# A Cognitive Approach To *e*-Learning

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**ABSTRACT**

Like traditional classroom instruction, distributed learning derives from passive training paradigms. Just as student-centered classroom teaching methods have been applied over several decades of classroom instruction, interactive approaches have been encouraged for distributed learning. While implementation of multimedia-based training features may appear to produce active learning, sophisticated use of multimedia features alone does not necessarily enhance learning. This paper describes the application of cognitive science principles to enhance learning in a student-centered, distributed learning environment.

The basis of the application of cognitive principles is the innovative use of multimedia technology to implement *interaction elements* that support scenario-based training. These simple multimedia interactions are used to support new concepts and later combined with other interaction elements to create more complex, integrated practical exercises. This technology-based approach may be applied in a variety of training and education contexts, but is especially well suited for training of equipment operators and maintainers.

Based on classroom training material developed by the US Army for operation and maintenance of wireless logistics communications equipment, the Pacific Northwest National Laboratory designed and developed an interactive, student-centered distributed-learning application for Combat Service Support Automated Information Systems Interface (CAISI) operators and maintainers. This web-based training system is also distributed on CD media for use on individual computers, and material developed for the computer-based course can be used in the classroom. In addition to its primary role in sustainment training, this distributed learning course can complement or replace portions of the classroom instruction, thus supporting a blended learning solution.

**ABOUT THE AUTHORS**

**Frank L. Greitzer** has a BS in mathematics and a PhD in mathematical psychology with a concentration on human learning and memory. A chief scientist at the Pacific Northwest National Laboratory (PNNL), Dr. Greitzer has managed R&D programs in training and advanced distributed learning applications developed for the Department of Energy, the Federal Aviation Administration, the International Atomic Energy Agency, and the US Army. Dr. Greitzer's interests in the area of training focus on applying cognitive principles and advanced technology to develop innovative, interactive, student-centered education and training.

**Douglas M. Rice, Sharon L. Eaton, Michael C. Perkins, Ryan T. Scott, and John R. Burnette** are members of the multidisciplinary team at PNNL that developed the CAISI e-Learning application. Mr. Rice served as technical lead for system design and development; Ms. Eaton was the technical editor and instructional designer; Mr. Perkins was the graphic designer/developer; Mr. Scott supported multimedia development and integration; and Mr. Burnette served as an in-house subject-matter expert.

**Sarah R. Robertson** has a BS in Business Administration and leads the CAISI training development team effort for the US Army CAISI Project Office and serves as the Contracting Officer/Technical Representative for the CAISI e-Learning development project being conducted for the US Army by PNNL.

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## INTRODUCTION

Despite the great promise of the technology and Internet revolution of the 1990s, electronic learning (*e*-Learning) has not yet achieved its potential. Although the foundation for next-generation learning has been in place since the mid-1990s, today less than 15% of industrial training is delivered via computer, without an instructor present (Galvin, 2002).

There are many possible reasons for this: (a) the technology is still young and immature and a culture-change is needed for its acceptance; (b) industry and government standards are still being worked out; (c) demonstrations of training effectiveness have not been widely reported to validate the methods and claims about the advantages of *e*-Learning; (d) economic factors—arguments based on return on investment—still need to be resolved and potential beneficiaries of the technology need to be convinced about the economic viability of the approach; (e) difficulty for instructors to transfer knowledge into the new *e*-Learning medium; (f) fear of trainers losing their jobs to computer-based training; (g) and finally, technology-based training applications may fail to reach their expected potential because the technology is not employed effectively.

Early attempts to employ technology in education resulted mostly in automating existing courseware, with computers acting as electronic flashcards. Adhering to this behaviorist computer-based instruction paradigm, many *e*-Learning applications still tend to reflect passive, linear, expository teaching methods in which material is presented for students to read, then students are tested for rote memorization; and the cycle is repeated.

Many online training applications that employ state-of-the art multimedia are not successful. Implementation of multimedia-based training features that allow students to interact with simulations, animations, video, and sounds may give the impression of engaging the student in more active forms of learning, but sophisticated use of multimedia features does not necessarily produce the desired effect. As Michael Allen (2002) observes in a well-articulated article advocating discovery-based *e*-Learning: "Lurking behind many of today's slick delivery systems are shop-worn, passive learning paradigms that Socrates spurned in the fifth century B.C."

On the other hand, some have argued that active (or interactive) paradigms are not the answer either. In a slightly irreverent article in *e-Learning Magazine*, Thalheimer (2003) argues that interactivity is "too simplistic" a concept to be useful in instructional design, and that "it can even be dangerous." Thalheimer ponders what exactly accounts for successes in employing interactivity in training, citing psychological research to assess possible underlying factors. For example, citing the finding that asking questions about some learning points in the instructional message improves memory only for those learning points (Nungester & Duchastel, 1982), he concludes that interactivity (in the form of prompting for large numbers of responses) is not a useful construct. However, these findings seem to imply only that asking questions about certain learning points within a body of material does not enhance memory for other, unrelated learning points within the material. In fact, there is ample evidence that exposure to some semantically-related material actually improves memory for other related material—presumably due to rehearsal or other organizational processes (Borges & Mandler, 1972; Greitzer, 1976).

Thalheimer also considers the effect of reward/reinforcement (e.g., through feedback) on interactive learning. Citing the finding that feedback has no effect on correct answers (e.g., Hogan & Kintsch, 1971), he concludes that feedback is not an underlying factor in interactive learning. However, information inherent in feedback on incorrect answers enables learners to correct their answers (i.e., improve

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performance, *learn*). This supports, rather than refutes, the role of feedback and interactivity.

Thalheimer concludes that retrieval practice is the important, underlying construct that accounts for successes in interactive training. Certainly, retrieval practice is an especially important construct in training contexts that employ questions as a primary means of engaging the learner. It is clear, however, that interactivity applies to a much broader context. For example, an important contribution of interactivity concerns opportunities to develop familiarity with functional and operational features of equipment, especially when access to the real equipment is limited because of availability, safety, or other factors.

In our view, the most important prescription for the use of interactivity is that the design of active learning applications should be grounded in principles of cognition. Interactive examples should be selected that meet criteria of relevance, realism, and importance (those that specifically address learning objectives). Design of interactive features should focus on providing opportunities for students to learn (through virtual experience) the functional value of the material by working directly with the content.

The purpose of this paper is to discuss principles that form the foundation of a cognitive approach to student-centered, interactive *e*-Learning and to describe specific methods and techniques that have been employed in developing an *e*-Learning application based on these principles.

## COGNITIVE PRINCIPLES AND THEIR APPLICATION

Greitzer (2002) outlined a set of cognitive principles to guide the design of active learning applications. Table 1 summarizes these principles and lists methods and techniques that were employed to implement these principles in interactive training. The foundation for the design and implementation of these principles is the notion of *interaction elements*, which form the basis of our student-centered/active learning approach. Interaction elements are basic objects for engaging the learner through ideas, problem-solving activity, or interaction. By associating specific learning objectives with interaction elements, the instructional designer can transform them into *learning objects* that transcend their original purpose and enable their re-use by other courses that call upon the same or similar learning objectives.

These ideas and methods are discussed below.

**Table 1. Cognitive Principles and Methods Employed in *e*-Learning Design/Development**

| Cognitive Principle | Design/Approach | Re-usable Implementation |
|---|---|---|
| **Stimulate Semantic Knowledge**—Relate material to the learner's experiences and existing semantic knowledge structures to facilitate learning and recall. | Interaction elements:<br>• Did You Know?<br>• Heads Up | Training content independent of user interface |
| **Manage Cognitive Load**—Organize material and build up gradually from simple to complex concepts. | • Simple → Complex<br>• Train and test in small chunks | Interaction elements focused on specific learning objectives |
| **Problem-Centered—**Immerse learner in activities that enable learners to work immediately on meaningful, realistic tasks. | • Checkpoint interaction elements | Flash, ShockWave, QTVR |
| **Interactive—**Emphasize interactive, problem-centered activities that require manipulation of objects to encourage active construction/processing of training material to help build lasting memories and deepen understanding. | • Multimedia objects<br>• Integrated Exercises<br>• "Game" objects | Interactive scenarios built from combinations of interaction elements |
| **Frequent and Varied Practice**—Implement a variety of interactive problems for practice, exercises and tests that aid understanding and provide feedback. | • Optional quiz items and interactions<br>• Random selection of alternative instances of quiz and test items | Multiple-use interaction elements for test and practice |

**Interaction Elements**

The emergence and maturation of electronic media-based technologies in recent years has made it increasingly feasible and cost-effective to apply the cognitive principles and student-centered training concepts to *e*-Learning development. Our cognitive-based, student-centered approach created a specific set of training features to form a foundation for the *e*-Learning development. Since they are focused on student-centered/active forms of training, we refer to these features as *interaction elements*.

The interaction elements are all identified with distinct icons that alert the student that these training aids are available, accessible simply by the click of a mouse (see Figure 1). Rather than forcing such material on the student, these aids are discretionary/optional in our user-centered format in which students control their own navigation, and levels of exploration, through the course.


**Figure 1. Icons used for Interaction Elements.**

The following paragraphs describe cognitive principles and the design of interaction elements to support cognitive-based *e*-Learning.

**Semantic Memory and Organization**

**Training Relevance**

Research on cognitive processing—how information is stored, retrieved, and represented (e.g., Atkinson and Shiffrin, 1968; Tulving and Donaldson, 1972; Lindsay and Norman, 1977)—points to the importance of helping students develop well-connected knowledge structures. When the knowledge structure for a topic is large and well-connected, new information is more readily acquired; the richness of connections facilitates information retrieval. We tend to organize and categorize new information in terms of what we already know (i.e., our knowledge about the world, or semantic memory). Because information that ties in easily with semantic memories is easier to understand and to remember, presentation of new material in training situations should seek to tap into the learner's existing semantic knowledge structures. Showing how the new information or procedures relate to one's experiences will facilitate this classification/memory storage process and improve retrieval of the information.

Human memory comprises a very limited working memory (Miller, 1956), and effectively an unlimited long-term memory (Atkinson & Shiffrin, 1968). Associative processes and organizational processes play an important role in learning and memory. It is well known that humans exploit relationships among items being memorized, and that material being recalled tends to reflect these relationships regardless of whether or not the material was organized when presented (Anderson & Bower, 1973).

**Implementation Concepts**

What methods or features (interaction elements) have been employed to stimulate semantic knowledge structures? One type of interaction element links to general facts about the world (relating to semantic memory) that may be identified with parts of the training content. Sometimes referred to as "factoids," this information is not critical to understanding the material but may help to enrich the student's experience and strengthen the memory representations of the material. We use the label ***Did You Know?*** to identify these interaction elements. Another type of interaction element helps to strengthen semantic knowledge and aid retrieval by putting material in a broader context and pointing out concepts that are especially relevant or important, particularly those that will come up again in subsequent training lessons. Such associations are called out for the student as a ***Heads-Up*** that the information will have particular significance. Lesson objectives and higher-level module objectives are made available through similar types of interaction elements.

**Cognitive Load**

**Training Relevance**

Knowledge can be viewed as schemas representing relationships among facts and concepts. Schemas are organizational units that allow many elements of knowledge to be treated as a single element in working memory, which reduces demands on working memory compared with controlled, conscious processing that requires higher cognitive loads (Schneider & Shiffrin, 1977; Shiffrin and Schneider, 1977).

If a learner has acquired appropriate automated schemas, cognitive load will be low; but if the material has not become organized into structured schemas, then cognitive load will be high, as the many elements that comprise the material must be considered discrete. In short, learners have difficulty with instruction unless they are already fairly acquainted with the material—which leads to a paradox (Carroll, 1987): “To learn, [users] must interact meaningfully with the system, but to interact with the system, they must first learn.” (p. 77). Caroll (1987; 1990) suggests that an effective approach to address this paradox is to encourage learners to work immediately on meaningful, realistic tasks; to reduce the amount of reading and other passive activity; to use prior knowledge to advantage; and to help make errors less traumatic and pedagogically productive.

**Implementation Concepts**

The challenge of reducing the learner’s cognitive load during training was a specific focus of our training system design. One aspect of our approach was to begin with simpler material and gradually move to more complex materials. A related strategy is to train in small chunks, guide student practice, and incorporate worked examples (e.g., Carroll, 1994). We implemented these types of features in highly focused sample problems (***Checkpoint*** interactions) on material that was just presented. ***Checkpoint*** interactions promote practice in manipulating objects to produce a correct outcome; feedback is provided and the learner can repeat problems as desired.

### Problem-Centered Activities

**Training Relevance**

Problem-centered training helps to instill learning experiences that are intrinsically rewarding, relevant, and enjoyable for the student (Wilson, Jonassen & Cole, 1993). Engaging learners in problem-solving activities, rather than passively digesting course content, not only increases motivation but also compels them to think about, organize, and use the information in ways that encourage active construction of meaning, help build lasting memories, and deepen understanding.

**Implementation Concepts**

The highly focused, interactive examples implemented as ***Checkpoint*** interaction elements provide opportunities for learners immediately to practice applying concepts. This is particularly useful when training technicians who are responsible for operating and maintaining equipment. Multimedia objects developed to simulate the real equipment can be integrated into interaction elements that illustrate particular concepts or operational states. For example, ***Checkpoint*** interactions can be developed to exercise the learner’s knowledge about proper procedures for assembling, operating, and troubleshooting equipment. Simulations allow students to take more risks and even make mistakes. By experiencing and recovering from failures in a controlled environment, they expand their knowledge and gain confidence.

### Interactivity

**Training Relevance**

Interactive experiences in applying what has been learned should be presented in realistic contexts. When carefully designed, quizzes and interactive exercises can provide unique and valuable opportunities for learning through exploration and discovery. The key to this enhanced type of performance testing is incorporating student-centered activities involving manipulation of objects to solve problems (i.e., working directly with the content rather than answering factual questions that only require rote learning).

**Implementation Concepts**

***Checkpoint*** interactions offer exactly the sort of interactivity that learners need to develop understanding and skills to operate and maintain equipment. Learners interact with virtual representations to see how they function and to get feedback and learn-by-doing (especially by making errors!). Interactive simulations also help to lower the costs of training on expensive/delicate equipment.

Interaction elements provide the foundation for problem-centered activities that promote deeper understanding of the material. Feedback and unconstrained access to interact with the problems implemented within interaction elements help the learner see and experience the correct solution. A distinct aspect of our approach was to implement interaction elements as building blocks to support problem-centered activities that grow in complexity from simple test of facts to more complex application of concepts and procedures in solving problems. We incorporated simple interaction elements into this strategy by using them individually when specific concepts are introduced and then re-using and combining them later to support more complex concepts that require integration of knowledge and skills. Many basic interaction elements were re-used to provide interactive quizzes and module tests.

**Frequent and Varied Practice**

**Training Relevance**

We have described schemas as basic organizational units for learning. Learning occurs when we set up new memory schemas that relate to existing ones. Through practice, the acquired knowledge can be encoded to require a minimum amount of cognitive resources to produce or apply: it becomes automated. Norman (1976) observes that practice helps to define a concept more thoroughly, in all its ramifications (not just in its basic principles). Knowledge in the form of a general principle may be applied to a variety of situations, but sometimes only with a large amount of mental effort. Gaining practice with a varied set of problems helps us develop and remember particular schemas (e.g., rules, sequences, configurations) that can then be applied very efficiently.

**Implementation Concepts**

To provide more varied practice, we developed alternative versions of quiz and test items that could be selected randomly from a pool of questions. This ensures that students who retake tests will not always receive the same sequence of questions and problems.
Further, we employed a scenario-based approach to enhance the realism, relevance, and variability of the learning experience through integrated, practical exercises. Because the design and development of these exercises represents a critical aspect of our interactive student-centered approach to training, the design of interactive, scenario-based practical exercises is discussed in more detail in the next section.

## DEVELOPMENT OF INTERACTIVE FEATURES AND SCENARIO-BASED EXERCISES

The previous section described how cognitive principles may be applied to the design and development of specific training features such as interaction elements and interactive quiz/test items. The ***Did You Know?***, ***Heads-Up***, and ***Checkpoint*** interaction elements are inserted throughout the training material, focusing on specific concepts covered in specific lessons. Because proficiency in a subject area typically requires the learner to integrate knowledge over a number of topics and circumstances, the cognitive design principles should be applied on a broader scale to bridge across training modules and lessons. To this end, we have incorporated scenario-based integrated exercises into the *e*-Learning application to facilitate acquisition and exercise of a deeper level of knowledge and skills.

Figure 2 represents the general concept underlying the implementation of cognitive-based *e*-Learning development: first building small, highly-focused interaction elements to provide frequent drill and practice, then combining these as building blocks for larger, more integrated exercises.

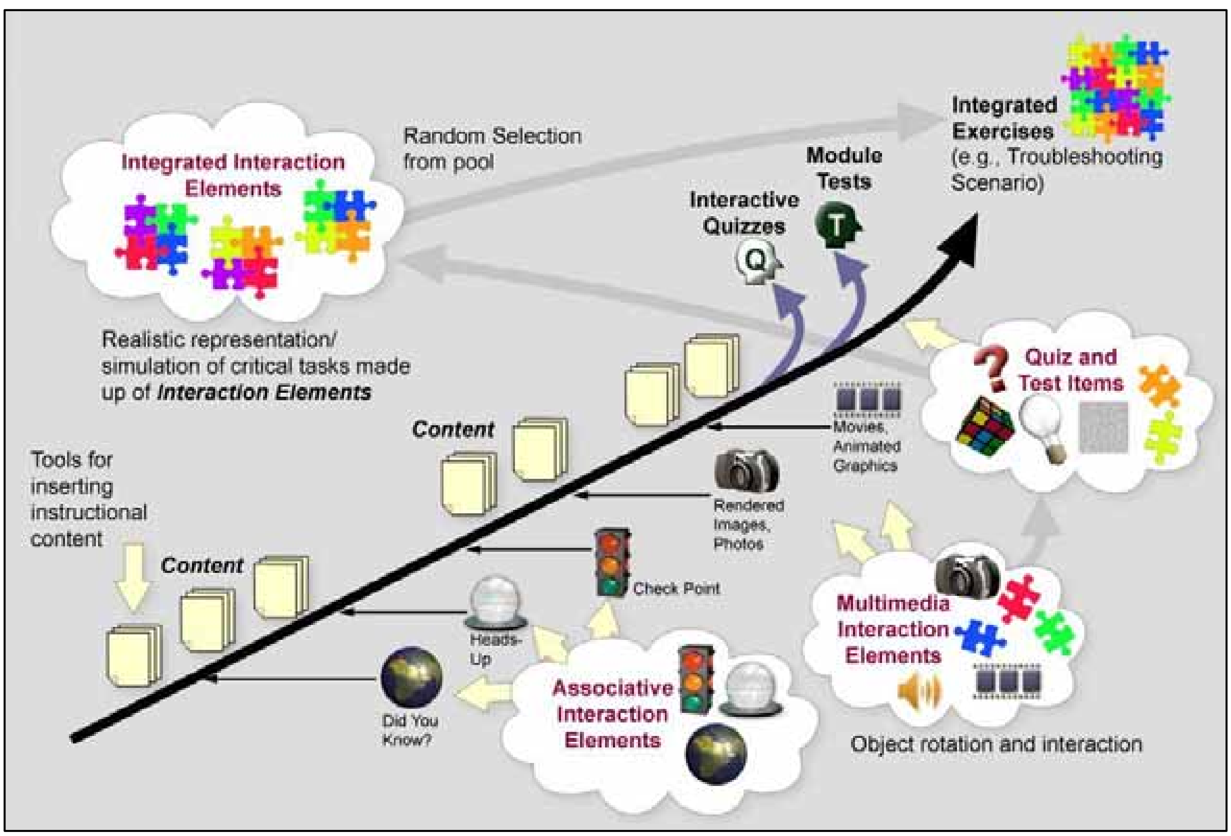



**Figure 2. Conceptual Framework for Cognitive-based *e*-Learning.**

More complex, integrated interaction elements are assembled from individual elements presented earlier in more focused or basic contexts. When the more complex problems are encountered later in training, their individual elements are therefore familiar. This allows the Integrated Exercises to focus on higher-level concepts required to apply knowledge to practical problems.

In this section we describe the development of interactive features, such as interaction elements, and their incorporation into more complex, integrated exercises.

**Multimedia Tools**

Tools to construct three-dimensional renderings of objects and flash interactions allow us to add to our collection of training aids (already comprising more traditional items such as photos, video, sounds, etc.). When teaching procedural knowledge (such as equipment maintenance and operation), high-fidelity object representations help establish well-connected knowledge structures. These more sophisticated interaction elements can be used effectively to support simulated interactions, demonstrations of relationships among objects, and basic building blocks for interactive student-centered learning. Multimedia tools used include Adobe Photoshop and Image Ready for image preparation, compression, and gif animation; Alias/WaveFront Maya for 3-D modeling, rendering, and animation; MacroMedia Director ShockWave Studio, Apple QuickTime, and Totally Hip LiveStage Pro for developing engaging movies, interaction elements and scenarios.

**Integrated Practical Exercise**

Interaction elements may be combined to create more complicated tasks that comprise sequences of activities and application of knowledge/skills in context, as required by integrated practical exercises. Implemented as extended scenarios, these integrated practical exercises test the extent to which students can apply knowledge and procedures learned earlier to problems that require integration of knowledge across lessons and modules. In essence, the integrated exercises are extended practical problems, composed of a series of interaction elements that are linked together within a given context, as defined by a realistic, practical scenario. Each step tests critical knowledge. Problems that comprise the steps in the integrated practical exercise scenario are chosen randomly from a pool so that specific performance requirements change as the scenario details unfold when the exercise is repeated. These non-static, realistic, complex interactions provide interesting and useful practice working with the equipment and applying troubleshooting procedures, which helps prepare learners for actual on-the-job experiences and responsibilities. Because the complex interactions are engaging, challenging, and relevant, we expect that learners will be more motivated to try them out repeatedly to improve their skills.

## APPLICATION

Cognitive learning principles and the approach described in the previous sections apply to a broad range of training topics and contexts. The exploitation of technology and multimedia in this approach makes it very appropriate for technical training. The use of rendered/interactive images, 3-D modeling, and movies is particularly useful for training technicians in equipment operation and maintenance, using computer based training or Web-based *e*-Learning. Because computer-based methods facilitate incorporation of varying learning experiences, this approach also can be productively employed in the classroom (computer-assisted instruction). It is therefore also relevant to blended training solutions that employ a combination of classroom instruction and *e*-Learning.

The *e*-Learning approach is particularly applicable to refresher training (also called sustainment training). Because many equipment-oriented, technician, and fabrication jobs have relatively high turnover rates, maintaining a well-qualified job force can be a very expensive proposition when training is delivered only through classroom instruction. Instead, many basic skills that have a significant cognitive component can be taught via *e*-Learning to reduce the number of class hours required.

Technician training, both in government and industrial contexts, is often described using three levels of instruction. Level I training typically entails an elementary introduction and orientation course that is delivered as a 3-4 hour class. Knowledge and skills required for Level I training can be effectively covered in a computer-based or *e*-Learning course without the time and geographic constraints of classroom instruction.

Level II training typically is required for operators and maintainers of equipment. Classes for Level II students may run from several days to a week or two, and they require "hands-on" activity and practice using or maintaining equipment. While traditional *e*-Learning has not been widely used for Level II training, the cognitive/interactive approach described here can be applied effectively to Level II training that has a high cognitive component, possibly in combination with a significantly reduced amount of in-class time (blended training). Level III training focuses on highly technical and hands-on instruction for personnel who will be responsible for repairing equipment; most industry trainers believe that this level of training requires substantial hands-on, in-class instruction.

**Equipment Operation and Maintenance Training**

We employed cognitive training principles in the design and development of a training application for the US Army's Combat Support System Automated Information System Interface (CAISI). The CAISI provides a wireless communications capability that allows various Army systems to communicate across the battlefield through their classified tactical packet network (Colacicco, 2001). The CAISI Project Office at Ft. Belvoir, VA, developed the training content and conducts classroom training as part of the fielding activities. In this two-tiered course, operators receive four hours of Level I classroom training that prepares them to set up, transport, break down, operate and recognize maintenance problems both in garrison and in the field. Administrators, or System Support Representatives (SSRs), receive both Level I and Level II training that includes in-depth instruction on network administration, security, maintenance procedures, and troubleshooting, requiring 40 hours of classroom instruction. Taught in a "lab-like" setting, approximately twenty soldiers work with actual equipment in small teams of two-to-four soldiers. To pass the course, students must pass a written exam and demonstrate the ability to set up the equipment and make it operational in a timed performance test.
Concurrent with the CAISI fielding and classroom training development, we developed an *e*-Learning application for Level I and Level II sustainment training. This Web-based training system is also distributed on CD for use on individual computers, and material developed for the computer-based course is also available for use in the classroom.

**Multimedia Implementation**
The Level II CAISI *e*-Learning course has thirteen training modules, each of which contain from two to nine lessons. The application contains a total of 257 rendered images (static and animated), constructed from 146 individual 3-D models. The models and images were constructed mostly from actual equipment; however, some details and modifications due to upgrades of equipment were produced from technical documentation. In nearly all cases, rendered images were used instead of photographs that came with the classroom training support package (source materials used in converting the classroom course to an online course). We also developed 45 movie/interactive multimedia files and 25 Checkpoint interactions.

As a supplement or alternative to photographs, rendered images have few disadvantages and several advantages over photographs. For objects rendered to support the CAISI training, time to produce 3-D models of equipment varied from 1-2 hours for simple devices such as panel antennas or the power supply, to 4-8 hours for more complex objects. While photos are cheaper to produce, they contain artifacts from gradations of tones and lighting effects, and the cost to produce 3-D rotational photographic images is comparable to that of 3-D rendered images. Also, for a given image quality, rendered images require smaller file sizes than photographs—offering an advantage in online performance. Thus, while the upfront costs may increase by 5%, lifecycle cost considerations turn the advantage to rendered images that yield better quality, flexibility, performance, and re-usability.

To illustrate, Figure 3 compares a photograph (left panel) and a rendered image (right panel) of the CAISI SSR transport case. Both images are comparable in file size (10-11 Kbytes), but the rendered image is of higher quality. In addition, renderings provide the developer complete control of lighting, angle- and field-of-view. While rendered 3-D models can be easily manipulated, photographs can only provide such flexibility if all such manipulations are planned and


**Figure 3. Photograph (left) and Rendering (right) of Transport Case.**

photographed in advance; otherwise, additional photo shoots must be scheduled. During the development of CAISI training, there were several modifications to equipment that required either new photographs, modified rendered images, or both. The choice to produce renderings instead of photographs ultimately saved time and labor hours when equipment modifications occurred.

When Web-based performance is an issue, smaller file sizes associated with rendered images can help improve the download time/throughput of the application—an important consideration from the learner's point of view. This is even more important when the *e*-Learning application uses object virtual reality (VR). As with still images, two methods are available: photography and rendering 3-D models. Photography is a labor-intensive method of developing object VR, and any change to the final product requires a complete re-shoot. While initial setup and labor required to render 3-D models is comparable to that of photography, modeling provides added advantages of flexibility and quality. In addition, modeling allows the developer to construct images of objects that may not exist or are not available for photography. For these reasons, we used 3-D modeling to construct images of the equipment so that the animated, rotational and other modeled images were available for interactive portions of the training.

**Some Interaction Elements Used in CAISI Training**

Figure 4 shows an example of a ***Did You Know?*** interaction element that describes an earlier version of CAISI. By providing some additional context, this information may help the learner relate more critical content to existing semantic memory structures or facilitate creation of such structures. Figure 5 shows a sample ***Heads-Up*** interaction element that informs the learner about key points or helps to establish links or relationships across training modules. Figure 6 shows a sample ***Checkpoint*** interaction that allows learners to exercise their knowledge about the meaning of different lights on the modem. This ***Checkpoint***, like most others that were implemented, is not only embedded within the relevant training content, but is also placed in the pool of test items that is used to generate quizzes, module tests, and the final exam. Test items for quizzes, module tests, and a final end of course examination are all randomly selected from associated test item pools. Exposure to these items as well as the interactive ***Checkpoints*** makes it likely that, by the time learners encounter these questions or problems in an integrated exercise, they will be relatively familiar with the "mechanics" and better able to focus on the concepts or strategies being tested in the more complicated integrated exercise.

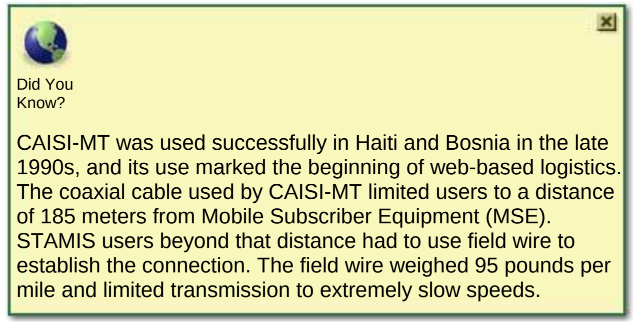
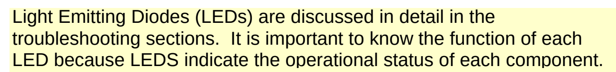



**Figure 4. A *Did You Know?* interaction element that pops up when its icon is clicked.**

**CAISI Integrated Exercise**




When Level II learners have passed the module tests

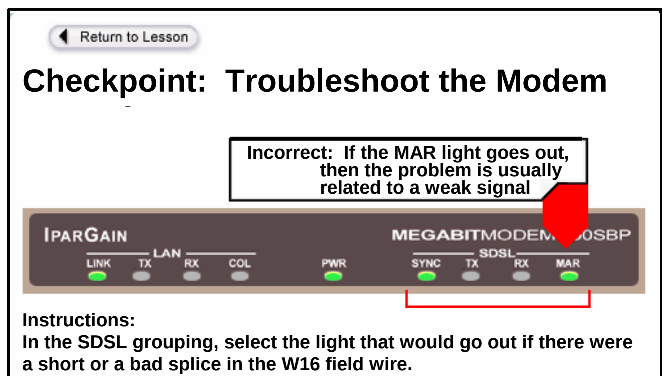



**Figure 6. A Checkpoint interaction element.**

**Figure 5. An example of a *Heads Up* interaction element.**

and the end of course examination, they can take the Integrated Exercise—the final step in the process of getting credit and certification for the course. The Integrated Exercise requires the learner to pull together knowledge gained from different course modules and apply that knowledge to real, practical problems. The Integrated Exercise covers major CAISI activities of Planning and Deployment, Equipment Setup, and Troubleshooting. Variability in the Integrated Exercise is achieved by randomly selecting certain questions or scenario events from sets of alternative events: The resulting complete scenario comprises 120 different possible sequences.

The troubleshooting activity is the most important component of the Integrated Exercise because it addresses knowledge and skills that are difficult to teach in a classroom setting and most likely to need recurring, refresher training. Ten different troubleshooting scenarios taken from actual field experience are employed in the Integrated Exercise. The learner encounters one of these, randomly selected, each time he or she takes the exercise. Performing the troubleshooting requires a deeper understanding of the equipment, network architecture concepts, and testing methods—i.e., it is a predominantly cognitive activity. The breadth of troubleshooting problems covered in the exercise and its highly interactive nature provide an opportunity to sharpen the learner's skills that is not currently afforded during the classroom training.

## IMPACT

In addition to providing refresher training for personnel trained in the classroom, the *e*-Learning approach described here has also impacted classroom instruction. Some multimedia features have been incorporated into the classroom-based training to help reduce classroom instruction time and to augment or enhance the classroom experience. For example, rendered images were substituted for photographs in the classroom training materials. Interaction objects such as 3-D renderings, multimedia movie files, and animated .gif files developed for the *e*-Learning application are also available for use as classroom demonstrations. These multimedia files, particularly those that demonstrate assembly of equipment and conditions associated with troubleshooting procedures, are useful in showing examples that may be difficult, time-consuming, or impossible to create with actual equipment in the classroom.

## CURRENT WORK AND FUTURE PLANS

Currently, we are conducting research and development on enhancing and streamlining the interactive scenario-development process to reduce costs and increase generality and reusability of this important component of the cognitive-based *e*-learning approach. One aspect of this effort is addressing implementation concepts and requirements—and instructional design impacts—of reusing the content of interaction elements and more complex integrated exercises within the framework of the Department of Defense's Advanced Distributed Learning (ADL) Sharable Content Object Reference Model (SCORM)—for more information on ADL and SCORM, see http://www.adlnet.org/.

Looking ahead, we envision that the *e*-Learning version of the course could be used to deliver training content prior to and during fielding, thus reducing the amount of classroom time that will be required. Blended learning environments might be employed such that, for example, with approximately 16 hours of *e*-Learning accomplished by students at their convenience, the classroom-based instruction could be reduced from five days to less than one day (comprising hands-on activities). Such compression ratios are in line with that which has been reported in the literature (e.g., Hall, 1997). Besides cost savings from reducing instructor and student labor hours, benefits would also result from reducing or eliminating the need to distribute reference material, enabling easier and timelier updates of course material in electronic form, and providing students ready access to up-to-date course material.

## CONCLUSIONS

More than ever before, new and more accessible technologies—and new types of content—are helping to redefine traditional classroom training and to create new opportunities for learning. To be sure, bringing training to students through a computer network instead of sending them to schoolhouses represents a major cultural change for business, industry, and the military. Indeed, a transformation in the approach to training is needed to overcome the limited throughput of traditional classroom instruction. This transformation is in progress, particularly in the military. A recent article in *Training & Simulation Journal* recognizes the need for a change in the training business and culture in the military: "The reservist would be able to complete the knowledge portion of a course while at home, during his off-duty time or even during drills at the reserve station. When they come to the training center, they would complete the performance training for the course in an abbreviated fashion." (Papp, 2003; p 6).

In this paper, we have described cognitive principles and methods for applying these principles to the design and development of a training experience that is more interesting, relevant, and effective—not only for electronic learning, but also for traditional classroom-based instruction. We believe that application of these principles will facilitate the transformation in training.

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