Scenario-Based Training on Human Errors Contributing to Security Incidents

Frank L. Greitzer
Pacific Northwest National Laboratory
Richland, WA 99352
frank.greitzer@pnl.gov

Daniel J. Pond
Los Alamos National Laboratory
Los Alamos, NM 87545
pond@lanl.gov

Marjorie Jannotta
The Human Factor Research and Consulting, Inc.
Lafayette, CO 80026
mjannotta@comcast.net

ABSTRACT

Error assessment studies reveal that "human errors" are often the consequence of unsuitable environmental factors, ineffective systems, inappropriate task conditions, and individual actions or failures to act. The US Department of Energy (DOE) initiated a program to determine if system-induced human errors could also be contributing factors to security incidents. As the seminal basis for this work, the Enhanced Security Through Human Error Reduction (ESTHER) program at Los Alamos National Laboratory (LANL) produced a contributing factors data set and systems categorization for security related incidents attributed to human error. This material supports the development and delivery of training for security incident inquiry officials. While LANL's initial work focused on classroom training, a collaborative effort between LANL and Pacific Northwest National Laboratory (PNNL) has focused on delivering interactive e-Learning training applications based on ESTHER principles. Through training, inquiry officials will understand and be capable of applying the underlying human error control concepts to new or novel situations. Their performance requires a high degree of analysis and judgment to accomplish the associated cognitive and procedural tasks. To meet this requirement, we employed cognitive principles of instructional design to engage the learner in interactive, realistic, problem-centered activity; we constructed scenarios within a guided-discovery framework; and we utilized learner-centered developmental sequences leading to field application. To enhance the relevance and realism of the training experience, we employed 3-D modeling technologies in constructing interactive scenarios. This paper describes the application of cognitive learning principles, use of varied media, and the implementation challenges in developing a technology-rich, interactive security incident training program that includes Web-based training.

ABOUT THE AUTHORS

Frank L. Greitzer has thirty years of R&D experience in areas of cognitive psychology, user-centered design, expert systems, and advanced performance support and training. After receiving a BS in mathematics in 1968 from Harvey Mudd College and a PhD in mathematical psychology in 1975 from the University of California, Los Angeles, Dr. Greitzer held university teaching positions and R&D positions in the federal government and the aerospace industry prior to joining the Pacific Northwest National Laboratory (PNNL) in 1992. As a principal scientist at PNNL, Dr. Greitzer has managed a variety of R&D programs, including advanced distributed learning and training applications. Dr. Greitzer's current research focus is on advanced training technology and applications of cognitive science to support information analysis.

Dan Pond, creator of ESTHER, is a Technical Staff Member in the Decision Applications Division at Los Alamos National Laboratory. He earned his doctorate at North Carolina State University and has more than 25 years experience as a human factors/system safety professional in industry, academia, and government. His professional accomplishments have led to invited membership in Sigma Xi (the scientific research honor society) as well as inclusion in Who's Who in America and Who's Who in Science and Engineering, among other biographical publications.

Marjorie Jannotta is an Organizational Development consultant and president of The Human Factor Research and Consulting, Inc., founded in 1990. She is a curriculum designer who also conducts organizational research. Her Ph.D. is in Adult Learning and Research from The University of New Mexico, where she was an adjunct associate professor in Organizational Learning and Training Technologies. She is now part of the National graduate education faculty at Lesley University in Cambridge MA. Conference topics have included applied research models and self-directed applied learning. She has produced award-winning training programs that combine the principles of Adult Education and Instructional Systems Design.

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INTRODUCTION AND BACKGROUND

It is widely accepted and documented that many mishaps of various types are inadvertent or unintentional and that human errors underlying these mishaps often form patterns of recurrence when examined over time (Pond and Leifheit, 2003). Recognition and explication of these patterns can make it easier to identify many direct causes and contributing factors to human error in the security arena. Consequently, the effects of error can be ameliorated by changing the environments, systems, and procedures that foster their occurrence. At the United States Department of Energy (DOE), this cycle of error identification, correction, and impact of correction leads to important "lessons learned" that can reliably be applied beyond a pilot or study site.

In keeping with protocols emerging from the field of human error analysis, there is a need to examine those security-related errors that are unintentional (such as "forgetting") as well as those which are intentional but incorrect. There is also a need to distinguish these human errors from deliberate and malicious breaches (such as deliberately violating a procedure in the interest of ease or expediency), which are addressed through separate programs. Further, in reviews of the circumstances surrounding an incident of security concern, the DOE[1] makes a distinction between inquiries and investigations: An inquiry focuses on determining whether an infraction, violation, or a compromise or potential compromise has occurred. An investigation, which is conducted by law enforcement entities, focuses on whether or not laws have been broken. Here, we are concerned with the training of security incident inquiry officials on human error awareness.

Typically, most security incident reports address only direct causes—e.g., equipment/material failure, external phenomena such as energy blackouts, personnel decisions/action, non-malevolent breach of proper action, and acts that are willfully malevolent.[2] The Enhanced Security Through Human Error Reduction (ESTHER) program at Los Alamos National Laboratory (LANL) aims to identify more specific, underlying factors that contribute to human errors in security incidents. The ESTHER program has produced and tested a system for examining security related incidents attributed to human error. The ultimate result of this system is an aggregated data set that will figure prominently in developing "lessons learned" protocols to reduce the likelihood of human error in security events across the DOE.

Drawing from research on safety errors and documentation in other fields, the ESTHER program identified an overarching set of "direct causes" that reflect the surface-level reason(s) for human error; that is, the most obvious causes and those usually initially reported by respondents during the inquiry process. ESTHER research then focused on compiling an evolving set of factors contributing to these direct causes. A set of 28 contributors was identified, divided into four categories:

- Data Flow (e.g., information, system status/feedback, procedures/directions)
- Work Setting (e.g., distractions, environment, management systems)
- Work Planning/Control (e.g., job pressure, task difficulty, task aversion, experience/skill)
- Employee Readiness (e.g., preoccupation, fatigue, illness, misperception, memory).

The contributing factors and direct causes are collectively housed in an on-line form managed by the DOE's Incident Tracking and Analysis Center (ITAC). Security officials across DOE sites use (or will soon use) the ITAC form when reporting the results of security inquiries. The reported results of security inquiries will later be aggregated across sites for analysis by human error specialists, with the ultimate

[1] Applicable DOE references: DRAFT DOE M 470.S-7, Safeguards and Security Program References; and DOE O 471.4, Incidents of Security Concern, 3-17-04.

[2] Such direct causes frequently (and incorrectly) have been labeled "fundamental" or "root" causes.

aim of creating effective interventions to diminish the occasions for human error.

To promote accurate reporting by security inquiry officials, a training program has been initiated to raise awareness of human error, support skill development, and practice identifying cause and contributors to error using ESTHER terms. While LANL's initial training efforts focused on classroom instruction, a collaborative effort between LANL and Pacific Northwest National Laboratory (PNNL) has begun to complement classroom-based workshops with interactive computer-based training. This paper describes the philosophy, approach, and implementation of this course.

TRAINING NEEDS AND REQUIREMENTS

A critical objective for security inquiry officials is that they gain an appreciation of the necessity to re-engineer how they approach, think about, and document data collected during a security inquiry. Their documentation needs to be in a form that is accessible, consistent, and meaningful across DOE sites. It also needs to be in a form that enables subsequent analysts to accurately identify causes and contributors to human error. Documentation, combined with later analysis by human error specialists, must afford ample information for correcting systemic contributors to repeated, frequent, or high consequence security errors. This represents a significant change in scope of responsibility for the learners and has impact on the collective and individual attitude regarding the inquiry process and skill development.

Because of the major change that is required in documentation practice, the course developers and the client agreed that a classroom training workshop was necessary to introduce inquiry officials to the concepts of human errors as contributing factors to security incidents. Personal contact engages students in discussions among themselves and with experienced instructors who can enhance motivation and awareness. However, since security inquiry officials are located at numerous and geographically diverse DOE sites, there are significant costs and logistics challenges in providing initial and refresher training to the officials and their management. Thus there is a need to augment more traditional classroom instruction with distributed or self-directed learning with take-home training material that enables them to expand their understanding.

Over time it is expected that course requirements will come to depend more heavily on mediated instruction, and less on classroom instruction. This will free learners to master critical content materials at their own pace, and will enable recent hires to more quickly learn and apply skills that are expected to inform satisfactory job performance. As costs of developing mediated instruction are amortized, instructional costs per trainee will be reduced.

It was desired that the classroom-based and distributed instruction should be tightly integrated and consistent to ensure that learners receive maximum benefit. Thus, the design and development of the classroom-based and distributed instruction needed to take place in a coordinated, collaborative instructional design/development environment. For both modes of instruction, a critical need was recognized for learners to transfer their knowledge to real-world situations. Thus, there was a requirement to create learning material that was as realistic as possible. In-class and self-instructional material, including simulations and interactive scenarios approaching virtual reality (VR), were considered important anchors to learning and would augment and reinforce the hands-on instruction. To achieve this goal for effective transfer of training, a guided-discovery learning architecture was deemed most appropriate. The course objectives are:

- Learners will gain an overview of human error in the context of security and other fields including aviation and medical safety
- Learners will receive practice with, and opportunities to discuss applying ESTHER principles, contributors, and factors (terms) in realistic scenarios drawn from actual or composite security events
- After the training, learners will be able to discriminate among causes and factors in active security inquiries, document causes and factors accurately using ITAC, and describe other crucial information regarding an event
- Learners will receive practice in completing ITAC/DOE forms designed especially to capture environmental and personal factors that contribute to human error
- Learners will learn how to use self-directed distributed learning material to deepen their skills in discriminating among ESTHER factors and applying them correctly given realistic scenarios
- Learners will gain an appreciation of the DOE mandate to change how they conduct and document security incidents, as well as the skills to do so.

APPROACH

LANL and PNNL collaborated to develop the course for DOE security incident inquiry officials. LANL provided the subject-matter expertise, created 3-D interactive simulations of actual security incidents, and developed/conducted the classroom-based instruction, and PNNL designed and developed the distributed learning material and interactive 3-D models to support scenario-based instruction. The course uses several modes of delivery based on recognition of differing learning styles and potentials for distance and self-directed learning in the future.

Student Population

Inquiry officials are resident across the US at various DOE sites and come from a variety of backgrounds. In the first year of ESTHER, an estimated 15 officials will undergo training, and in the second year an additional 12. Ultimately a force of perhaps 50 will be trained across DOE sites.

Many DOE security officials have received training in criminal investigation from a background in traditional policing positions including military police, federal investigators, or state/municipal police departments. Ideally, to better apply ESTHER principles, security officials would also have a background in accident investigation. Still others come from miscellaneous backgrounds in the DOE complex and have moved into the position of security inquiry officials as a result of transfer or promotion. All officials receive special training in DOE security procedures, local security protocols, interviewing, documenting, and related skills.

Research reported by Isabel Briggs-Myers (1985) indicates that those learners from policing professions prefer fact-based, straightforward, and step-wise instruction, with a clear focus on how material is to be applied. This “just the facts” preference has informed ESTHER training approaches both in mediated and classroom design. The more varied educational design strategy will appeal to learners with various dominant learning styles, however, and ESTHER training does not solely rely on a single method that would appeal to an idiosyncratic group of learners.

Classroom Instruction

Classroom instruction follows principles and premises that are well known in the field of adult education. Designed as a workshop, the classroom instruction takes place in an informal setting that includes short lectures with visuals, small group activities, and an approach that builds on the experience and existing knowledge base of learners. The instructional team is made up of experienced educators with content expertise in security, human error assessment and mitigation, and classroom leadership in adult learning settings.

The one-day workshop uses a tightly paced learning format that includes discussion, overheads, video clips of human error “disasters” and examples drawn from outside the security industry. The first half of the day provides background, overview, and general information intended for a wide range of security and management personnel. The second half of the day focuses on detailed error assessments and reporting, and is intended for security incident officials and managers only. Links between errors and safety or other consequences are established, and learners grow to appreciate the necessity for change in the way they apprehend and document inquiry data. Learners actively engage in actual and composite cases in a “learning laboratory” and apply their learning throughout the session. They are also prepared to use mediated materials after the course for their own self-paced learning and deeper application of skills first developed in the classroom.

The one-day workshop is reinforced and expanded by a second, ½ day classroom session some weeks later, after learners have had the opportunity to practice skills in the field and deepen their understanding and application via self-instructional, mediated modules. The follow-on session helps to anchor learning, troubleshoot problems using the system in the field, and provides expanded conditions for practice and mastery of the ESTHER process. It also affords program evaluators an opportunity to further assess the effectiveness and usefulness of training.

Blended Learning Environment

As learners cannot be expected to apply a new system of discriminating among human error causes and contributors plus documenting them accurately after a one-day training session, they are provided with hard copy resources including background reading and references to use later; they also have access to course materials and interactive scenarios for practice in a self-directed learning environment. It is expected that a longitudinal “check-in” post-training system will help keep skills fresh and update learners on newly-developed learning scenarios, using self-directed mediated materials.

We recognize that providing a variety of learning media and modalities increases the likelihood that the instruction will be effective for a population of students with diverse backgrounds and learning styles. Thus, we seek to use the best of several available learning methods to accommodate a variety of learner aptitudes, equipment availability, cost considerations, and instructional content. The result, "blended training," affords modules of instruction that best match the learner, the content, and the available media. Often, orientation or context material is provided through one medium and another medium is selected for deeper learning, practice, drill, and mastery. ESTHER training optimizes blended training by triangulating instructional approaches using classroom, self-directed virtual/mediated methods, and field application. This varied pathway to learning is summarized in Figure 1. This blended learning environment has an additional benefit of allowing self-paced individual learning that serves widely dispersed populations through media available at the work site.

Guided Discovery Concept and Approach

Clark (1998) suggested four instructional architectures that reflect different assumptions about how learning takes place, the role of the instructor or instruction, and the final goal of the instruction. In the *Receptive* architecture, the learner is like a sponge that absorbs the instructional material. In the *Directive* architecture, the instruction sequences and chunks the material and provides frequent opportunities for learners to respond, and corrective feedback is provided. In the *Guided Discovery* approach, the instructional system facilitates learning by providing the coaching and support while learners work on problems adapted from actual work settings. In *Exploratory* learning approaches, the learner has maximum control in navigating through the instructional material that comprises information, examples, demonstrations and exercises.

Many traditional courses adopt the receptive or directive architectures: information is presented in a series of lessons, each of which is followed by some multiple-choice or objective questions to test the learner's understanding. In the guided discovery architecture, the goal is to construct a more experiential approach that presents realistic problems (also called scenarios) and to provide coaching to facilitate learning. As the learner gains knowledge and skill, the level of coaching diminishes. In contrast, the exploratory architecture is open-ended from the outset—i.e., no coaching is provided and the learner is left to his or her own devices to acquire the knowledge and skills that meet learning objectives.

There are many appropriate learning modalities for the willing adult learner. In the classroom, adults learn best from a well paced and practical sequence of learning, in a collegial and respectful climate. They want to be able to apply what they learn immediately. They learn well in small groups. ESTHER training incorporates these delivery methods into the face-to-face instruction. Adults also have optimal gain from

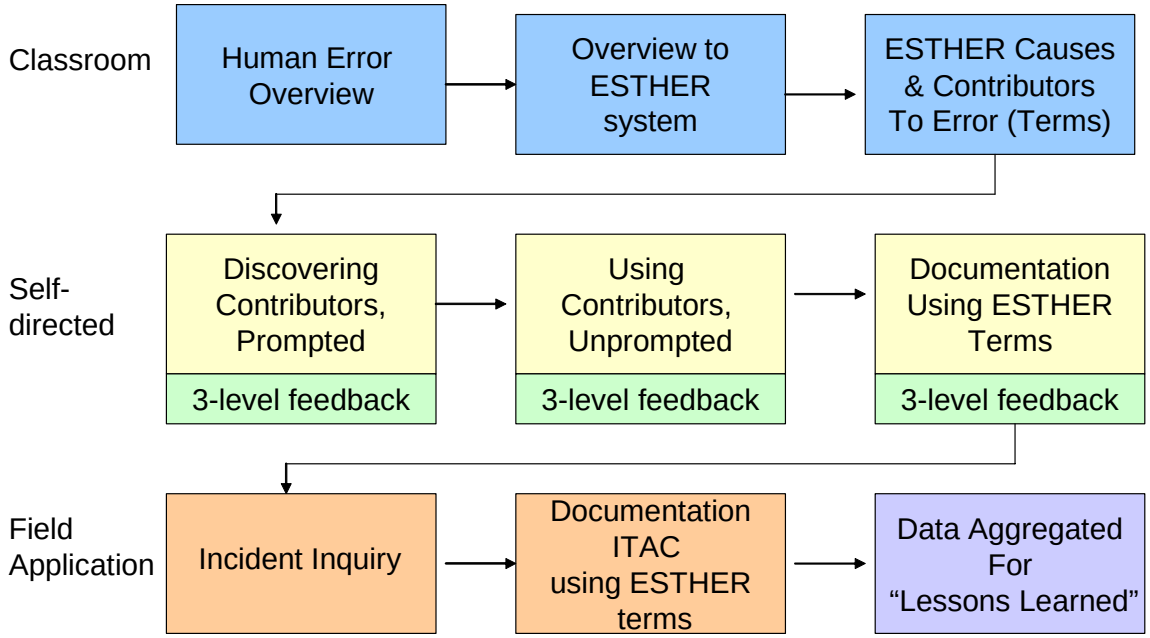

Figure 1. Pathways to learning for ESTHER training include classroom instruction, self-directed e-Learning, and experience in the field.

discovery learning, which allows them to build on what they already know in a simple-to-complex sequence, and base their learning in the context of their own life experience.

Greitzer and colleagues (Greitzer, 2002; Greitzer, Rice, Eaton, Perkins, Scott, Burnette, and Robertson, 2003; Greitzer, Merrill, Rice, and Curtis (2004); see also Merrill, 2002) have described instructional design principles for effective learning systems based on cognitive/learning research, leading to the following guidelines:

- Relate material to previous experience (learner uses relevant experience as a foundation for new knowledge)
- Demonstrate what is to be learned using interactive, problem-centered activities
- Engage learners by requiring them to use their new knowledge to solve real-world problems
- Progress from simple to complex tasks, guiding the learner with feedback and coaching early and gradually withdrawing this support as learning progresses
- Encourage learners to use the new knowledge or skill in everyday life (demonstrate knowledge in a relevant applied setting).

Guided Discovery learning is used as a primary method in the distributed learning application. We believe that this instructional architecture, more than the others, offers the greatest potential for cognitive skills training. This view is consistent with a number of extant instructional theories including Nelson's (1999) collaborative problem solving guidelines, Jonassen's (1999) constructivist learning environments, van Merriënboer's (1997) four component instructional design model, and Schank, Berman, & MacPerson's (1999) learning by doing model.

By allowing learners to advance through a logical event sequence in which they continually apply and expand their learning, they progressively gain content and apply their knowledge via decision-making in realistic situations. This architecture has a secondary advantage of encouraging learning in a climate that is absent of a human authority figure, which can produce anxiety or ambivalence that interferes with the adult learning process.

Structuring Guided Discovery Material

One of the risks of using realistic, rich learning tasks is that learners may become overwhelmed by the complexity of the tasks. Various methods are available for managing the cognitive load of learners. One method is to progress from simple to complex tasks. In this way, the cognitive load associated with the whole task is reduced compared to what would be expected without the part-task training. Complex tasks may be broken down into simpler parts that may be trained separately and gradually combined into whole tasks. This approach was demonstrated by Greitzer and colleagues (Greitzer, 2002; Greitzer et al., 2003) in a Web-based training application on operation and maintenance of Army logistics communication equipment.

While part-task approaches help to manage the learner's cognitive load, they are less effective than whole-task approaches in meeting complex learning objectives that require transfer of training to new situations (van Merriënboer, 1997). Whole-task approaches focus on integrating component skills from the outset. Instruction begins with the most simple, but realistic, case that must be learned. Then cases with intermediate complexity are constructed by removing or modifying certain simplifying conditions, and so forth until more complex tasks are presented. Mastery for the learner thus progresses in a logical and natural sequence.

In structuring the training content for this application, we used both part- and whole-task designs to help manage the learner's cognitive load. The part-task methodology divided the inquiry task into three main components that address separate learning objectives. The first component focuses on raising the awareness of the learners about specific instances or "observations" that are associated with human errors in various example scenarios. The objective in this phase of training is for the learner to successfully identify such observations. The second component focuses on developing an understanding of the ESTHER error contributors – these are the higher-level concepts for which the individual observations are exemplars. The objective in this phase of training is for the learner to successfully apply the human error contributors in realistic scenarios. The third component focuses on skills required in applying the knowledge gained earlier to the use of the online ITAC form used to report the results of inquiries.

The part-task instruction is aimed at less-experienced students who have not yet mastered the understanding and interpretation of the ESTHER contributors. This design specifically provides a method for the guided-discovery portion of the training. Once a sufficient level of understanding has been demonstrated, learners

may remove the guided/part-task support and apply their knowledge to whole-task scenarios. In whole-task scenarios, the learner responds directly using the ITAC form, without intermediate steps that require identification of specific observations.

Another aspect of our design approach that aims to provide additional management of cognitive load is the attempt to control task difficulty. Scenarios that involve fewer error contributor factors should be intrinsically easier than those that involve a larger number of contributors. Thus, we can control the cognitive load of scenarios offered to the learner based on a rough indicator of task difficulty corresponding to the number of contributor factors that apply to a given scenario. This task difficulty information is readily available from the specifications/descriptions of scenarios, which may also be implemented within a data model for the problem space that represents the learning content (Greitzer, Merrill, Rice, and Curtis, 2004).

Assessing Outcomes

Outcomes may be assessed using the classic 4-level evaluation model developed by Kirkpatrick (1998). Level 1, learner response, will be assessed through written evaluation form(s) and end-of-course focus groups in the classroom setting. This may also include projections by the individuals themselves of their ability to apply what they have learned and/or the usefulness of doing so. Instructor effectiveness, satisfaction with course content, room suitability, and learner materials and equipment effectiveness will be captured at this level. A short interactive assessment will also accompany mediated materials used for self-directed study.

Level 2 assessments move the evaluation beyond learner satisfaction and measure the extent to which the learner has advanced in skills or knowledge. In the workshop setting, these assessments are provided by instructors observing the learner's performance in classroom activities. In the distributed learning application, performance assessments are made based on the learner's responses to interactive exercises, which are implemented as scenarios. These interactive scenarios are also available to be used by the instructor during the workshop.

Level 3 assessment measures the degree to which learning is applied in the field or "on-the-job." The primary medium for Level 3 assessment will be a post-hoc analysis of documentation by security inquiry officials, and self- and supervisor reports given to ESTHER analysts.

Level 4 assessment addresses whether the training is *yielding value for the organization.* Here we expand beyond the impact on the learners and begin to ask what happens to the organization as a result of the training. This is done by examining incident/report data that come in through the ITAC system. This analysis aims to assess the extent to which the reports reflect more of the foundation for corrective actions, the appropriateness of suggested corrective actions themselves, and, in the long run, determining if there's been a reduction in recurring incidents.

Kirkpatrick advises, "Be satisfied with evidence, because proof is usually impossible to get." The assessments for this project are designed to collect evidence at all four levels of assessment over time and collectively analyze results to improve training content, approaches, materials and methods, and also to help determine the expansion and further directions of the program.

RESULTS TO DATE

Development of the course is in progress. Some workshops have been conducted, but full integration with the computer-based instruction (electronic learning, or e-Learning) has not yet occurred. In this section we focus on a description of the design and implementation of the computer-based material, which provides guided-discovery learning material used during the workshop and used as mediated self-paced instruction and refresher training.

Description of e-Learning Application

The e-Learning application comprises three main components. The guided-discovery learning component ("Discover Contributors") is aimed at students who are not familiar with the ESTHER concepts or are unsure about them. The "Use Contributors" component is designed for learners who are more familiar with the ESTHER concepts and who can benefit from more practice applying the concepts. A third component, "Resources," provides a collection of course material, links, and other useful reference material. Design and implementation of these components are described in this section.

"Discover Contributors" Component. This guided discovery portion of the application can be used for self-study as well as workshop exercises for discussion. To manage the difficulty of scenarios, we

established three categories of difficulty based on the number of ESTHER contributors that apply.

To implement the guided discovery notion, we provide scenarios that allow the learner to explore various types of information such as a "scene re-enactment" or a testimony from a co-worker or some documents (see Figure 2). Based on information gathered during this exploration of material, the learner identifies **observations** that correspond to contributors that apply to the given scenario. Their observations are in everyday language without the more precise terms required by ESTHER. This guided step with observational cues helps the learner transition to the terminal objective of correctly discerning among lists of causes and contributors to error that are needed for subsequent analysis by ESTHER specialists. Thus, the guided discovery process takes learners from the simple to complex (in terms of tasks) as well as from the familiar to the technical (in terms of discrimination and language). We provide feedback on three levels:

- First level feedback indicates that some were missed (not checked) and/or that some were checked incorrectly (it does not provide answers)
- Second level feedback identifies the incorrect items and provides hints about missed items (e.g., direct the learner to a particular scene)
- Final feedback gives them the correct answers and allows learners to review the scenario with answers identified.

After answering correctly, the learner can review the information in a mode that highlights the contributors within the scenario representation. That is, when the learner revisits the material following completion of the scenario, the observations are highlighted and annotated in the various scenes of the re-enactment (or in other evidence that is displayed such as email or testimony transcripts). A post-scenario summary page

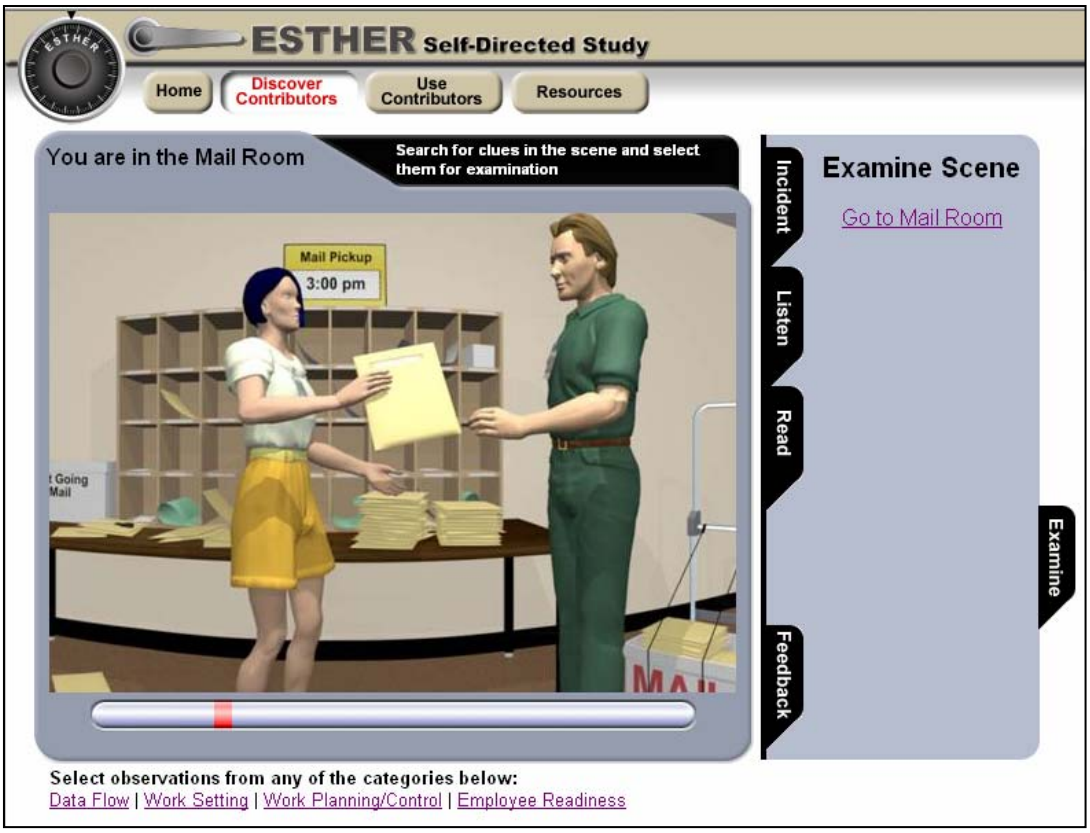

Figure 2. Sample screen showing a computer-based guided discovery scenario. The learner reads a description of the Incident and virtually explores the workplace in which the incident occurred. This includes a re-enactment of the incident in the "Examine" tab (mail room is shown here); testimonies by co-workers (in the "Listen" tab); and available written documentation such as email (in the "Read" tab). The learner clicks on objects to see more information. In the guided discovery component, the learner selects observations that indicate likely human error contributors. In the more advanced exercise component, the learner responds by filling out the Web-based incident reporting form.

is then provided to review what was learned in the scenario and to discuss briefly some other perspectives and interpretations that might apply. The purpose of this discussion is to convey that security incident inquiries are based in part on personal observation that has a subjective aspect, which allows for some flexibility and interpretation. This type of discussion occurs frequently and is encouraged during the workshop; it is considered an important part of the e-Learning application to convey that the purpose of the inquiry process is to identify *potential* human error contributors and not to make final determinations of errors or wrongdoing.

The final step in the guided-discovery learning for each scenario is to relate the observations that were identified correctly to the ESTHER contributors on the ITAC form. When the learner clicks on an observation, the associated error contributor is highlighted on the ITAC form. Also, a text "comment" or description is displayed to remind the learner about what was observed (ideally this is an example of comments that may be entered on the ITAC form). Thus, this final step in the guided discovery scenario shows how the observations map to the contributors listed on the ITAC form.

This process can be repeated in other scenarios, with more complexity introduced based on the learner's performance. The learner can also select scenario sets with higher levels of difficulty.

"Use Contributors" Component. The Use Contributors component works much the same way as the Discover Contributors component, except that the amount of coaching (guidance) is less. The list of observations (which act as cues or prompts for the learner) in the guided-discovery component is absent in this component. The scenarios allow the learner to explore the multimedia material in the same way as before (scene re-enactment, testimony from a co-worker, email or other documents). However, the learner must respond directly using a representation of the ITAC form. This provides direct experience with the ITAC form, working with realistic cases.

As in the guided discovery component, we provide feedback on three levels (with a slight twist at the third level):

- First level feedback indicates that some were missed (not checked) and/or that some were checked incorrectly (it does not provide answers)
- Second level feedback identifies the incorrect items and provides hints about missed items (e.g., direct the learner to a particular scene)
- If the learner fails to get all answers correct on the third try, we return to the guided-discovery mode and present the same scenario with the guided-discovery format.

"Resources" Component. This part of the e-Learning application provides access to references, relevant papers, video examples, PowerPoint presentations that were used or referred to in the workshop, links to related Web sites, workshop handouts, site-specific information, and the like. The CD was constructed to be useful to the workshop instructors during the workshop as well as a training and resource guide for inquiry officials to refer to on their own.

Implementation of Multimedia and VR. Because the e-Learning application stresses experiential learning, a premium is placed on incorporation of interactive graphics and multimedia to enhance the realism and engage the learner. Several types of multimedia interactions have been employed.

For the scene re-enactment interactions, we used 3-D modeling software (Maya 3D) to render office environments and objects. Implementation of the interactive multimedia objects within the re-enactment interactions was accomplished using Macromedia Director and then exporting to ShockWave. This provided a realistic rendition of objects that enables the learner to interact even more with details in the scene, such as to inspect a notepad more closely or to see details of a calendar on the wall or to read the label of a prescription bottle. It also allows the learner to control a panoramic view of a modeled environment, such as to look around an office by rotating about from one end to the other. ShockWave also enabled us to provide feedback (following completion of a scenario) with notes and overlays placed in relevant locations within the scene to call out critical features that the learner should have noticed. While most of the scene elements are static, future versions will include more animation of objects, scene fly through, and character action. We may also exploit more advanced features that enable the learner to interact with 3-D objects within ShockWave multimedia.

For the testimonies that were implemented to represent interviews with co-workers, we used recorded narrations that accompanied the written transcripts. Representations of documents and other type of written material were implemented in HTML so that they too

could be highlighted with feedback following the learner's responses.

Finally, photo-realistic 3-D virtual reality (VR) examples were developed to provide a "fly-on-the-wall" type of experience for the learner as well as more interactive versions. The instructors use the VR examples in the workshop to demonstrate concepts through realistic scenarios. We use 3D Studio MAX, Adobe Photo Shop and Unreal Tournament Engine to render images into a VR world. Some VR scenarios are composed of simple generic components such as office equipment. Since extremely realistic scenes may be constructed from blueprints, photographs or actual measurements, some of the VR scenarios are photorealistic. At the most advanced stage of VR implementation (3-D interactive objects), the scenario unfolds in a movie-like way that allows the learner to manipulate objects and fine tune observational or analytic skills.

The VR technology lends itself well to guided discovery learning by placing the learners within a scenario and allowing them to explore the environment much as they would in the real world. An advantage is that VR scenarios are carefully constructed to emphasize key points that are exposed or discovered in a photorealistic world that may be manipulated by the course designer to achieve learning objectives. Because it was unresolved at the time of this writing whether a runtime-only version of the VR software would be available on CD, the VR examples were planned to be implemented as movie files on the CD and used within the training material (as linked files to illustrate points) or placed in the Resources component for reference.

CONCLUSIONS

This paper describes an innovative approach to training that attempts to take advantage of the benefits of both classroom instruction and distributed e-Learning. We have conveyed in some detail the methods we used to structure the guided-discovery learning components that are available both in the classroom and to individual learners as self-directed study.

In its fully integrated form, we anticipate that the course will benefit from the computer-based material designed to enrich the classroom-based instruction through instructor-directed examples and demonstrations, and from the self-directed computer-based guided discovery learning that is available to the learners following the initial workshop. This blended learning approach takes advantage of the interpersonal experiences of classroom training while employing independent e-Learning to enable the learner to acquire a deeper understanding and skills in using tools and applying newly acquired knowledge.

At the time of this writing, we have not had an opportunity to assess formally the course's acceptance by the learner population or its effectiveness in improving the awareness and understanding of inquiry officials about human error contributors—i.e., Kirkpatrick's level 1 and level 2 evaluations (however, we have observed that in-class renditions of the material were well-accepted by learning populations in the past). Similarly, we have not had an opportunity to develop measures based on level 3 (impact on in-the-field performance) or on level 4 (impact of the program in reducing the occurrence of human errors contributing to security incidents). Nevertheless, we have identified operational measures and we have the means to collect the data (through the DOE's ITAC form). Because it is not often that such a comprehensive set of performance effectiveness measures are available to span each of Kirkpatrick's four evaluation levels, we are encouraged by the potential of this training program to generate important data on training effectiveness for an innovative approach to instruction.

Interim conclusions about the effectiveness of the implementation of a program are fostered not only by assessing the resulting training product, the performance gained by its students, and the ultimate impact on the over-arching organizational goals, but also by examining artifacts of the process that may have implications for future application of the development approach. In this regard, we can provide some insights. This was a "virtually" developed product with contributors from four states working together to design and produce instructional design yielding classroom, VR, e-Learning, and evaluation systems; pilot programs; review and revision cycles; and distribution/delivery strategies across a nationwide complex. Our own "lessons learned" includes an acknowledgement that people who have never met can collaborate in a collegial manner, interacting to meet a complicated programmatic goal. Under suitable direction and coordination, this system of development could be replicated to take advantage of appropriate talent while reducing time- and budget-consuming travel resources.

Finally, we envision that this training application and its instructional design/development approach can have impacts beyond the domain of improving the value of DOE security inquiry reports and ultimately lowering

the occurrence of security incidents. The approach described here may be used to develop similar types of training for other organizations with investigative responsibilities, including the Department of Defense and many such applications in the private sector.

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