develop the instruction would be reduced to whatever is required to maintain and update the course, but the ROI is not particularly sensitive to development costs. It seems far more sensitive to delivery costs. They are included in this analysis for the delivery of the ADL instruction but not for the classroom instruction it replaces. If the savings in training delivery costs were fully considered in this calculation, the ROI would increase substantially. Also, as suggested earlier, 30% time savings is likely to be an underestimate of the student time in training that can be saved. Further, even though this analysis assumes Web-based capability for delivering the instruction, it does not take into account reductions in travel and temporary duty costs, which, if included, would further increase ROI. Finally, the administrative efficiencies, improved tracking and assurance of student progress, and other benefits provided by ADL technology—benefits that were not considered in the previous analysis—have their place and would continue to argue for its use.

Less time in school means more time on the job. Savings in time needed to reach training objectives not only reduce training costs, but also increase the supply of people for operational forces without increasing the number of people in uniform. Ways to account for accompanying increases in readiness and effectiveness due to force multiplication remain to be determined, but they, rather than savings in training costs, may be the most significant impact of reducing the time required by operational forces to reach performance levels.

In short, a significant return seems likely to result from an investment to convert some proportion of training to ADL technology. This value arises primarily from the reduction of student time spent in the training infrastructure. Even with ADL, seasoned military personnel must provide additional training, mentoring, and monitoring for people early in their careers. Certainly, efforts must be made to preserve the camaraderie and espirit de corps gained by students undergoing the rigors of training together. The argument for ADL is not to suggest the massive replacement of people by the technology. It is, instead, that ADL reduces costs to train and increases force effectiveness by releasing people sooner from the training infrastructure and ensuring their competencies. A cost-effective, optimal balance between the use of ADL and more people-intensive approaches to training and education remains to be determined.

3. Performance Aiding

Most of the discussion to this point has focused on education and training applications using ADL technology. Something remains to be said about its use in providing on-demand performance aiding. The term Interactive Electronic Technical Manual (IETM) is a generic label for such a device (Gafford & Heller, in press). Fletcher and Johnston (2002) presented data on effectiveness and costs of several portable, electronic maintenance performance systems, one of which was the Integrated Maintenance Information System (IMIS).

IMIS was a wearable, computer-based performance aid for avionics maintenance. Thomas (1995) compared the performance of 12 Avionics Specialists and 12 Airplane General (APG) Technicians in troubleshooting three F-16 avionics subsystems. Within each of the two groups of subjects, six of the fault isolation problems were performed using paper-based technical orders (TOs) (Air Force technical manuals), and six were performed using IMIS.

Training for APG Technicians includes all aspects of aircraft maintenance, only a small portion of which concerns avionics. In contrast, Avionics Specialists must meet higher selection standards and receive 16 weeks of specialized training that focuses on avionics maintenance. Costs to train APG Technicians are about half the costs for Avionics Specialists. Table 2 shows the results of the study.

Table 2. Maintenance Performance of 12 Air Force Avionics Specialists and 12 APG Technicians Using TOs and IMIS

Technicians/Performers	Correct Solutions (Percent)		Time to Solution (Minutes)		Average Number of Parts Used		Time to Order Parts (Minutes)	
	TOs	IMIS	TOs	IMIS	TOs	IMIS	TOs	IMIS
Avionics Specialists	81.9	100.0	149.3	23.6	8.7	6.4	19.4	1.2
APG Technicians	69.4	98.6	175.8	124.0	8.3	5.3	25.3	1.5

As shown in the table, findings of the study were as follows:

- **Avionics Specialists using TOs compared with those using IMIS.** The Avionics Specialists using IMIS found more correct solutions in less time, used fewer parts to do so, and took less time to order the parts. All these results were statistically significant. The results concerning time to order parts are to be expected because IMIS automated much of this process.
- **APG Technicians using TOs compared with those using IMIS.** The APG Technicians using IMIS found more correct solutions in less time, used fewer parts to do so, and took less time to order the parts. All these results were statistically significant.
- **APG Technicians using IMIS compared with Avionics Specialists using TOs.** The APG Technicians using IMIS found more correct solutions in less time, used fewer parts to do so, and took less time to order the parts than did Avionics Specialists using paper-based TOs. All these results were statistically significant.
- **APG Technicians using IMIS compared with Avionics Specialists using IMIS.** The APG Technicians performed just about as well as the Avionics Specialists and even slightly better in the number of parts used. None of these comparisons were statistically significant.

The economic promise suggested by these results could well vanish if the costs to provide the performance aid (i.e., the IMIS) exceed the costs they otherwise save. Teitelbaum and Orlansky (1996) estimated IMIS reductions in depot-level maintenance, organizational-level maintenance, and maintenance and transportation of inventories of spare parts. They found annual savings from the use of IMIS at about $38 million for the full Air Force fleet of F-16s. They assumed an 8-year useful life for IMIS and estimated about $18 million per year to maintain and update it and amortize its development costs.

The result is a benefit of about $20 million per year in net savings or an ROI of about 1.11, which excludes the significant impact of IMIS on sortie rate, readiness, and operational effectiveness.

F. The ADL Vision

The long-term ADL vision is an extrapolation from such developments as portable, increasingly accessible computing (including hand-held, worn, or even implanted computers), the global information infrastructure (currently manifest in the World Wide Web with its multifarious search engines), modular object-oriented architectures, Web 2.0 technologies, and natural language processing. The march toward devices that might be described as personal learning associates seems inevitable.

As currently envisioned, these devices will act as personal accessories. They will respond on demand to each individual's needs for education, training, and performance aiding by assembling relevant objects from the global infrastructure and engaging the user in guided conversations, such as those described by Hu, Graesser, and Fowler (in press), to enhance user knowledge and skills and/or problem solving capabilities. Learning in these cases is not a matter of just working through pre-specified lessons but is a return to the 100,000 year old tutorial practice of an individual and a sage working together to enhance knowledge and skill. In this case, the human sage is supplanted by a computational device that has access to something approaching the whole of human knowledge carried throughout the global information infrastructure.

As described Dodds and Fletcher (2004) and by Wisher (in press), objects drawn from the global infrastructure must be portable, durable, reusable, and accessible. Gallagher (in press) discusses the history and development of the Sharable Content Object Reference Model (SCORM), which can ensure that objects have the first three of these qualities.

In addition, the objects must be accessible. As discussed in more detail by Lannom (in press), the development of the Content Object Repository Registration/Resolution Architecture (CORDRA) and its use by the ADL registry provide global visibility for objects while allowing their developers to retain control over access to them. They are then available for reuse or repurposing.

These developments have provided ways for objects to be identified and collected for local use from the global information infrastructure. The continued operation of Moore's Law and the market-driven effort to imbue computer technology with natural language understanding should ensure development of affordable, mobile, conversation-capable computing. The major issue that remains for ADL is development of the envisioned individualized tutorial capabilities. Progress and promise can be seen in this area (e.g., Graesser, D'Mello, & Cade, 2010; Hu, Graesser, and Fowler, in press), and it remains key for realizing the full ADL vision.

G. Conclusion

In short, the aforementioned research suggests that effective use of ADL technology

- Increases instructional effectiveness
- Reduces time needed to learn
- Ensures that all students learn
- Is preferred by students
- Is effective and efficient for distributing instruction anytime, anywhere.

Most of research and data to support these conclusions have been available for some time. The usual lag between research findings and their application in practice is observable here as elsewhere. As argued first by Fletcher (1992, 1997) and later by Corbett (2001), ADL technology may make Scrivin's educational imperative and Bloom's tutorial instruction affordable.

The "Rule of Thirds" that emerges from empirical evaluations of technology-based instruction was mentioned earlier in this report. The Rule of Thirds is strictly a statistical statement. It summarizes a large body of empirical findings, but it does not directly address cause and effect.

An often quoted statement that "The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (Clark, 1983, p. 445) does address cause and effect. This point of view seems both fair and unequivocal. The presence of any technology is no guarantee that effective instructional content, effective ways to present it, or even that the unique strengths of the technology itself will be present or used. On the other hand, the absence of technology, including ADL technology, is a reasonable guarantee that its unique functionalities will be unavailable.

Another statement to consider is that "If you don't have a gadget called a 'teaching machine,' don't get one. Don't buy one; don't borrow one; don't steal one. If you have such a gadget, get rid of it. Don't give it away, for someone else might use it. . . . If you begin with a device of any kind, you will try to develop the teaching program to fit that device" (p. 478, Gilbert, 1960).

Gilbert seems both right and wrong. He is certainly correct in suggesting that instructional designers and developers who adapt a "teaching machine" will try to fit the teaching program to it. However, the new functionalities such a device makes available motivate its adoption and instructional adaptations to it.

It is less certain that such adaptations are to be avoided. They might well be enthusiastically sought, just as printed textbooks were sought long ago. If properly applied, technology should improve—if not revolutionize—the effectiveness and efficiency of teaching programs. It is up to researchers, developers, and instructors—not the technology itself—to see that it does.

Finally, there is the Columbus effect. In keeping with technologies that made carriages go without horses and telegraphs transmit without wires, the Columbus effect will doubtless apply to our efforts to provide tutorial instruction without humans. We envision the development of personal learning associates and are building toward them. However, just as Columbus headed for the East Indies and ended up with something entirely unexpected, we may end up with something as unforeseen and different from horseless carriages and wireless telegraph as automobiles and radio. Nonetheless, making education, training, and problem solving aids as affordable and universally accessible as possible seems as good a start as any.

Illustrations

Figures

Tables

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Abbreviations

ADL	Advanced Distributed Learning
APG	Airplane General
CBI	computer-based instruction
CORDRA	Content Object Repository Registration/Resolution Architecture
DTIC	Defense technical Information Center
ICW	Interactive Courseware
IETM	Interactive Electronic Technical Manual
IMI	interactive multimedia instruction
IMIS	Integrated Maintenance Information System
ITS	intelligent tutoring system
JKDDC	Joint Knowledge Development and Distribution Capability
NTIS	National Technical Information Service
OUSD(P&R)	Office of the Undersecretary of Defense for Personnel and Readiness
R&D	research and development
ROI	return on investment
SCORM	Sharable Content Object Reference Model
TO	Technical Order
TR	Technical Report

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14. ABSTRACT

The Office of the Undersecretary of Defense for Personnel and Readiness (OUSD(P&R)) established the Advanced Distributed Learning (ADL) Initiative in 1997 to assist the military Services in making "learning" (education, training, and performance/decision aiding) available on-demand, anytime and anywhere. ADL was intended to capitalize on opportunities provided by research on learning technology. These opportunities suggested that technology could make the benefits of individualized tutoring affordable by reducing the costs and increasing the effectiveness of learning. The empirical research on which these opportunities were based continues to be relevant and is reviewed in this report.

15. SUBJECT TERMS

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