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Live, virtual, and constructive environments for performance support

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ABSTRACT

LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS FOR PERFORMANCE SUPPORT

**by
John Michael Lacontora**

As military systems become more complex, the operation and support of these systems becomes intrinsically more difficult. The U.S. Army's current procurement process relies on industry to provide embedded training and performance support tools for the systems they produce. These tools are relatively new and in the early stages of development. As yet, they have failed to meet the needs of the technicians that are required to support these complex systems. Current efforts to provide enabling technologies that enhance the capabilities of automotive maintenance technicians are concentrated in three professional communities. First is the Performance Improvement community where work is focused on developing and implementing performance support system technologies that deliver information that is stored in information systems. Second is the Knowledge Management community working on organizational knowledge management techniques that capture, store, and map information that is delivered to workers within an organization. The third is the Training and Education community focusing on developing curriculum and delivery systems that support "life-long-learning" requirements.

This dissertation addresses an essential component of performance systems, namely the ability to deliver the knowledge needed to guide a problem solver to a solution state, thereby enhancing worker capabilities. This objective is met by developing the LockTel Framework that provides a construct for segmenting knowledge into three environments for

performance support, the live, the virtual, and the constructive environments. It provides a means for the maintenance technician to gain knowledge associated with completing a given task. Seventy-eight maintenance technician trainees at an U.S. Army training center tested the framework. The hypothesis behind the proposed construct was strongly supported, thereby establishing the foundation for future work in live, virtual, and constructive environments for performance support.

**LIVE, VIRTUAL, AND CONSTRUCTIVE
ENVIRONMENTS FOR PERFORMANCE SUPPORT**

**by
John Michael Lacontora**

**A Dissertation
Submitted to the Faculty of
New Jersey Institute of Technology
In Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Information Systems**

Department of Information Systems

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Dedicated to my beloved wife, Linda
To my sons, John, Matthew, Brent and Eric
To my grandson, John
In memory of my parents, John and Dora and my father-in-law Wilbur
To my friends and mentors who provided me guidance and support

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GLOSSARY OF TERMS

Agents: People, roles, or intelligent software that aid in the operations of an online or distributive community.

Best Practice: The most effective and desirable method of carrying out a function.

Cognition: The science of understanding the human thought process.

Cognitive Psychology: The profession of the study of human thought.

Cognitive Load: The limits or amount of thought process that occurs in the humans working memory.

Community of Practice: A group whose members regularly engage in sharing information, knowledge and learning, based on common interests.

Computer Based Learning: Learning that is provided through a computer.

Decision Support System: Software tools that allow managers and other knowledge workers to make decisions by reviewing and manipulating data in a data warehouse.

Diagnostics: Troubleshooting by following an exact procedure (US Army, TM 9-2320-280-20-1).

Drivers: A function that causes actions to occur within an online community. In a community of practice the main driver is the subject matter that forms the community. It could also be the benefits that are derived from participation in the community.

Electronic Performance Support System: A system that provides workers with the information, advice and learning experiences they need to get up to speed as quickly as possible and with the minimum of support from other people. An EPSS also provides the electronic infrastructure that captures, stores, and distributes knowledge throughout an organization to enable it to learn faster than its competitors.

Environments: Live, Virtual and Constructive Environments for Performance Support (J Lacontora):

-Live Environment – A computer-aided performance support environment which enables a user to solve problems where system information is not available through collaboration with external resources.

-Virtual Environment – A computer-aided performance support environment which provides the user with conceptual or high-level understanding of a given system or function.

-Constructive Environment – A computer-aided performance support environment that provides the user with information on techniques, processes and procedures associated with completing a task on a given system.

Expert System: A type of computer program that makes decisions or solves problems in a particular field, by using knowledge and analytical rules defined by experts in the field.

Explicit Knowledge: Knowledge that can be easily expressed in words or numbers, and can be shared through discussion or by writing it down and putting it into documents, manuals or

databases. Examples might include a telephone directory, an instruction manual, or a report of research findings.

Hypertext/ Hypermedia: Software that allows the user to control the flow of the presentation. Can include links between text, graphics, sound and video objects. Hypertext/Hypermedia can be used to create CBT, online information, interactive multimedia, and performance support systems.

Information Systems: The entire infrastructure, organization, personnel, and components that collect, process, store, transmit, display, disseminate, and act on information. These include computers-hardware and software, communications, as well as policies and procedures for their use.

Job Aids: Mechanisms that store information external to the user and guide work performance because they can be used on the job, describe when and how to perform a task, and reduce the amount of information the user would otherwise have to recall. Job aids can be delivered via print or electronic media

Knowledge Engineering: The process of extracting knowledge from an expert with enough detail and completeness that the knowledge can be imparted to others or an information system.

Knowledge Management: A function that employs a variety of methods and technologies for knowledge collection, knowledge storage, knowledge retrieval, knowledge dissemination and application enable knowledge sharing.

Knowledge Mapping: A process to determine where knowledge assets are in an organization, and how knowledge flows operate in the organization. Evaluating relationships between holders of knowledge will then illustrate the sources, flows, limitations, and losses of knowledge that can be expected to occur.

Knowledge Worker: An employee whose role relies on his or her ability to find and use knowledge.

Learning Environment: The phrase learning environments provides a framework for segmenting or constraining a person's learning space. This space can be physical or psychological. Physical, symbolizing a physical place where one learns, a classroom, laboratory or library and psychological, symbolizing a synthetic place in cyberspace where a knowledge seeker travels to find knowledge on the task being performed.

Learning Objects: A content object that is used to deliver learning in small segments and have standard characteristics such as being self-contained, be reusable, can be aggregated with other learning object, can stand alone, be tagged with metadata, and can be combined with other media.

Learning Styles: Learning styles associated with computer-aided learning consist of global, sequential, verbal, visual, active, reflective, sensing, and intuitive.

Learning Transfer: The process of applying what was learned in one situation to another situation for which it was not directly targeted.

Mental Model: A representation a collection of knowledge that builds a foundation for understanding and provides the tools for problem solving. A mental model is a person's

conceptualization, or personal theory, of some domain or environment. When making decisions people use mental models to evaluate choices and frame discussions.

Norms: Social normalities that provide social structure, governance and acceptable behaviors within online or distributed communities. Unwritten rules governing expected behavior in a specific social interaction.

Perceived Usefulness: Is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance,” This follows from the definition of the world useful: “capable of being used advantageously.” Within an organizational context, people are generally reinforced for good performance by raises, promotions, bonuses, and other rewards (Davis, 1989; Pfeffer, 1982; Schein, 1980; Vroom, 1964).

Performance Support System: A system that provides a means to integrate knowledge and learning experiences, with software tools to improve the quality and quantity of worker performance with as little support as possible from external sources.

Performance Support Tools: A tool that provides information or support to person that aids in the performance of a process or task. Some performance support tools are notebooks, ledgers, job aids, manuals, electronic assistants, mentors, advisors, and coaches.

Process Maps: A graphic description of a process, showing the sequence of process tasks that is developed for a specific purpose and from a selected viewpoint.

Simulations: Modeling and Simulations are inter-related in that simulations are typically driven by a number of models. Models are typically descriptive in nature, mathematically based, and useful to the developer (e.g., an aerodynamic model). A simulation is typically a numerical implementation of the developed models and is used for a variety of purposes (e.g. flight training simulator).

Live, Virtual, and Constructive Simulations: A broadly used taxonomy for classifying simulation types. The degree of human participation in simulation is variable, as is the degree of equipment realism. The following definitions delimit the specific degree of human participation and equipment realism for the purposes of consistency and standardization.

-Live Simulation: A simulation involving real people operating real systems.

-Virtual Simulation: A simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a Command, Control, Communications, Computers, and Intelligence (C4I) team).

-Constructive Simulation: A simulation that involves simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes.

Discrete and Continuous Simulations: Two main types of simulations include:

-Discrete: *An event simulation* (frequently used for modeling industrial processes)

-Continuous: A human in-the-loop simulation (frequently used for training).

Socio-Technical: A combination of both the social and technical components of a distributive information system. Socio-Technical refers to the interaction between social and technical issues within an organization.

Tacit Knowledge: The knowledge or know-how that people carry in their heads. Compared with explicit knowledge, tacit knowledge is more difficult to articulate or write down and so it tends to be shared between people through discussion, stories and personal interactions. It includes skills, experiences, insight, intuition and judgment.

Troubleshooting: The process of making measurements and observing the operation of the vehicle to find out if anything is wrong with it and then locate and problem that exists (US Army, TM 9-2320-280-20-1).

User: The person that uses a computer.

CHAPTER 1

INTRODUCTION AND MOTIVATION

The primary objective of a performance support system is to deliver knowledge to its user to perform a process or complete a task. Performance support systems emerged to enable automotive technicians to keep pace with the vehicles they must support. Over the past ten years, the defense automotive industry has been able to continuously improve their products through process improvements and technical innovations. In particular, the automotive industry has changed the military ground vehicles fleet from analog systems to integrated digital systems. Moving from analog to digital was an easy task for the engineers that designed and produced these systems but a difficult task for the logistic community that is responsible for servicing and repairing these engineering marvels.

In 1995, the military logistics community began to develop and introduce sophisticated diagnostic tools that aided the service technologist in diagnosing faults that could not be diagnosed through standard troubleshooting procedures. The questions the service technicians ask are “How do I chase the digits around the vehicle to find the root cause of a fault?” and “If the digit starts here, how do I know it’s going through its intended process, or is it even getting to the place where it causes some action to occur?” It is difficult to chase a digit with a multi-meter, a method of troubleshooting an electrical problem that many automotive technicians use.

Compounding the problems of troubleshooting a fleet of vehicles is the accelerating rate of change in the number of types and models of ground vehicle systems entering the

fleet. System parts are improved and integrated into a system as they are going down the production line.

The defense industry as a whole realized that service technicians could not be trained on all systems and models that they were required to be supported, thus the introduction of Electronic Performance Support Systems. These systems, one in particular, the Turbine Engine Diagnostic (TED) System, aided the user in isolating the problem, determining the fault, and, in some cases, gave guidance on the repair process. The difficulties with this type of performance support system is that the developers assume users have a basic understanding of maintenance processes and procedures, that they are trained on how to maintain and repair the specific turbine engine that they are working on, and that they are experienced in performing the task at hand. Most of these assumptions would hold true if the turbine engine and its components remained stable throughout the product's lifecycle, but this is rarely true. Modifications are frequently introduced that require subsystems to be replaced with newer models that are made up of new and different components. These interim upgrades provide difficulties in the training of maintenance technicians because of their sporadic introduction into the fleet.

Another recent event that occurred in the late 1990's had a major impact in the development of performance support systems: the downsizing of the organization and personnel that support the organization's equipment. The maintenance support community attempted to solve this dilemma by creating multi-capable maintenance technicians. This "super mechanic" is required to be trained to support an entire system. For example, the multi-capable technician understands the entire tank system versus a subsystem of a tank, i.e. automotive, armament, or fire control, systems. An enabler was developed and fielded to

assist these multi-capable technicians in performing maintenance, diagnostic, troubleshooting, and repair tasks, but this fell short of expectations.

In 1997, the U.S. Army developed and fielded the Soldier Portable On-System Repair Tool (SPORT) that is still the accepted method of presenting Interactive Electronic Technical Manuals (IETMs) and providing performance support. This system has been proven to reduce the requirement of technicians to use paper technical manuals and to provide linkages to product support if a problem cannot be resolved using the information provided by the SPORT. In addition to providing the SPORT to technicians, the Army provides distance learning courses and electronic forums for soldiers to increase their knowledge of a given system.

Also, at the same time, the U.S. Army introduced new training devices and simulators to aid in providing more training in the same or a shorter period of time. These devices were used mainly for constructive and virtual part-task training device, e.g., the Virtual Maintenance Trainer (VMAT) that uses 3D graphics to depict a system. With this trainer, the student interacts with images to gain an understanding of the system and is given support in performing a limited number of diagnostic and repair procedures.

These innovations aimed to enable maintenance technicians to become more efficient, flexible, and multi-capable in supporting complex systems. As time went on, it became apparent that even though the maintenance technicians were more capable, the information sources that they needed to access were becoming less organized. In some cases, even if the information was valid for a given task, technicians were not able to act on it because of their lack of understanding of the system and how the system fit into their problem.

To help bring this information into focus, the employment of a new, innovative construct is needed to constrain the knowledge seekers to seek knowledge in three different environments: live, virtual, and constructive. Such a construct provides a means for the maintenance technician to gain the knowledge needed to complete a given task. In this context, information-seeking behavior is the complex actions and interactions which people engage in when seeking information (Byron, 2000).

For the purposes of this study we define the three environments; live, virtual, and constructive, for performance support as follows:

- Live environment – A computer-aided performance support environment that enables the user to solve problems when system information is not available through collaboration with external resources.
- Virtual environment – A computer-aided performance support environment that provides the user with conceptual or high-level understanding of a given system or function.
- Constructive environment – A computer-aided performance support environment that provides the user with information on techniques, processes and procedures associated with completing a task on a given system.

Once the basic understanding of live, virtual, and constructive environments for performance support is established, we can begin to organize information into these three categories. The result is a “mental model framework” that serves as the basis of this thesis. This framework can facilitate automotive technicians to better use existing knowledge to solve problems or to at least provide a means to bring them closer to the solution state for the problem they need to solve.

In order to evaluate the effects of the manipulations introduced during the experiment, a quasi-experiment was performed using a mixed quantitative and qualitative experimental design. To measure the effects of introducing the live, virtual, and constructive environments for performance support over the use of the existing Electronic Technical Manual for the High-Mobility Multipurpose Wheeled Vehicle (HMMWV) concept mapping and questionnaires were used to capture the data that resulted from maintenance technicians performing troubleshooting tasks under a given conditions.

1.1 Motivation

Over the past decade, the automotive industry has strived to support their technicians with the knowledge they need to troubleshoot and repair the complex vehicles they produce. During that time, performance support systems began to emerge as a means to provide technicians the data, information, and knowledge they need to perform tasks effectively and efficiently. These systems helped but did not deliver the knowledge a technician needs to perform complex tasks when no published information was available.

From a knowledge management point of view, it is very difficult for an information system to deliver tacit knowledge, the know-how that people carry in their heads, to a technician while performing a task. This gap, the inability to deliver tacit knowledge, drove me to this thesis topic: Live, Virtual, and Constructive Environments for Performance Support.

1.2 Dissertation Overview

This dissertation presents a new and innovative framework, the LockTel Framework, to aid knowledge seekers in extracting with knowledge that is mediated by computer-aided performance support systems. It evaluates the change in the automotive technician's mental model when presented with this new framework and provides a user's view of the perceived usefulness of the framework.

It is important, while seeking knowledge from a performance support system, to have a good understanding of where the knowledge resides, thus allowing an individual to seek information within a computer-aided domain. This research addresses a major deficiency in the technicians' ability to search knowledge from various sources while engaged in performing a task by segmenting that knowledge searching into three environments; live, virtual, and constructive. This dissertation provides a framework to bridge the gap between computer-supported learning and computer-aided performance support systems with the objective of providing maintenance technicians a better method of seeking knowledge, bringing them closer to a solution state.

1.3 Dissertation Outline

The dissertation proposal includes five chapters. Chapter 1 provides an overview of the dissertation topic and boundaries of the study. Chapter 2 consists of a background literary review of the various factors associated with computer-aided performance support. This extensive research identifies a void in the way knowledge seekers retrieve information from a performance support system. Chapter 3 presents the LockTel Framework. Chapter 4 presents

the experimental design and the results of the experiment. Chapter 5 provides a view of future research opportunity that would be a logical extension of this dissertation.

1.4 Dissertation Boundaries

The LockTel Framework provides a method for technicians to categorize and retrieve knowledge from a computer-mediated performance support system. It is not a software or design technique; rather, it is a method for how humans can interact with data, information, and knowledge within a performance support situation. This dissertation does not discuss the development process of performance support systems nor does it focus on the capture and creation of the knowledge that supports these types of systems. This dissertation also does not attempt to address whether or not knowledge can be stored in an information system.

CHAPTER 2

BACKGROUND LITERATURE

2.1 Learning

The knowledge required to support complex systems requires that one “learns as they do.” The premise of learn as you do is critical to automotive service technicians supporting modern vehicles. What follows in this section addresses the constructs of learning that directly and indirectly affects the delivery of knowledge to workers performing a troubleshooting task.

Individuals tend to learn in the most efficient and effective way for them personally (Gery, 1995). In a performance situation, change is frequent. Thus, continuous adaptation and learning is required. When a person is presented with a problem that is not clearly understood but they have the basic skills and knowledge to solve the problem, learning the specifics, such as knowledge about a particular system on-the-job, will bring them to the solution.

Researchers indicate that novices often focus on the surface features of a problem and fail to understand the conceptual deep structure in the manner that experts do. The distinction between surface and structural knowledge has been a consistent theme in cognitive research involving novice and expert differences in analogical reasoning and knowledge transfer (Jacobson and Archodidou, 2000). In Yi and Davis’ (2003) study, *Validation Model for Computer Software Training*, the findings strongly suggest that observational learning and training intervention improve task performance. Learning processes that occur at or around the workplace are frequently more powerful than formal

training settings (Kesslers, 2001). The matrix below, Table 2.1, describes some of the significant differences between traditional training and performance support oriented learning. These differences are important for performance support system developers to understand, particularly when they are developing systems that require workers to “learn as they do.”

Table 2.1 Traditional Training versus Performance Support

Traditional Training	Performance Support
Event-oriented: not integrated with work environments or other performance support tools	Task-oriented; Learning is systematically integrated with job-task
Responsibility of trainer or program to teach	Learner responsible for performance and required learning to achieve the task
Defined, program-controlled objectives, sequences, processes	Job-task defines learning objects
Measured on test results and learner satisfaction	Measured on effectiveness of job task performance
Textbook oriented	Includes learning systems, information systems, job aids, procedures guides, etc.

Learning transfer is a concept that must be understood and used in creating training programs and performance support tools. It refers to the ability to take what is learned in one situation and to apply it to another situation for which it was not directly targeted (Kolodner, 2002). Learning transfer includes not only the results of reasoning but also the reasoning processes of the learner (Kolodner, 2002). Without learning transfer, a person would need to be formally trained on every task that they might encounter. The concept helps explain why training institutions focus on teaching basic skills and knowledge about automotive systems to apprentices and to provide system specific training to the novice. Through learning transfer, a person should only have to be trained on new concepts and applications associated with unfamiliar systems.

2.1.1 Learning Styles

To incorporate learning styles into a performance support system is a difficult task for system developers and content providers. If a worker “learns as they do,” the learning materials should be presented in a way that fit with the worker’s learning style. However, people learn through different learning styles. Carver and Lane (1999) conclude that previous to multimedia courseware, instructors were unable to effectively address the different learning styles that appear outside the classroom. The results of numerous research studies in computer-based learning suggest that computer-mediated learning can bridge that gap and present the learning in the learner’s preferred learning style, thus optimizing the learning process (Larkin-Hein and Budny, 2001).

Over the past ten years, many researchers have published papers on learning styles that address the importance of learning styles in the transfer of knowledge from the instructor to the student or, in the case of performance support tools, from the knowledge owner to the knowledge receiver. The Dunn and Dunn Learning Model referenced by Larkin and Hein (2001) suggests that improvements in productivity and learning will come when instruction is provided in the manner that capitalizes on the individual’s learning strengths. As a model, Dunn embraces several general principles (Price and Dunn, 1990, Larkin-Hein and Budny, 2001):

- Most individuals are capable of learning
- The learning conditions in which different individuals learn varies extensively
- Individual learning preferences exist and can be measured reliably

- Most students are self-motivated to learn when they have the option of using their learning style preferences and experience success
- Most teachers can learn to use individual styles as a basis for instruction
- When selected teachers are not capable of learning to use individuals' learning styles as a basis for instruction, students can be taught to teach themselves and, thus, bypass their teachers' styles
- Use of individual learning style strengths as the basis for instruction increases learning and productivity

To build intuitive performance support systems, developers must understand, target, and incorporate different learning styles within the systems they develop. Learning styles associated with computer-aided learning consist of global, sequential, verbal, visual, active, reflective, sensing, and intuitive components (Carver et al., 1999).

2.1.2 Learning Objects

Learning objects are a relatively new way of thinking about learning content. Learning objects are mainly developed for use in the development and delivery of computer-based learning. These objects, also known as learning nuggets, can be used as stand alone learning points or combined into a complete lesson, as discussed below. Traditionally, content comes in several hour chunks; learning objects are much smaller units that typically range from a two to fifteen minute duration (Friesen, 2001). Learning objects are self-contained, are reusable, can be aggregated, are tagged with metadata, and have the ability to be combined with other media. Learning objects have the potential to serve as knowledge objects employed in performance support systems.

2.1.3 Learning Environments

“Learning environments” provides a framework for segmenting or constraining a person’s learning space, whether physical or psychological. Physical learning environments refer to a physical place where one learns, such as a classroom, laboratory or library. Psychological learning environments refer to a synthetic place in cyberspace where a knowledge seeker can find knowledge on the task being performed. Through the use of the different learning environments, a framework is provided to deliver learning to individuals in various situations, conditions and forms. Some of the major learning environments used today are traditional, distributive, computer-based, and blended. The U.S. defense modeling and simulations community added three additional learning environments: virtual, live, and constructive. These relatively new environments have become useful by providing meaning to some of the environments emerging in cyberspace. They also provide a useful framework for potential migration to performance support systems. Section four addresses these environments in greater detail.

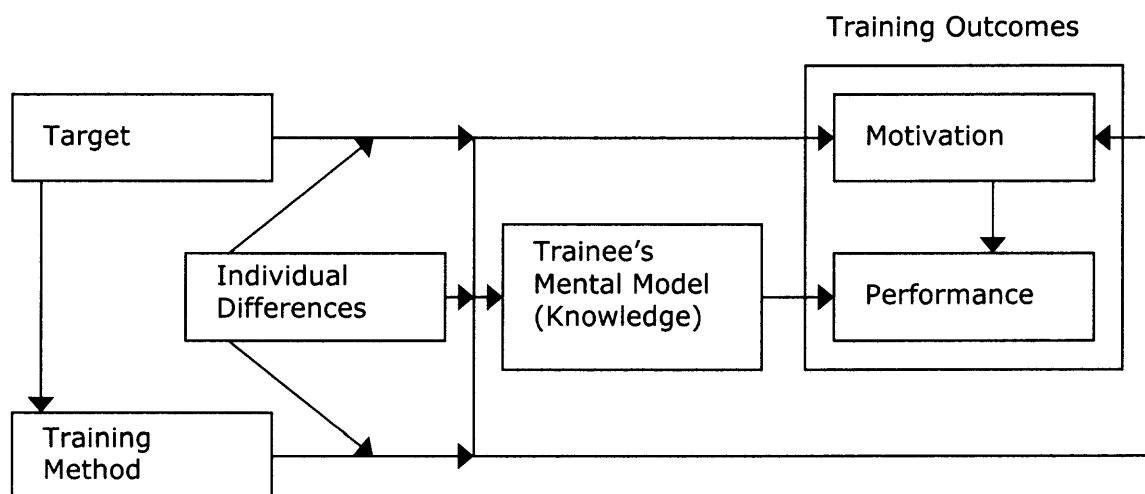


Figure 2.1 End-User Training Model.
(Bostrom et al., 1990)

2.1.4 Principles of Learning

Understanding the principles of learning helps us to grasp some of the methods trainees use to gain knowledge. Because performance support systems enable “learning as they do,” the constructivist view on the principles of learning is fitting.

From a constructivist point of view, learning consists of individuals' constructed meanings (Dewey, 1910). Learning is an active process in which the learner uses sensory input and constructs meaning from them. The more traditional formulation of the principles of learning is that the active learner (Dewey's term) needs to do something; that learning is not the passive acceptance of knowledge, which exists “out there,” but that learning involves the learner engaging with the world (Woods, 1996). Some of the key principles of learning that are addressed in Dewey's works are that people learn to learn as they learn; that it takes time to learn; and that motivation is a key component in learning (Woods, 1996).

Learning organizations are beginning to provide resources for individuals who are working together to increase their knowledge and skills, especially during times of rapid change, through learning networks (Confessore, 1997). The key concept in organizational learning is that there is a body of knowledge that can be leveraged for the good of the organization (Confessore, 1997). This knowledge can be collected through a performance support system-like environment and be made available to the entire organization. With an understanding of learning principals, organizations can configure their knowledge sharing methods to optimize individual learning and performance support.

2.1.5 Complex Learning

In most cases of a performance support system, when a user is seeking knowledge he/she will be involved in a complex learning situation, which is the preferred method for training for complex tasks. The basic idea is that there are four interrelated components essential in complex learning: the learning tasks, the supportive information, the delivery of just-in-time (JIT) information, and part-task practice.

Complex learning is always involved when trying to achieve integrated sets of learning goals or multiple performance objectives. It has little to do with learning separate skills in isolation; it is focused on learning the resources to coordinate and integrate the separate skills that constitute real-life task performance. Thus, in complex learning the whole is clearly more than the sum of its parts because it also includes the ability to coordinate and integrate those parts (van Merriënboer et al., 2002).

2.1.6 Self-Directed Learning

Self-directed learning implies that individuals seek out, make sense of, and then integrate new information into their knowledge base (Confessore, 1997). Performance support system tools can provide a means for individuals to engage in self-directed learning while performing a task or when they feel the need to enhance their knowledge. Performance support system tools should provide a means for users to engage in self-directed learning in any situation.

2.1.7 Cognition

Cognition is the science of understanding the human thought process. Cognition describes the psychological process humans go through to acquire, organize and use knowledge, with

an emphasis on the practical rather than the emotional characteristics. Cognition can be mediated by tools (Hutchins, 1995) and is rooted in the social and the practical part of the human thought process (Nardi, 1996).

Cognitive tasks are goal driven. They are focused on the purpose and the intention rather than the cause. Diagnostic and repair cognitive maps may aid in the process of capturing tacit knowledge for use as actionable information in a performance support system. Cognition is one of the key elements associated with the design and development of performance support systems.

2.1.8 Cognitive Theory

Cognitive theorists believe that understanding the processes of the mind is fundamental to understanding human learning and that human minds are capable of cognitive processing that mediates between environmental stimuli and overt response (Vandenbosch and Higgins, 1996). Behavior is not a property of the stimulus but is something that emerges from the interaction of the stimulus and the active mind and memory of the recipient (Vandenbosch and Higgins, 1996). People use self-knowledge and knowledge about the social world around them to translate their goals into behavior (Koivusaari, 1999). Cognitive processes are any mental activity that acquires, stores, transforms, reduces, elaborates, or uses knowledge (Lovett and Anderson, 1996).

Cognitive Load Theory assumes that a limited-working memory is connected to an unlimited, long-term working memory (Kirschner, 2002). As a result of this limited-working memory, performance support tools should be designed in such a way that working memory is capable of processing the information presented. Therefore, performance support systems

designers must ensure that the limits of a user's working memory are not exceeded or to have a method to augment the user's working memory when the information requirements exceed the cognitive overload threshold.

Cognitive Fit Theory, Figure 2.1, has been used to explain why graphs are sometimes better than tables in supporting decision-making (Tegarden, 1999). Cognitive Fit Theory states that a solution to a problem is an outcome of the relationship between the problem representation and problem solving tasks (Vessey, 1991). The better the fit between these two constructs the more effective and efficient the problem solving process (Tegarden, 1999). In performance support systems, Cognitive Fit Theory may help determine how to best represent the various types of information used in problem solving.

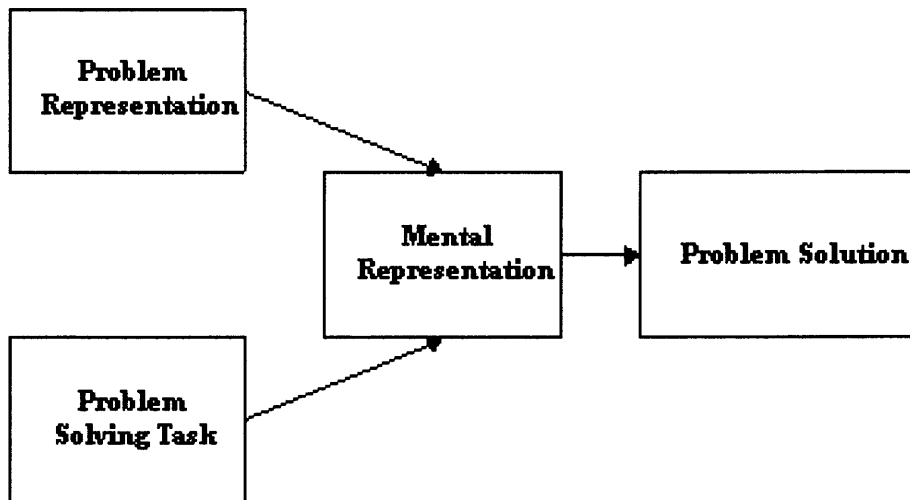


Figure 2.2 Cognitive Fit Theory.
(Tegarden 1999)

2.1.9 Distributive Cognition

The theory of distributive cognition focuses on the representation of knowledge and its implications (Hildreth et al., 2000). The theory looks beyond the individual to the

interactions between people, resources, and materials in the environment (Hollan, 2002). In a community of practice, discussed in greater detail in Section 2.8, distributive cognition is concerned with the process of how work gets accomplished or, in Hildreth's words, "how work gets done" (Hildreth et al., 2000). In performance support systems and knowledge management systems it is important to be aware of distributive cognition. It can play a central role in the capturing, storing, and distribution of data, information, and knowledge from one person to another.

2.1.10 Team Cognition

Groups perform better than individuals in developing problem solving strategies (Okada and Simon, 1997). Groups tend to be superior to individuals in both storage and retrieval of information; groups are able to correct faulty individual memories. Teams can derive a collective cognitive state by pooling individual information and focusing it on a team objective. Two people who, in collaboration, are requesting explanation from each other can have a change of knowledge (Okada and Simon, 1997). Vehicle maintenance technicians normally operate in shops where two or more technicians are located and they operate as a team in which each technician has specific skills and knowledge related to their expertise. When faced with a problem that they are unable to solve as an individual, they come together as a single cognitive unit (team) to solve the problem.

2.1.11 Cognitive Mapping

Knowledge has the ability to be represented in multi-representational learning environments. Cognitive maps process the information contained in surrounding environments (Billinghurst

and Weghorst, 1995); a functional taxonomy of multiple representations can be mapped to visualize how multiple external representations support cognitive processes in learning and problem solving (Ainsworth, 1999). A cognitive map is a graphical representation of an individual's mental model (Rodhein, 1999) and consists of concepts and relations that a participant uses to understand a situation (Scheper and Faber, 1994). Cognitive maps and mental models aid interpretive processes and enable individuals to screen out information in order to prevent information or cognitive overload (Klimoski and Mohammed, 1994).

2.1.12 Constructivism

Constructivist Theory holds that learning means constructing, creating, inventing and developing one's own knowledge. From this principle flows the belief that the mind actively constructs knowledge and invents concepts using existing understanding (Henry 2002). Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. Each of us generates our own "rules" and "mental models," which we use to make sense of our experiences. Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences (Dewey, 1910).

A major theme in the theoretical framework of Bruner (1966) is that learning is an active process in which learners construct new ideas or concepts based upon their current and past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions by relying on a cognitive structure. Cognitive structure (i.e., schema, mental models) provides meaning and organization to experiences and allows the individual to "go beyond the information given" (Burner 1966).

2.1.13 Summary

Learning by using systems that provide just-in-time performance support is a complex issue. These systems are viewed as flexible, open-ended learning environments that are learner-centered and self-directed. The main objective of learning support within a performance support system is to facilitate the movement of the user closer to the solution state by providing product as well as process knowledge. Through the understanding of learning theory, research developers of performance support systems should have a better understanding of the factors that impact on-the-job knowledge transfer.

With the development of guidelines for learning objects, performance support systems can begin to support workers with knowledge objects that are re-usable and transferable to solutions to solve problems where little or no information is available. Knowledge management is complimentary to learning and can provide methods to enhance performance support systems. The next section of this paper will address knowledge management.

2.2 Knowledge Management

As individual dependency on external knowledge increases, knowledge management systems are being recognized as a key resource across various organizations. Both in theory and practice, knowledge management initiative in organizational knowledge increases the performance of the worker. The primary focus of many of these efforts has been to develop new applications for information systems such as data mining, data warehousing and distribution, and knowledge mapping. These information systems also attempt to leverage

the intangible assets of organizations and professional communities through the use of social-technical networks.

As a practice, knowledge management addresses the issues of creating, capturing, transforming, and applying knowledge (Alavi and Leidner, 2001, Davenport et al., 1998, and Davenport and Prusak, 2000). Knowledge is a fluid mix of framed experiences, values, contextual information and expert insight that provides a framework for evaluating and incorporating information into new experiences (Davenport and Prusak, 2000). Knowledge management is not just an information problem of how to capture, organize, and retrieve, but is also a social problem.

Because knowledge is a complex concept, there are a number of factors that determine the nature of knowledge creation, management, and sharing (Nonaka 1994). Tacit knowledge refers to the knowledge that has personal qualities that make it difficult to articulate or communicate the knowing or the deeply rooted “know-how” that emerges from action in a particular context. Knowledge management attempts to distribute tacit knowledge from knowledge owners to knowledge seekers in the most efficient means possible. One of major complexities within knowledge management is the understanding that tacit knowledge cannot be stored and shared in its original state. It must be transposed into explicit knowledge prior to storage and delivered as explicit knowledge. Explicit knowledge refers to the codifiable knowledge that can be disembodied, recorded, and transmitted, the “know-what,” which can be extracted from the knowledge holder and shared with another individual asynchronously through an information system.

Most knowledge management professionals theorize that knowledge cannot be stored in an information system and, at their best, information systems can transform data into information for a knowledge seeker's use.

In order for a performance support system to operate efficiently it must utilize good knowledge management practices. At the core of a performance support system is the ability to deliver information to a practitioner at the moment he/she needs it to solve a problem or complete a task. Knowledge management tools can provide a means for a performance support system to transform data, information, and tacit knowledge into explicit knowledge.

A knowledge management initiative is a strategic plan that seeks to develop and utilize the existing assets of knowledge and experiences of the individuals within an organization in order to enhance a business process (Davenport and Prusak 2000). Technology can support the transformation of data and information into knowledge, but the development of knowledge management system decisions must be based on *who* (people), *what* (knowledge for complete tasks), and *why* (to enhance performance).

2.2.1 Knowledge – Tacit and Explicit

In order to build a comprehensive performance support system, one should have a basic understanding of at least two categories of knowledge, tacit and explicit.

Tacit knowledge is personal, context-specific knowledge that is difficult to formalize, record, or articulate; it is stored in the minds of people. The tacit component is mainly developed through a process of trial and error encountered in practice and processed in the mind.

Explicit knowledge is the component of knowledge that can be codified and transmitted in a systematic and formal language: documents, databases, performance aids, e-check lists, charts, etc.

2.2.2 Knowledge Categories

Ruelland and Brasenose (2002) distinguish three categories of knowledge; procedural (the how), conceptual (the what), and strategic (the why). These categories aid in the classification of knowledge objects for use in performance support tools. Other categories of knowledge documented in paper and text include:

Externalized Knowledge – Knowledge is complex and initially tacit; however, it can be externalized and embedded in products and processes. One of the aspects of tacit knowledge is the cognitive dimension that comprises beliefs, ideals, values, schemata, and mental models that are deeply ingrained in the participants. This cognitive component, like other aspects of tacit knowledge, is difficult to articulate and shapes the perception of the participants. This cognitive component should be extracted to retain context and fullness of the captured explicit knowledge.

Multilocational Knowledge – Knowledge might reside both within and outside the organization. Knowledge management encompasses activities surrounding the integration of this knowledge from different sources in different forms and maintaining it. Knowledge management creates value by actively leveraging the know-how, experience, and judgment within and outside an organization. The initial key to knowledge creation thus lies in mobilization and conversion of this tacit knowledge into a form of explicit knowledge.

Migratory Knowledge – Migratory knowledge is knowledge that is independent of its owner or creator. As knowledge becomes more codified, its capacity to move, meaning the ability to transfer knowledge from one person or organization to another without losing its context and meaning, increases. Codification implies some kind of capture – on documents, databases, pictures, illustrations, spreadsheets on a disk, e-mails, videotapes, or on a web page on a corporate Intranet. Codification however does not imply that capture has to be electronic; it can be on paper, tape, or film.

Declarative Knowledge – Corresponds to things that we are aware we know and can usually describe to others (Anderson 1997) or knowledge about facts and things (Yi 2003, Fiore 2003).

Procedural Knowledge – Knowledge that we display in a behavior but of which we are not conscious (Anderson 1997, Fiore 2003).

Other types of knowledge include: Structural Knowledge, Perceptual Knowledge, Conceptual Knowledge, Objective Knowledge, Subjective Knowledge, Collective Knowledge, and Machine Knowledge (Anderson 1997, Chen 2002, Fiore 2003).

2.2.3 Components of Knowledge

Components that make up knowledge include intuition, grounded truth, judgment, experience, values, assumptions, beliefs, and intelligence. These concepts aid in the capture and sharing of knowledge within a knowledge management system.

2.2.4 Knowledge Hierarchy

Davenport identifies only three entities of knowledge: data, information, and knowledge—whereas other researchers describe other entities, such as, wisdom, insight, resolve, and action in the hierarchy of knowledge (Davenport et al., 1998). In this paper, we will view the knowledge hierarchy structure as data being the lowest form, to information, to knowledge, and ultimately to wisdom. What is essential is that most knowledge management experts believe that computer systems can only deliver two entities of the knowledge hierarchy - data and information.

2.2.5 Knowledge Transfer

Knowledge transfer is nominally concerned with the process of moving useful information from one individual to another (Davenport et al., 1998). Since the introduction of information systems and the World Wide Web, knowledge transfer has moved from exclusively face-to-face discussions to include information system nodes and links. When an automotive maintenance technician is engaged in performing a troubleshooting task, methods of knowledge transfer are very important. People will seek knowledge in the most efficient manner that will get them closest to the solution state.

2.2.6 Knowledge Management Process Models

The Nortel knowledge management initiative found that a good process-oriented knowledge management strategy should have a tripartite focus on process, people and technology (Massey et al., 2002). Figure 2.3 illustrates the tripartite strategy method and shows that the process and the people define the technology requirements.

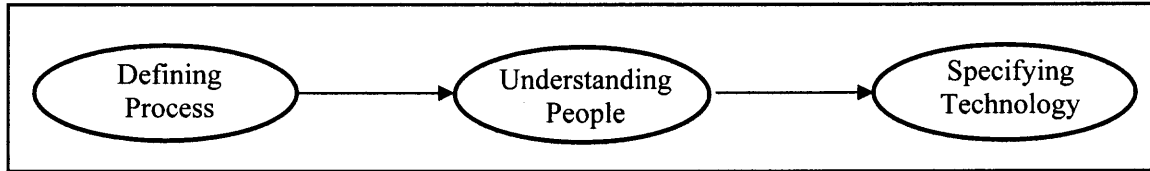


Figure 2.3 Knowledge Management Tripartite Strategy.
(Massey et al., 2002)

2.2.7 Knowledge Objects

Knowledge objects contain compartments, or slots, for different but related elements of knowledge (Merrill 1996). All knowledge objects have a set of information slots including name, portrayal, and description (Merrill 1996). The slots permit high-level identification of the knowledge object. Li and Merrill (1990) have identified four types of knowledge objects: entities, properties, activities, and processes. The use of knowledge objects containers within the performance support domain provide a means to aid in the capturing, classifying and redistribution of knowledge in the context that is to be used.

2.2.8 Types of Knowledge Sharing

In most performance support systems, stored information is static and loses its relevance over time. Knowledge management system developers strive to keep the data and information within a knowledge management system in motion and current, and to create an environment that encourages knowledge updating and sharing. This type of convention allows for the sharing of tacit knowledge by providing the means for personal interaction between the knowledge owner and knowledge requester. The three types of knowledge sharing that could be employed within a CoP are: knowledge retrieval, knowledge exchange, and knowledge creation. Knowledge retrieval is knowledge sharing with the purpose of the individual

retrieving existing organizational knowledge. During knowledge retrieval, the individual learns from the organization. Knowledge exchange is knowledge sharing from an individual to other individuals with the purpose of exchanging existing individual knowledge. During this process, people learn from other people. Knowledge creation is derived from knowledge sharing among individuals with the purpose of generating new knowledge (Huysman 2000).

2.2.9 Group Knowledge

Knowledge transfer is concerned with the process of moving useful information from one individual to another (Ladd et al., 2002). In military maintenance training, soldiers work in teams and are called “battle buddies.” From this foundation, the Army maintenance workforce is built around support teams and maintenance sections. These teams are organized to perform specific maintenance functions. Within these teams, the knowledge is centered on the senior member of the team, the team leader or section sergeant. This person has the responsibility to share his/her domain knowledge with the other team members.

Team members hold common or overlapping cognitive representations of task requirements and procedures (Cannon-Brown et al., 1993) that could be coupled to represent the team’s knowledge resources. In military teams, members rely on their team members to fill in knowledge gaps when performing complex tasks.

2.2.10 Knowledge Management System Drivers

Based on the assumption that distributive knowledge management systems, like CoPs, are socio-technical systems, drivers provide the means for a knowledge management system to function, operate and have a purpose. Some of the primary drivers associated with

knowledge management systems are knowledge requirements, the need for shared understanding, technology, organizational structure, personal needs, professional needs, and economics.

2.2.11 Knowledge-in Context

One of the most significant changes in contemporary learning is that knowledge is no longer regarded as an abstraction and decontextualized substance existing in the mind of an individual, but rather is a constructive process that emerges in specific situations and context (Jacobson and Archodidou 2000). Cognitive mapping has provided the means to convert tacit knowledge to explicit knowledge within a performance support system. This process provides system developers with a capability to deliver knowledge in the proper context.

2.2.12 Knowledge Maps

A knowledge map is defined in an information retrieval perspective as the categorization of documents characterized by concepts (Lin and Hsueh 2002). Knowledge maps link various concepts from shared documents and knowledge owners with knowledge seekers. Specifically, document categories are built into the knowledge maps to represent a concept hierarchy where learning paths can be traversed and associated with the problem solving process (Lin and Hsueh 2002).

2.2.13 Summary

Knowledge is a critical component of performance support systems. In order to maintain relevancy of a performance support system, the knowledge associated with that system must

remain current. As a practice, knowledge management addresses the issues of creating, capturing, transforming, and applying knowledge (Alavi and Leidner 2001, Davenport et al., 1998, and Davenport and Prusak 2000).

The systems of today tend to contain an overwhelming amount of data and information that needs to be transformed into knowledge for a given process or task. Knowledge maps are used to guide a user to the relevant knowledge. Specifically, document categories are built into the knowledge maps to represent a concept hierarchy where learning paths can be traversed and associated with the problem solving process (Lin and Hsueh 2002). Computer-mediated performance support systems have the potential of delivering tacit knowledge in a distributive environment.

2.3 Environments

Environments, both physical and computer-aided, provide a means for knowledge workers to gain knowledge from external sources to help in the completion of a process or task. They also provide a place for knowledge workers to operate within, to build links to knowledge resources, and to interact with, to aid them in achieving their goals.

An environment, in the context of this paper, is constrained a space within which one works or interacts and is also the conditions within that space that influence how one feels or derives actions. This environment has a direct influence on the level of performance one achieves. In the next section, computer-aided training environments that have been developed by the Department of Defense to augment traditional training methods are discussed.

2.3.1 Virtual, Live, and Constructive Environments

Over the past 20 years, through an evolutionary process, the Department of Defense has developed computer-mediated learning environments defined as virtual, live, and constructive. These environments, sometimes called domains, are not well defined but serve as a basis for researchers and system developers. The only standard definition provided for virtual, live, and constructive learning environments is found in the field of simulation.

The definition begins with the problem of categorization. There is no clear division between the three categories (DoD 5000.59-P 1995) and the degree of human participation in the simulation is infinitely variable, as is the degree of equipment realism. This categorization of simulations also lacks a category for simulated people working on or with real equipment. The definitions are as follows (DoD 5000.59-P 1995):

- **Live Simulation:** A simulation involving real people operating real systems
- **Virtual Simulation:** A simulation involving real people operating simulated systems. Virtual simulations inject a human-in-the-loop in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a command and control team)
- **Constructive Model or Simulation:** Models and simulations involving simulated people operating simulated systems. Real people stimulate (insert inputs into) such simulations, but are not involved in determining the outcomes

In most operational simulation systems these categories are very distorted. For example, a part-task trainer is considered a constructive simulation or training device, and a

computer representation of a functional system is considered a virtual training device. They may both be computer representations of the same functional system.

Many organizations have conducted experiments blending these environments for the purpose of achieving an optimal solution for a given training objective. The most well known of these experiments is the Advance Learning Environment (Hubal, 1998). This study provides empirical evidence that by combining the three learning environments, the effectiveness of a training event and the efficiency of its delivery are improved and also that the combination reduces the cost of conducting the training. The study also coupled the virtual, live, and constructive learning environments with four constructs to give these learning environments some additional meaning. These constructs are depicted in Figure 2.4 and show their relationships to the three environments (Hubal and Helms, 1998):

- Familiarize - To gain a high level understanding of the system, its make-up, functions and capabilities
- Conceptualize - To observe the system in operation as it relates to a given task or function
- Acquire - To acquire knowledge on the techniques and procedures associated with a given system and its related systems
- Practice - To internalize the techniques and procedures by practicing the knowledge acquired. This construct could be performed using computer simulation, a mockup, or a real system;
- Validate - To test the ability to perform a given task or procedure.

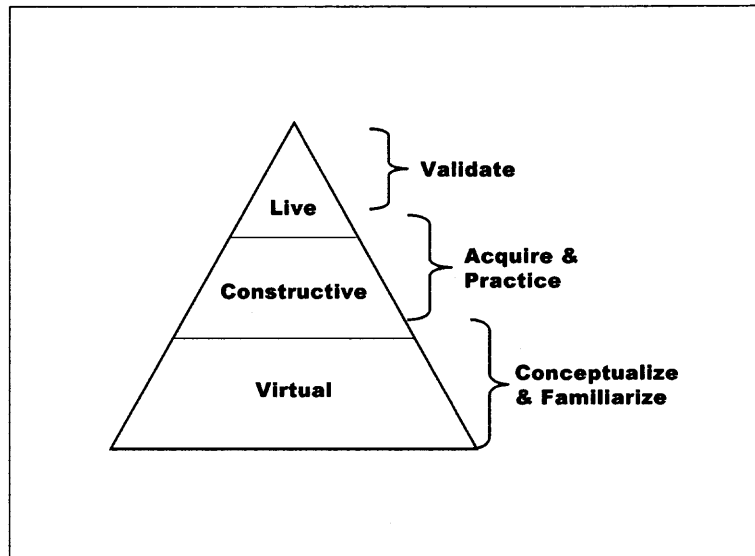


Figure 2.4 The Three Learning Environments.
(Hubel and Helms, 1998)

2.3.2 Socio-Technical Environment

Computer-mediated collaborative systems such as Communities of Practice (CoP) are comprised of a social structure consisting of agents, drivers and norms (de Moor 1998). Agents, in the context of a CoP, are the participants within the community that add structure and sustain the life of the community. These participants have roles, such as community leader, knowledge manager, community member, community librarian, etc. Other agents, such as intelligent agents, can be utilized to support information system requirements. Drivers are another key component of a CoP. They provide the social, political, organizational, and technical components of the community. Their main functions are to keep the community organized, relevant, and motivated. Norms of a community serve as the rules that the community leaders and members follow to ensure community well being. There are many classifications of norms that govern socio-technical systems behavior, many of which are implicit (Whitworth 2003).

2.3.3 Summary

Computer-mediated learning environments have the capability to enable learning, segment the user's knowledge discovery space, aid in the categorization of knowledge objects, and provide a space where an individual can interact with objects that can provide a means to get closer to the solution state.

2.4 Problem Solving

The core objective of a performance support system is to aid the user in the process of completing a task. Problem solving is one of the key functions associated with completing a task while diagnosing a fault. The reason most performance support systems fail is that they ignore the fact that problem solvers will only use a tool if it takes them closer to the goal state (Lovett and Anderson, 1996). Instead, the problem solvers will use their problem-solving experiences, their history-of-success, and the resources available to them and thereby will develop a mental model that will get them to the goal state. Lovett and Anderson (1996) validated a common finding among researchers that problem solvers are very sensitive about how close a particular move will take their current state to the goal state. Thus, the problem solver creates a sequence of problem transformations, which moves the problem from its initial state to the goal state, creating a path to the solution (Bhaskar and Simon, 1978; Simon, 1978; Mayer, 1983).

2.4.1 Problem Solving Methods

This section reviews a select group of problem solving methods that relate to the tasks associated with diagnostics and repair. Problem solving methods are not new. Some

methods are influenced by a method developed as far back as 825 A.D. by Alkwarazmi, whose works and name derived the word algorithm (Rosen 1995). Descartes (1637), in his Discourse on Method, observed that the problem solver must go about things in the right way and must use the right method to arrive at a solution; otherwise nothing will be discovered (Rosen 1995). Dewey's Model (1910) divided the problem solving process into four stages: define problem, suggest possible solutions, identify possible alternative solutions, and test. His method resembles the classic scientific method of observation, analysis, hypothesis, and experimental validation (Deek, 1998).

2.4.2 Stepien, Gallagher, and Workman's Model

Stepien, Gallagher, and Workman (1993) offer a standard model of problem solving. It consists of a seven (7) step process. (1) Analyze the problem – understand the problem and discuss it with others, if possible; (2) List what is known – write down information that is known about the problem; (3) Develop problem statement – describe what is to be solved and produced from what is known about the problem; (4) List what is needed – write down questions to be answered, information to be found, and concepts or principles to be learned; (5) List possible actions – identify tasks to be completed and consider potential solutions; (6) Analyze information – inspect information gathered and implement appropriate solutions; (7) Present findings – verify outcome and report results.

2.4.3 Problem Solving Under Pressure

In the military, it is important that a maintenance technician has the ability to solve complex problems under time pressure. The use of information while solving problems under

pressure is normally constrained by the problem solver. Under stress, individuals emphasize prior expectations or internal hypotheses about their environment and tend to narrow their attention to dominant cues and to exclude peripheral cues (Staw et al., 1981). Physiological stress has been manipulated by excess pacing of experimental tasks and time pressure (Lazarus and Eniksen, 1952). Thus, when a soldier is introduced to new concepts, processes and technologies, they may exclude the benefits of the new concepts and use the tools they know to complete a task while working under pressure.

2.4.4 General Motors Corporation, Strategy Based Diagnostics

General Motors (GM) Corporation developed a seven (7) step fault diagnostics process named GM's Strategy Based Diagnostics: (1) Verify concern – verify that there is a legitimate problem and see if the problem can be duplicated; (2) Make preliminary checks – perform visual inspection and conduct quick checks. See if things are working as they should; (3) Follow diagnostic systems checks – follow published diagnostic procedures; (4) Check bulletins - check bulletins based on defined symptoms; (5) Diagnose – diagnose using stored codes, symptom fault trees, procedures of intermittent faults, self-test where no published procedures exist or check to see if it operates as designed; (6) Re-examine concern - check for what is not broken; (7) Repair and verify – make repairs and verify and report results.

2.4.5 The U.S. Army Fault Diagnostic Process

The U.S. Army utilizes an integrated diagnostic process as its foundation for troubleshooting faults. This process is exercised through a step-by-step troubleshooting process called the

malfunction test or inspection and a corrective action process. This process consists of several phases: visual checks, function checks, automated testing, manual testing, and evacuate to higher level maintenance when solving the problem is beyond the capability of the technician. The method is based on the notion that automotive diagnostics is an art and that wisdom is the key ingredient for problem solvers to get to a solution state.

2.4.6 A Diagnostic Process for a Military Vehicle

The automotive industry relies heavily on technical manuals to aid service technicians in performing troubleshooting and repair tasks. This method was successful in the 20th Century, but falls short in providing the necessary information required to perform the complex diagnostic repairs and tasks of the 21st Century. The experiment will focus on specific troubleshooting and repair tasks associated with the military's Truck Utility Cargo, M998 (HMMWV) and a fault symptom associated with the starting and charging system. The specific fault symptom is that the vehicle will not start. This fault is relatively simple to troubleshoot and repair in a vehicle with analog systems, but becomes complex when it is associated with a vehicle equipped with digital control systems. One reason for the complexity is that the insertion digital technologies lead to intervening effects that make it difficult to find the cause of a malfunction. Hmelo-Silver and Pfeffer (2004) state that complex systems have intermediate steps that intervene between cause and effect, which may not be linear or predictable.

The fault symptom troubleshooting process for the HMMWV, 'vehicle will not start,' consists of several steps found in technical manual TM 9-2320-280-20-1 (Figure 2.6). The first step, fault symptom step 0, is the fault description and the start point. Step one asks the

question “Does the engine crank normally?” From this point, the decision tree separates into two main branches: run starting system mechanical tests and run starter circuit tests. This process is illustrated in Figure 2.5.

The complexity of the test increases as the technician precedes through the diagnostic tree and concludes when the technician finds the cause of the fault or evacuates the vehicle to higher-level maintenance. In the early steps, the process requires the troubleshooter to conduct visual and operational checks, and then to use diagnostic tools (see Figure 2.7 and 2.8). In the case of the HMMWV, the first diagnostic tool used is the Simplified Test Equipment (STE), which uses software to isolate the cause of the problem. If the cause is not identified by the STE, the process moves to the use of a Breakout Box. This diagnostic tool aids the technician in identifying circuit problems that cannot be identified using a STE. From that point, if the cause is not identified, diagnostics becomes an art.

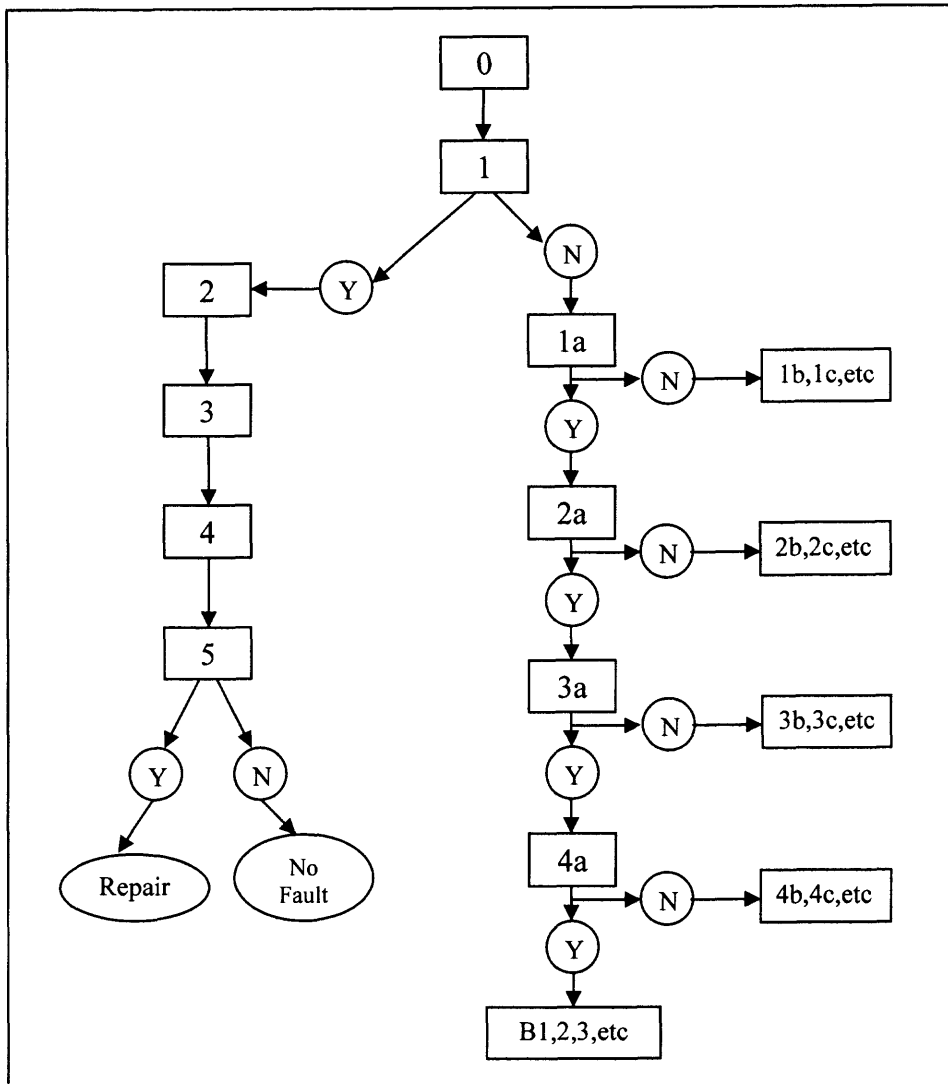


Figure 2.5 Diagnostic Decision Tree: Engine Will Not Start.

**ARMY TM 9-2320-280-20-1
AIR FORCE TO 36A12-1A-2092-1-1
MARINE CORPS TM 2320-20/7B**

Volume No. 1

(SUPERSEDES TM 9-2320-280-20-1, 19 JANUARY 1990)

**TECHNICAL MANUAL
UNIT MAINTENANCE**

TRUCK, UTILITY: CARGO/TROOP CARRIER, 1-1/4 TON, 4X4, M998 (2320-01-107-7155) (EIC: BBD); M998A1 (2320-01-371-9577) (EIC: BBN);

TRUCK, UTILITY: CARGO/TROOP CARRIER, 1-1/4 TON, 4X4, W/WINCH, M1038 (2320-01-107-7156) (EIC: BBE); M1038A1 (2320-01-371-9578) (EIC: BBP);

TRUCK, UTILITY: HEAVY VARIANT, 4X4, M1097 (2320-01-346-9317) (EIC:BBM); M1097A1 (2320-01-371-9583) (EIC: BBU); M1097A2 (2320-01-380-8604) (EIC: BB6); M1123 (2320-01-455-9593) (EIC: B6G);

TRUCK, UTILITY: TOW CARRIER, ARMORED, 1-1/4 TON, 4X4, M966 (2320-01-107-7153) (EIC: BBC); M966A1 (2320-01-372-3932) (EIC: BBX); M1121 (2320-01-456-1282) (EIC: B6H);

TRUCK, UTILITY: TOW CARRIER, ARMORED, 1-1/4 TON, 4X4, W/WINCH, M1036 (2320-01-107-7154) (EIC: BBH);

TRUCK, UTILITY: TOW CARRIER, W/SUPPLEMENTAL ARMOR, 1-1/4 TON, 4X4, M1045 (2320-01-146-7191); M1045A1 (2320-01-371-9580) (EIC: BBR); M1045A2 (2320-01-380-8229) (EIC: BB5);

TRUCK, UTILITY: TOW CARRIER, W/SUPPLEMENTAL ARMOR, 1-1/4 TON, 4X4, W/WINCH, M1046 (2320-01-146-7188); M1046A1 (2320-01-371-9582) (EIC: BBT);

TRUCK, UTILITY: ARMAMENT CARRIER, ARMORED, 1-1/4 TON, 4X4, M1025 (2320-01-128-9551) (EIC: BBF); M1025A1 (2320-01-371-9584) (EIC: BBV); M1025A2 (2320-01-380-8233) (EIC: BB3);

TRUCK, UTILITY: ARMAMENT CARRIER, ARMORED, 1-1/4 TON, 4X4, W/WINCH, M1026 (2320-01-128-9552) (EIC: BBG); M1026A1 (2320-01-371-9579) (EIC: BBQ);

TRUCK, UTILITY: ARMAMENT CARRIER, W/SUPPLEMENTAL ARMOR, 1-1/4 TON, 4X4, M1043 (2320-01-146-7190); M1043A1 (2320-01-372-3933) (EIC: BBY); M1043A2 (2320-01-380-8213) (EIC: BB4);

TRUCK, UTILITY: ARMAMENT CARRIER, W/SUPPLEMENTAL ARMOR, 1-1/4 TON, 4X4, W/WINCH, M1044 (2320-01-146-7189); M1044A1 (2320-01-371-9581) (EIC: BB5);

TRUCK, UTILITY: S250 SHELTER CARRIER, 4X4, M1037 (2320-01-146-7193) (EIC: BBK);

TRUCK, UTILITY: S250 SHELTER CARRIER, 4X4, W/WINCH, M1042 (2320-01-146-7187);

TRUCK, AMBULANCE, 2-LITTER, ARMORED, 4X4, M996 (2310-01-111-2275) (EIC: BBB); M996A1 (2310-01-372-3935) (EIC: BB2);

TRUCK, AMBULANCE, 4-LITTER, ARMORED, 4X4, M997 (2310-01-111-2274) (EIC: BBA); M997A1 (2310-01-372-3934) (EIC: BBZ); M997A2 (2310-01-380-8225) (EIC: BB8);

TRUCK, AMBULANCE, 2-LITTER, SOFT TOP, 4X4, M1035 (2310-01-146-7194); M1035A1 (2310-01-371-9585) (EIC: BBW); M1035A2 (2310-01-380-8290) (EIC: BB9).

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**HEADQUARTERS, DEPARTMENTS OF THE ARMY,
THE AIR FORCE, AND MARINE CORPS**

JANUARY 1996

Figure 2.6 Electronic Technical Manual.

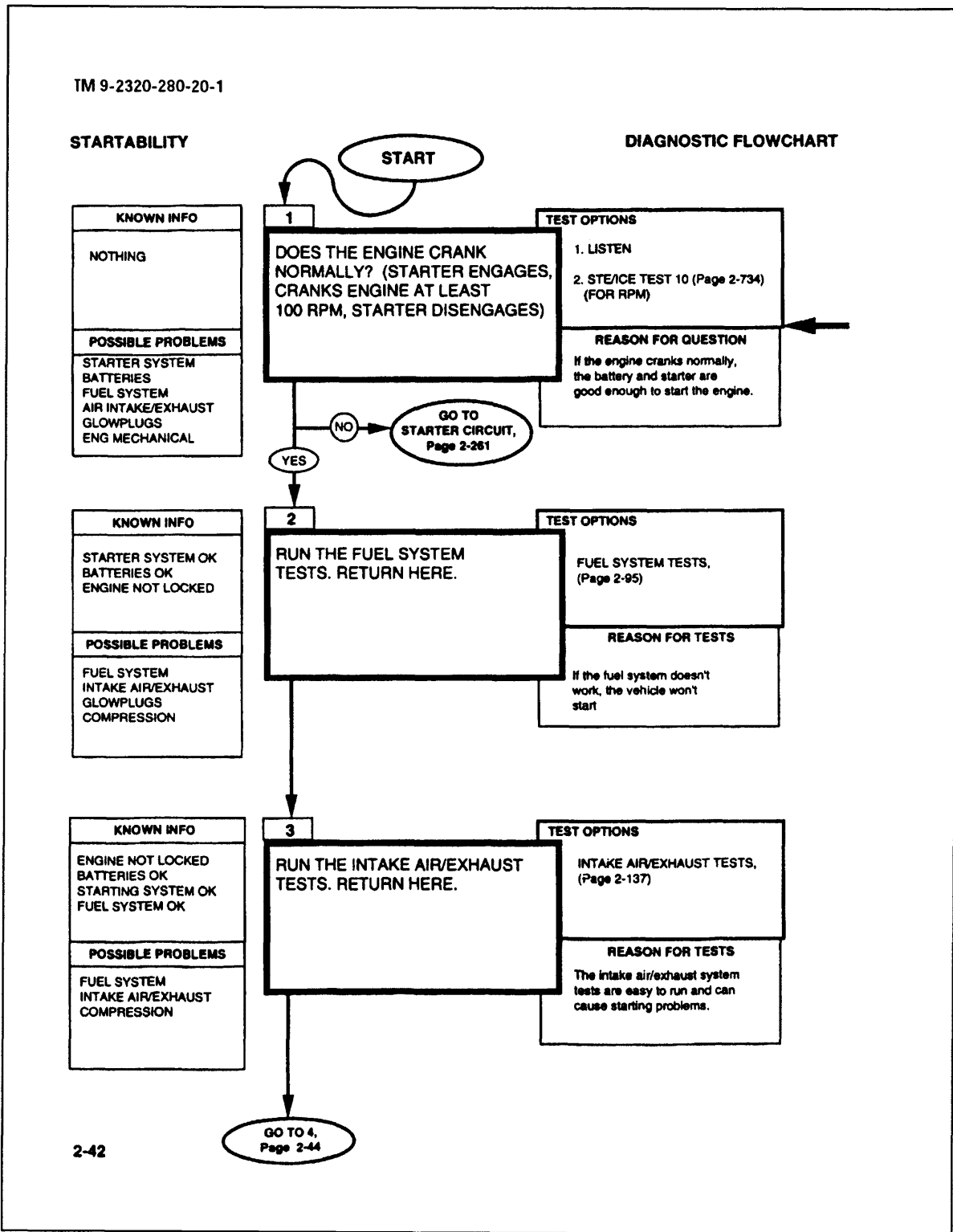
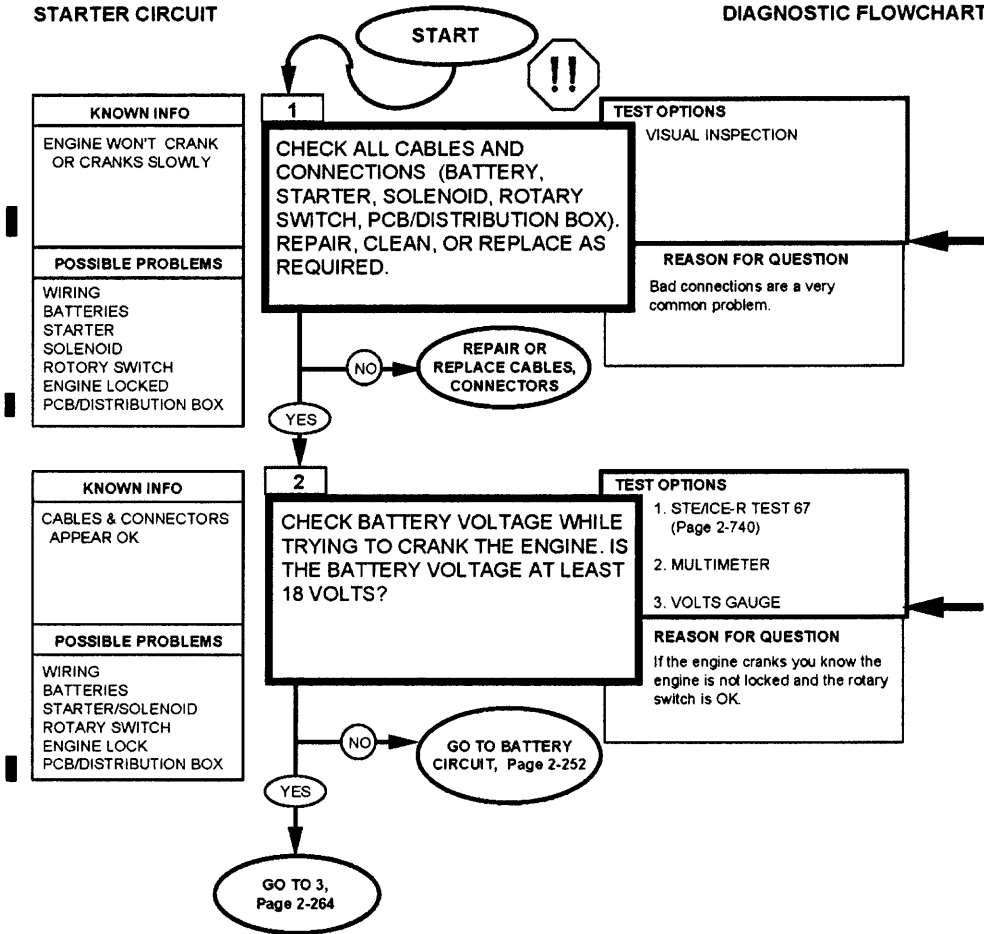


Figure 2.7 Troubleshooting Procedure 1.

TM 9-2320-280-20-1

STARTER CIRCUIT

DIAGNOSTIC FLOWCHART



2-262 Change 1

Figure 2.8 Troubleshooting Procedure Continued.

2.4.7 Summary

Problem solving methods have gone through several transitions over the years, from Dewey's Model on problem solving to GM's Strategy Based Diagnostic Process. A performance support system's primary purpose in diagnostics and repair is to move the problem solver as close to the solution state as possible with the information available. GM's Strategy Based Diagnostic Process provides a means for problem solvers to solve problems where no procedures are available. However, these problem-solving techniques fall short in the area of diagnostics and repair of complex systems. In order to improve on these processes, we need to clearly depict the actions of the problem solvers. We must also incorporate the understanding that problem solvers use knowledge resources differently when performing under pressure. Troubleshooting a fault in the automotive industry relies heavily on the problem solving skills and abilities of the automotive technician. The next section addresses mental models and the importance of their use by system developers when creating and validating performance support systems.

2.5 Mental Models

When we interact with our environments, we form internal models of ourselves, others, and the artifacts of technology with which we interact (Henderson et al., 2002). When making decisions, people use mental models to evaluate choices and frame discussions (Carley et al., 1992). A mental model is a person's conceptualization, or personal theory, of some domain or environment (Jih and Reeves, 1992). Mental models can serve as both explanatory and predictive tools when we interact with our environments. They provide a conceptual framework for describing, explaining, and predicting future system states (Klimoski and

Mohammed, 1994). Mental models are declarative representations of how the world is organized and may contain general knowledge, abstract knowledge and concrete cases that exemplify our knowledge (van Merriënboer et al., 2002). Mental models refer to a structure of known elements (e.g. declarative knowledge) and the relationships among those elements (Shavelson, 1974). These structures serve as mechanisms that enable individual tasks to be described and functions and forms of tasks to be explained and observed to illustrate the integration of tasks and anticipated future task requirements (Rouse, 1986).

Strong mental models allow for both abstract and case-based reasoning. Mental models may be viewed from different perspectives and can be analyzed as conceptual models, structural models, or casual models. Conceptual models (what is this?) focus on how “things” are interrelated and allow for the classification or description of objects, events or activities. A structural model (how is this organized?) describes a plan for reaching a particular goal and how each plan is related to another. Plans can be distinguished in scripts (what happens when?) that focus on how events are related in time and help to understand and predict behavior and building blocks or templates (how is this built?) that focus on how objects are related in space and help to understand or design artifacts. Casual model (how does this work?) focuses on how principles affect each other and help to interpret processes, give explanations for events, and make predictions.

2.5.1 Mental Model Mapping

Competent individuals can recognize patterns rapidly and develop mental maps that guide them through a thought process. Mental models represent a collection of knowledge that builds a foundation of understanding and provides the tools for problem solving (Brandt and Uden, 2003). Mental model mapping has the ability to determine a person's domain knowledge, which is a powerful determinate of a person's cognitive performance. These are able to represent problems in ways that facilitate problem solving (Glazer, 2000). When making decisions or talking to others, people use mental

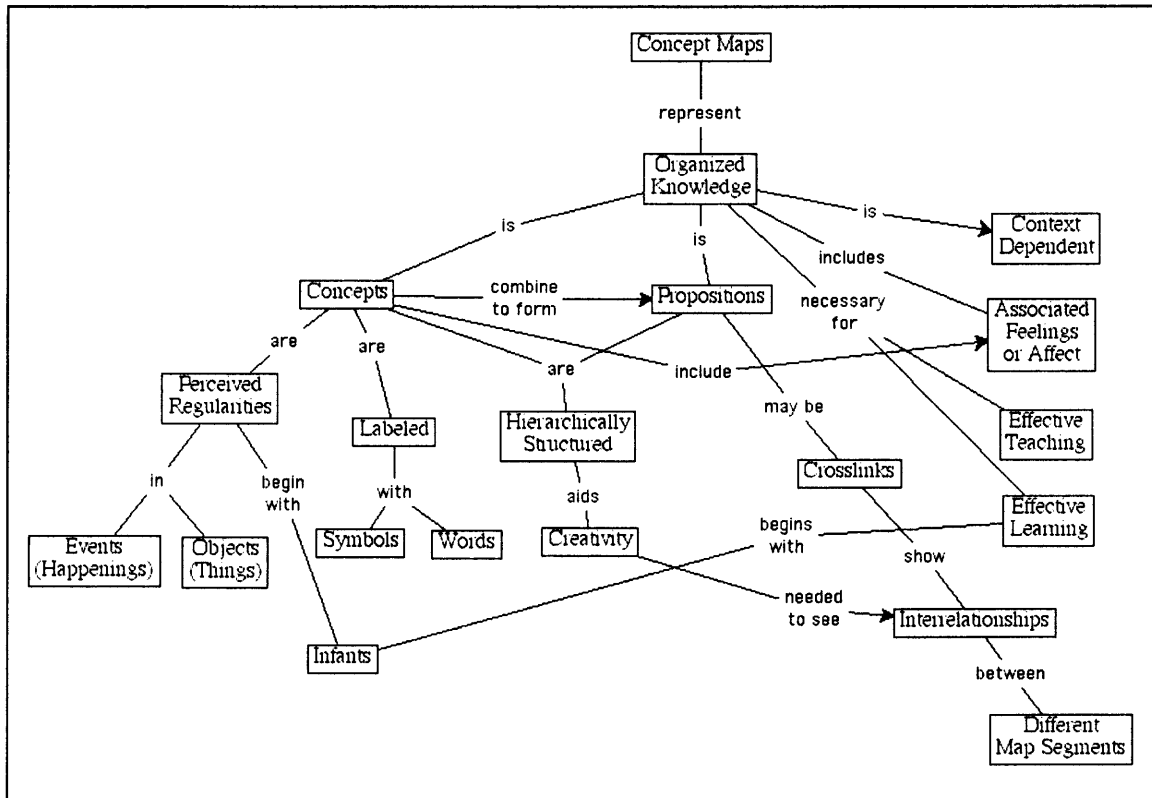


Figure 2.9 Concept Map Example.

models of the world to evaluate choices and frame discussions (Carley and Palmquist, 1992).

Mental models aid in the interpretive process by enabling individuals to screen out

information in order to prevent information overload and they are used to clarify individual cognitive functions or understanding (Kraiger and Wenzel, 1997).

Researchers have used many methods to capture mental models. Some of the primary methods researchers use are concept maps, influence diagrams, procedural mapping, schema (process and event), content analysis, cognitive mapping, and relational models. Concept maps, Figure 2.9, are a specific kind of mental model representation and are one method of representing and measuring an individual's knowledge (Crosadell et al., 2003). Concept maps provide a visual representation of conceptual and relationship knowledge within a given domain. They resemble a spider web, consisting of many nodes connected to one another by lines that indicate relationships. These concept maps can be used to visualize a mental model of an individual engaged in problem solving. The concepts depicted on a map can provide a researcher with a snapshot of the problem solver's knowledge and understanding of the problem, task, and tools available to aid in solving the problem. Concept maps provide access to conceptual knowledge. They are a direct method of looking at the organization and structure of an individual's knowledge within a particular domain and at the fluency and efficiency with which knowledge can be used (Williams, 1998).

Influence diagrams are a simple visual representation of a decision problem and are analogous to the elements on which cognitive maps are based (Chapra et al., 2000). Influence diagrams offer an intuitive way to identify and display essential elements, including decisions, uncertainties and objectives, and how they influence each other. Procedural mapping attempts to characterize the implicit and explicit procedures used by individuals in the performance of a given task (Carley and Palmquist, 1992). Cognitive mapping provides the means to represent the cognitive structures in memory.

Schemas are developed from experience and help individuals recognize an object or an event (Kraiger and Wenzel, 1997). Schema theory proposes that bodies of knowledge are stored in coherent wholes, or schemas, that represent mental constructs for objects, events, or ideas (Rumelhart, 1977). Content analysis examines the content of written text and generalizes the frequency with which particular words are used in the text (Carley, 1992). Researchers use cognitive maps to compare mental models between individuals to make comparisons in learning and decision-making (Carley, 1992).

A relational model is a static frame consisting of tokens that represent entities of the world and a set of relations that define the physical relationships among the entities (Glasgow and Malton, 1999). Relational models can be depicted as a spatial model where the relationships of interest are spatial in nature. Based on Vandenbosch and Higgins (1996), Figure 2.10, a conceptual mental model process model was developed to explain that the terminology was developed consisting of the terms “mental model maintenance’ and “mental model building.” Mental model maintenance implies that basic routines remain appropriate. In comparison, mental model building is much riskier and its benefits more remote.

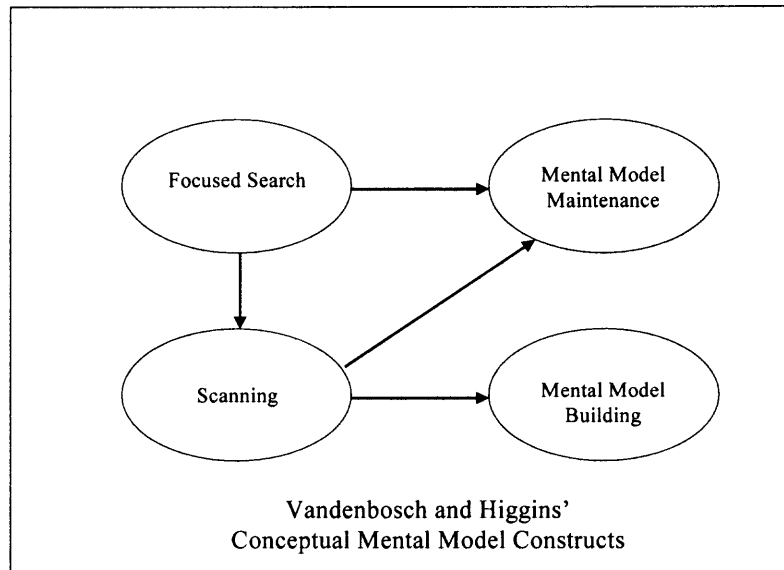


Figure 2.10 Conceptual Mental Model Process Model.

2.5.2 Shared Mental Model

The construct of shared mental models is drawn from theories of individual mental models and is used to illustrate group cognitive functioning of understanding (Klimoski and Mohammed, 1994). The model below, Figure 2.11, represented in many research papers, describes the measurement of shared mental models (Klimoski and Mohammed, 1994).

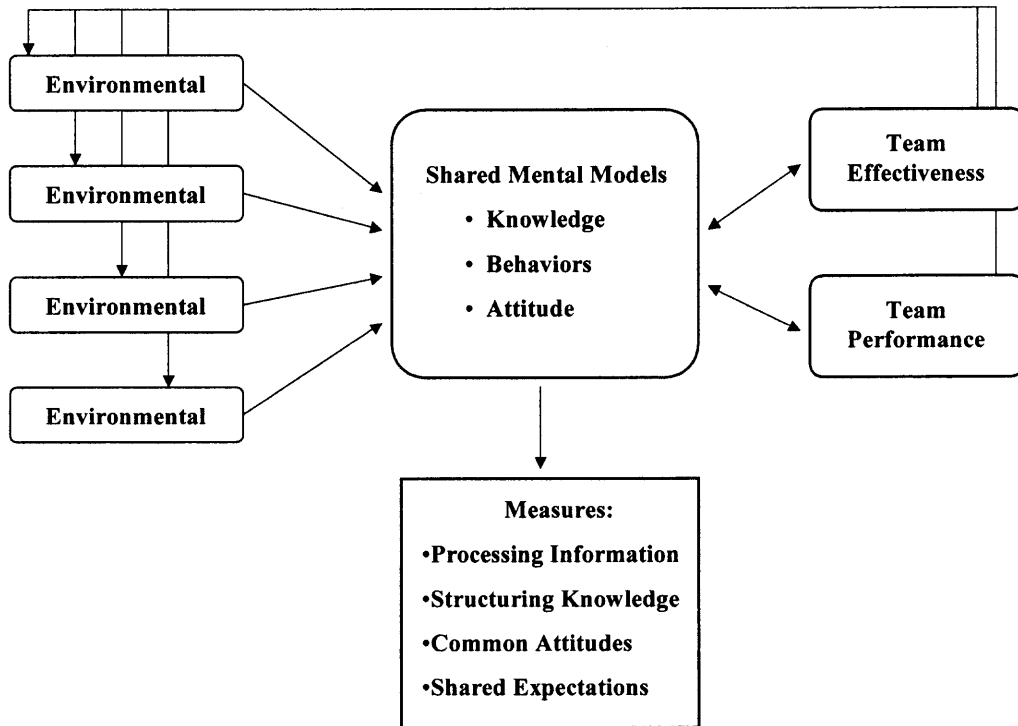


Figure 2.11 Shared Mental Model Measures.
(Klimoske and Mohammed, 1994)

Shared mental models for team decision making is defined as knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and, in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members (Cannon-Bowers, Salas and Converse 1993).

2.5.3 Team Mental Models

Individual cognitive maps can be compared, or combined, to create a team cognitive map (Carley, 1997). They represent the union of the collective knowledge of two team members that are represented by individual cognitive maps.

2.5.4 Meta-Mental-Models

A meta-model is a model for a model. If the learner has acquired the knowledge components and knowledge structure for a conceptual network, then he or she has a meta-mental-model for acquiring a conceptual network for a specific area (Merrill, 2000).

2.5.5 Norman's Model

Norman's Model and Interaction Effects serves as a foundation for the review of mental models. Lim, Banbasat, and Todd (1996) depict Norman's Model as a system model for decision makers. Norman (1986) identifies three modes of learning: accretion, structuring, and tuning. These modes are closely related to Hubel and Helms' (1998) blending learning environments, described in Section 2.3.1, live, virtual, and constructive environments. These environments are associated with the learning modes of validation, acquire and practice, conceptualize and familiarize.

2.5.6 Graphical Representations

A mental model can be graphically represented using concept maps. This representation, figure 2.9, consists of concepts and propositions that can be graphically represented using nodes and arcs. One of the advantages of using graphs to represent mental model maps is that they permit a mathematically precise method for analysis. They create an opportunity for researchers to code text to show the relationship between concepts and their relationships (Carley, 1997).

In order to combine information from individual mental model maps into a single representation of a team, it is necessary to first translate the maps into a consistent

representational form. In order to determine the group mental model of a maintenance team, the best method of measure is to combine the maps of individual member through a union of maps to represent the team's capabilities.

2.5.7 Summary

Mental model maps provide the means for researchers to capture and analyze an individual's thought process. These maps can be constructed using various methods, such as concept maps, influence diagrams, procedural maps, schema, content analysis cognitive mapping, and relational diagrams. Individual representations can be combined to obtain a team's mental model. This emphasis on mental model maps is because of their ability to illustrate the effects of changes that are introduced throughout performance support interventions.

2.6 Performance Support Tools

In the Industrial Age, performance support tools consisted of notebooks, ledgers, job aids, manuals, mentors, advisors, and coaches. In the Information Age, the age of computer automation, performance support tools evolved into databases that produce spreadsheets, graphs, electronic documents, electronic technical manuals, help tools, expert systems, and computer-based training. Today, as we move into the Knowledge Age, we have the ability to distribute knowledge through the Internet using constructs, such as distributive education, knowledge maps, performance support systems, and Communities of Practice. Even though this evolutionary process is still in its infancy, we are beginning to understand that computer-mediated performance support systems are more than just a performance support tool. They have the potential to capture, store, and distribute large amounts of knowledge to virtually

any place, at any time. A Community of Practice construct also incorporates a social structure that connects individuals to groups of people with the same interests or goals and can also provide the means for individuals to connect virtually to experts, mentors, and advisors through LANs, WANs, and the Internet.

The objectives of performance support tools are to enable people to perform their job functions with accuracy and consistency, and to provide the means to link to assistance when necessary. It is very difficult for developers and managers of performance support tools to get to that end, and there is a lot of research that still needs to be done. The following sections provide information that is critical to areas associated with individual performance support systems in a distributive domain.

2.6.1 Electronic Performance Support System

Electronic Performance Support Systems (EPSS) are evolving in response to the need to provide information that is framed in the specific context of the task-at-hand (Kabel and Kiger, 1997). EPSS grew out of the failures associated with Expert Systems in the early 1990's. Many users of Expert Systems found that the information and the rule-base at its core became obsolete almost immediately upon its implementation. These failures forged the way for researchers to develop systems that have the ability to provide a means for user groups to keep information current and provide paths to experts, through knowledge maps, when solving complex problems.

The objective of an EPSS is to provide whatever is necessary to generate performance improvement and provide learning at the moment of need (Witt and Wager, 1994). EPSS must also be a computer-based system that improves workers' productivity by providing on-

the-job access to integrated information, advice and learning experiences (Raybould, 1990). The basic framework of an EPSS integrates principles found in various research areas including artificial intelligence, computer-based training, computer-mediated communications, and performance centered design (Massey et al., 2002). An EPSS provides support to the user in order to achieve a performance objective (Gery, 1995) and provides a vehicle for Just-in-Time knowledge delivery (Cole et al., 1997).

A basic definition of EPSS is a computer-based system that supplies access to one, several, or all of the following; integrated information, advice, learning experiences, expert consultation, and tools with which the user can control the sequence and scope of the information at the moment when the information is needed (Moore et al., 2000). Learning may occur during the use of an EPSS, but the primary purpose is to help the user to perform a task and improve productivity (Witt and Wager, 1994)

2.6.2 Modes of Presenting Information

An EPSS uses multimedia technology to present information to the user, often using the following modes: text; fixed or animated graphics; audio, including voice and music; full-motion video; still images; logic diagrams, including steps, flowcharts, formulas or scientific notation; or computer simulations.

2.6.3 Basic Types of Information

An EPSS relies on many types of information to provide a user with assistance in solving a problem or performing a task. Some basic types of information that are used in an EPSS are procedural, process, concept, structure, principles, facts, classification, and examples

(Raybould, 1995). Understanding that there is a typology of information, aids in the purposing and construction of knowledge objects within a performance support system.

2.6.4 Knowledge Capture

The diagnostic process of an automotive maintenance technician is experience-based and is captured through a procedural mapping process (Carley and Palmquist, 1992). The diagnostic process within an EPSS is experience-guided: skilled workers search for certain sensory related values which lead them – as they know from experience – to the cause of the malfunction very quickly and without much effort (Fischer et al., 1999). An expert's behavior is difficult to capture as tacit knowledge and incorporate into a performance support tool. Fischer suggests that the development of an experience-based documentation system should provide for the capturing of technical artifacts that could be used for performance support (Fischer et al., 1999). An EPSS provides a means to convert tacit knowledge into explicit knowledge. Other methods of knowledge capture are mental model capture, cognitive mapping, procedural mapping, data mining, and recording of electronic messaging.

2.6.5 Tools Associated with an EPSS

There are many types of tools and program modules that can be employed within an EPSS framework. Advisory, interactive performance aids and interactive training manuals are the most common tools associated with an EPSS.

2.6.6 Use of Electronic Performance Support System

An EPSS can be used in a variety of ways to provide assistance to workers while they are performing a task. Some documented uses of an EPSS are to provide support to technical workers while installing, configuring, maintaining, troubleshooting, and repairing products. EPSS are also used to provide knowledge mapping to experts and to provide help desk support.

2.6.7 Similarities between Instructional Systems and Performance Support Systems

There are many similarities and many important differences between instructional systems and electronic performance support systems. The fundamental difference is of the purposes of the two products. Learning systems are built to achieve some type of learning outcome and performance support systems are built to provide insight in order to improve a worker's performance. Because of these differences, designers use different methodologies to create them (Witt and Wager, 1994). However, an EPSS developer must still have a basic understanding of the learning process to enable learning to occur while performing a task.

2.6.8 Performance Support Tools Lessen the Need for Formal Instruction

In recent times, performance support tools have emerged as a means to aid individuals in performing tasks with little or no prior experience or training in the specific system. This is accomplished by invoking the user's mental model of how to solve a problem or perform a task, then to provide the specific information needed to accomplish it. Based on the premise that information can be transformed into knowledge by the person who processes a conceptual framework or mental model in order to take action on that information, we can

conclude that the need for formal instruction is decreased. This provides a means for end-users to complete complex tasks by receiving information from a performance tool, transforming that information into knowledge, and then completing the task.

2.6.9 Electronic Performance Support System Design Development Process

The development of an EPSS is very similar to the application development process. For an EPSS project to become successful, the development team members must combine both training and application development expertise (Benko and Webster 1997). The EPSS development process consists of several phases: analysis; design; development; testing; and integration.

2.6.10 Distributive Electronic Performance Support Systems

As products increase in models, geographic dispersion, complexity, and service life, it is increasingly apparent that EPSS tools must be globally distributed across the workforce. As mentioned earlier, a distributive version of an EPSS can be supported within a Community of Practice. As stand alone EPSS are transformed to Web-based applications, they begin to take on a life of their own as Communities of Practice. Communities of Practice are closely related to an EPSS because both are derived from the desire to improve individual and organizational performance by providing information and learning, on-demand, and at the point-of-need.

2.6.11 Summary

An EPSS is a computer-mediated system that is intended to provide on-the-job access to task-based information, learning, and the transfer of knowledge to enable improvements in productivity (Cole and Fisher, 1997). EPSS evolved from Expert Systems and incorporate many of the characteristics of those systems, including intelligent agents. A key factor in developing a successful EPSS is the staffing of the project (Benko and Webster, 1997), because EPSS projects tend to be more complex than other software development projects. An EPSS is both a performance support tool and a learning system that requires skills from many disciplines in order to be developed.

One disadvantage of the EPSS is that Electronic Technical Manuals (ETMs) are used as the foundation information for learning and solving problems. These ETMs use hypermedia tools to navigate through content. The use of hypermedia technical manuals has shown to be not as effective as traditional manuals from a user's point of view. Because most ETMs are hypermedia versions of their former version, it takes a user longer to search for information, mainly because they cannot thumb through pages like they could with traditional manuals, and sometimes they never find the information they are seeking.

EPSS provide access to integrated information, knowledge, learning experiences, advice, and guidance at the point-of-need to bring individuals closer to the solution state (Massey et al., 2002). EPSS are the interim system that will lead to a system that provides the means for a user to receive just-in-time knowledge.

2.7 Communities of Practice

Communities of Practice (CoP) provide the means for individuals who share the same profession or interest to share data, information, and even knowledge on a given subject. As an example, automotive repair technicians can participate in a CoP that provides job aids, technical assistance, training materials, and knowledge that enhance their skills and job performance. CoPs emerged in the mid 1990's as a way to share knowledge about a common interest. The most prevalent CoPs are those in the health care industry in which people search for better ways to diagnose and treat injuries and illnesses. One of the characteristics that differentiate CoPs from EPSS is the social structure of a CoP. This social structure provides the vehicle for knowledge cultivation and sharing. It also provides the means for organizations to collaborate and share knowledge across time and distance (Hildreth et al., 2000).

There are several accepted definitions for CoPs and there are two that are closely related to EPSS: CoPs are comprised of practitioners who work as a community in a certain domain doing similar work (Davenport, 1998), and, a CoP is a group of people who share a concern, a set of problems, or a passion about a topic, and who deepen their understanding and knowledge of this area by interacting on an ongoing basis (Wenger, 1998).

In many types of knowledge work, people require conversation, experimentation, and shared experiences to accomplish their work (Allee, 2000). Knowledge sharing serves as the unifying framework within a CoP and is accomplished by capturing and reusing past experiences, embedding knowledge into products, services and processes, mapping networks to experts, and mining customer knowledge base and practitioner data (Allee, 2000).

The benefits of CoPs include increased idea creation, increased quality of knowledge and advice, assistance in problem solving, and the creation of a common context (Millen et al., 2002). Parboosingh (2002) points out that the experiences of practitioners suggest that interacting with peers and mentors in a workplace provides the best environment for learning and enhances both practice and judgment.

2.7.1 Types of Communities of Practice

There are about as many types of CoP as there are definitions. To gain a basic understanding of CoPs, three types are presented here. Informal CoPs are self-organized groups and are generally initiated by employees who communicate with one another because they share common work practices, interests, or aims. Informal CoPs are important for the development and sharing of expertise within a common group of practitioners. Supported CoPs are initiated to cultivate and share knowledge and capabilities for a given business or competency. Structured CoPs provide a cross-functional platform for members who have common objectives and goals.

2.7.2 Shared Norms within Communities of Practice

Based on the fact that a CoP is a socio-technical system, norms are an important characteristic of a CoP. Norms in a CoP are similar to those that develop in virtual communities. These norms provide protocols that aid in governance and set the standard for the behavior of its members. Norms are derived in response to three kinds of CoP imperatives: promoting shared purpose, safeguarding the quality of the group interactions, and managing scarce resources in the virtual commons (Whitworth and de Moore, 2003).

2.7.3 Boundary Objects

Boundary objects have the potential to serve as an agent in shifting artifacts from one process to another or from one community to another and they act as a brokering agent between humans, social systems (Wenger, 1998), and computer-mediated environments (Arias and Fisher, 2000). Boundary objects demonstrate that, although knowledge may be embedded in artifacts, it is a matter of capturing the knowledge and passing it on to others (Hildreth et al., 2000). Boundary objects provide a vehicle for supporting situation learning in a distributive CoP (Hildreth et al., 2000). It is important that the community understands its domain knowledge in order to gain a full understanding of the knowledge represented by its artifacts.

2.7.4 Stages of Development

Communities of practice move through various stages of development characterized by different levels of interaction among the members and different kinds of activities (Wenger, 1998). Wenger's stages of development are potential, coalescing, active, dispersed, and memorable. These stages, integrated with their typical activities, are illustrated below in Figure 2.12 (Wenger, 1998).

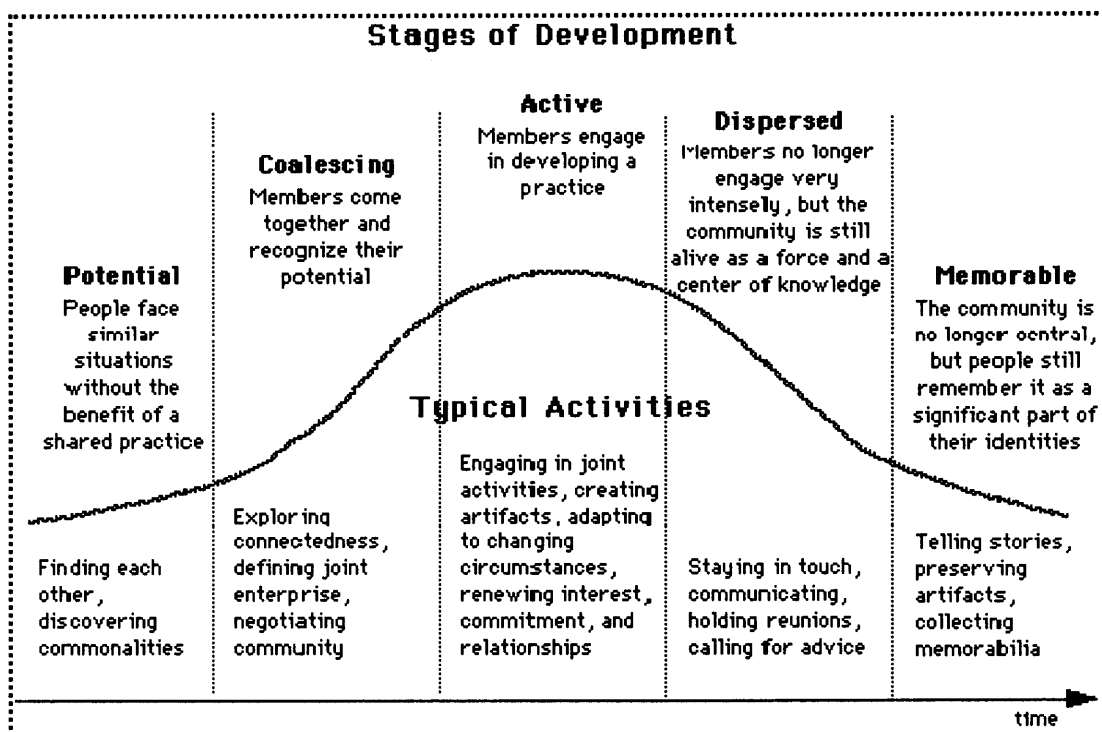


Figure 2.12 Communities of Practice Stages of Development Model.
(Wenger, 1998)

Some researchers look at community development as a natural, living, human institution that evolves as a natural system. Like families or villages, they form spontaneously, grow, mature, change, age, and die (McDermott, 2000).

2.7.5 Summary

A CoP is constructed based on the following assumptions. Learning is fundamentally a social phenomenon. People organize their learning around the social communities to which they belong. Knowledge is integrated in the life of communities that share values, beliefs, languages, and ways of doing things. Real knowledge is integrated in the doing, social relations, and expertise of these communities. Knowledge is inseparable from practice. It is not possible to know without doing. By doing, people learn.

CoPs provide the means to share knowledge to improve individual performance through a socio-technical framework that incorporates information system technologies and social systems. These components enable CoPs to deliver information that provides assistance to a worker and additionally provides a means for knowledge sharing (Hildreth, 2000). CoPs can also support distributed communities of practitioners who are interested in sharing knowledge and providing assistance to its members.

CoPs are the means to capture, store, and distribute knowledge in a given area of practice, and provide performance support tools to its members who deliver just-in-time knowledge to improve productivity and the confidence of the practitioner.

CHAPTER 3

THE LOCKTEL FRAMEWORK

Prior research has shown that learning environments are an essential part of performance support systems. The Hubel and Helm (1998) paper, “Live, Virtual, and Constructive (LVC) Environments for Training,” concludes that blended learning environments provide for a better, more efficient, and less costly method of training for complex tasks. This conclusion is the first time that blended computer-supported learning environments are found to be an important research topic. This study also provides us with a foundation for the transformation of LVC environments from learning systems to performance support systems.

Previous works in performance support and knowledge management assumed that there is only one environment an automotive technician interacts with, the computer-supported environment. They failed to recognize that within the computer-supported domain there are several environments an automotive technician can interact with. Through Hubel and Helm’s work, it can be seen that LVC environments within a performance support setting will provide us with a means to deliver knowledge to users while they are engaged in performing a task. This method can potentially also provide a means to combine military training and performance support into a single “embedded” performance support system.

Performance support systems are intended to provide training and performance support to workers while they are engaged in performing a task. Raybould (1990) provides us with this understanding by stating that performance support systems improve worker productivity by providing on-the-job access to integrated information, advice, and learning experiences. In concept, these systems are ideal for use in supporting both military and

civilian maintenance technicians in the automotive industry. The premise associated with performance support systems is two-fold: one, that users are required to possess the basic skills and knowledge associated with completing a task; and two, that the performance support system will provide the user with the specific knowledge needed to complete the task at hand. The reality is that these systems require massive amounts of content: information, training segments, procedural information, diagnostic information, system knowledge, and problem solving methods providing solutions to specific problems. When stored information is not available to meet the technician's needs, the technician is forced to do it alone, and in most cases fails to perform effectively. These systems also rely on the user's ability to find the information they need to complete the task, specifically, understanding how the system they are troubleshooting operates as designed, how to use the tools associated with the task, and how to resolve complex problems where the cause is difficult to isolate and there is no known published solution.

As discussed earlier, a majority of the performance support systems developed today simply converts paper-based technical manuals into digital technical manuals using the same format, but with hyperlinked text to navigate through the material. This method portrays the digital environment within a performance support system as a single environment. Thus, all the information needed to perform a task is associated with that environment and it is extremely difficult to sort through during the troubleshooting process.

Over the past ten years, the automotive industry, both military and civilian, has attempted to bridge the knowledge gap or shortfalls in the technicians' ability to service complex systems by providing more training to their automotive technicians through resident schools. This training method created an increase in non-productive time and the results of

the training, technician performance, did not offset the increases in non-productive time. Next, they made improvements to the diagnostic and repair tools. The results of these improvements aided the technician in isolating faults through an automated process. Unfortunately, only a small number of the faults could be isolated using these tools. In a laboratory, these systems improved the performance of technicians, but when they used the tools in the field, they were unable to find the information needed to properly diagnose the fault. The technicians began to second-guess the tool and shortcut the diagnostic process, resulting in an increase of replacing parts that were not faulty.

Next, the automotive industry introduced the expert systems. These systems provide technicians with procedures on how to solve a specific problem by providing a set of rules for completing the task. Expert systems helped technicians leap ahead in the diagnostic process given that an algorithm exists for them to do so. The acceptance of expert systems within the automotive industry was low because these systems were unable to solve a majority of the problems that faced the automotive technician. Again, there was simply not enough knowledge captured in expert systems for the variety of faults the technicians needed to solve.

In the late 1990's, the automotive industry simultaneously introduced Interactive Electronic Technical Manuals (IETM) and Electronic Performance Support Systems (EPSS). The most effective mix of the two was having the IETM exist as part of the EPSS. This combination is in use today as it provides an effective way to couple technical manuals that have been the technicians' textbook for automotive troubleshooting and repair since the inception of the automobile with an expert system to provide guidance to the technician when available. These systems still lack the ability to help technicians segment the knowledge

they seek and develop links to knowledge resources outside the technical manual. Today, with the introduction of distributive systems and virtual communities, there is the potential for an evolution of the EPSS system to be distributed through a Community of Practice (CoP).

In order for the automotive industry to move to the next level in providing performance support to their technicians, they must begin to address the issues associated with knowledge management and the linkages between the knowledge owners, knowledge brokers, and knowledge seekers. This knowledge management concept creates a critical path for automotive technicians to obtain knowledge when they need it most, while engaged in performing a task. The automotive industry should also understand that distributive learning and performance support systems have a socio-technical structure that, when understood, can be a key driver for knowledge transferability within the automotive technician community.

When introducing training materials or learning objects into an electronic technical manual the results provide a linkage between the learning tools and the technical manual framework. This linkage leads us to believe that combining computer-aided-learning and a digital technical manual framework creates a blended performance support system that a technician can interact with while performing a task. The results can also be seen as the creation of a pathway for a knowledge seeker to gain knowledge from knowledge owners while performing tasks.

Adding the capability for automotive technicians to obtain knowledge in a collaborative virtual workspace provides for the emergence of a tool that allows them to interact with knowledge owners while engaged in performing a task. In conclusion, there are many tools a user can engage with while seeking solutions to a troubleshooting task.

Based on the premise that most automotive faults do not have simple solutions, it then becomes problematic for information systems to record all the possible solutions associated with a given fault one may encounter. Thus, troubleshooting and repair of complex systems is still an art. The best a technical manual or a performance support system could hope to achieve is to move the maintenance technician closer to the solution state where they can invoke their experiences and solve the problem.

With the recent introduction of computer-supported performance support tools, it is feasible to connect knowledge seekers to knowledge owners with blended learning and performance support environments. What we do not understand is how a knowledge seeker interacts with computer-aided environments to gain the knowledge they need to solve a specific complex problem.

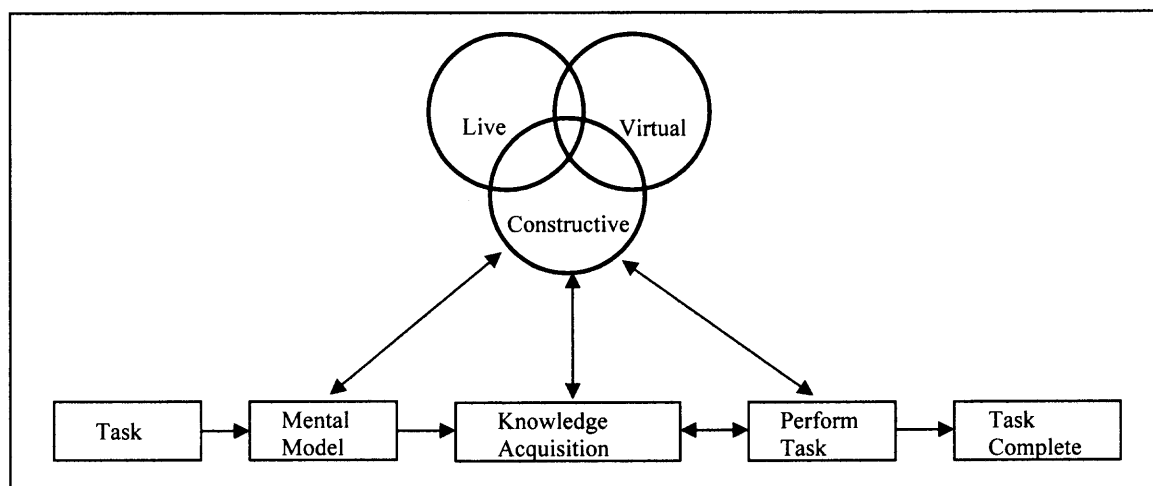


Figure 3.1 LockTel Framework.

The LockTel Framework (Live, Virtual, and Constructive Environments for Performance Support) is a blended knowledge management and training method that

segments knowledge retrieval into three separate environments: live, virtual, and constructive, as illustrated in Figure 3.1. With this framework, we can conceivably move the latest in troubleshooting tools to the next level by segmenting the way technicians seek information, knowledge, and even wisdom, to solve a problem.

The LockTel Framework is an extension of the LVC environments for training and creates a new construct for LVC environments in the performance support domain. With the development of the LockTel Framework, we can begin to evaluate its effectiveness by measuring the changes between a subject's mental models when using the current method and then when using the LockTel Framework. This method will focus on the difference between performing a troubleshooting task using an electronic technical manual and then performing a troubleshooting task using the electronic technical manual coupled with the LockTel Framework. It is also important that the LockTel Framework be useable in both a local and distributive setting, such as Electronic Performance Support Systems or Communities of Practice.

The key research questions resulting from the literature review and the LockTel Framework development process are as follows:

- Would the introduction of a new framework for knowledge retrieval have an impact on troubleshooting automotive systems?
- What impact, if any, would the introduction of the LockTel Framework have on a maintenance technician performing a troubleshooting task?
- Does the introduction of the LockTel Framework have a positive effect on the maintenance technician's mental model?
- Would maintenance technicians perceive the LockTel Framework as useful?
- Would time constraints mitigate the positive effects of the LockTel Framework?

CHAPTER 4

EXPERIMENTAL DESIGN AND RESULTS

4.1 Introduction

Performance support systems emerged as an enabler for technicians to keep pace in supporting complex systems. The primary objective of a performance support system is to deliver knowledge to its user, as needed, in order to perform a process or complete a task (Gery, 1995) (Witt and Kiger, 1997). However, many of the performance support systems that have been developed over the past decade are being left unused. This abandonment is because the users are unable to locate the information they need to complete specific tasks, particularly the lack of a method to effectively obtain actionable information beyond the boundaries of what is recorded in the system itself.

The research literature indicates that providing performance support is a multi-disciplinary approach to provide users with actionable information while performing a specific task (Gery, 1995) (Raybould, 1995) (Davenport et al., 1998) (Kabel et al., 1997). In particular, electronic performance support systems most improve the worker's performance by providing on-the-job access to integrated information, advice and learning experiences (Raybould, 1990). The first step in providing support to an automotive technician obtaining knowledge is to identify the potential sources of knowledge. For an automotive technician, these sources could include technical manuals, job aids, co-workers, expert systems, and knowledge maps. The second step is to provide a method for the technician to access the knowledge available to them, thus leading to the development of the LockTel Framework, as

a method for an automotive technician to retrieve knowledge while using an Electronic Performance Support System.

The experiment is designed to test three main propositions:

- The LockTel Framework will have a greater positive effect on a maintenance technician's mental model while retrieving knowledge for a troubleshooting task as compared to the current method of troubleshooting.
- The LockTel Framework will be perceived as being useful in performing a troubleshooting task.
- Performing a troubleshooting task using the LockTel Framework under a time constrained condition will not impact the positive effects of the LockTel Framework as opposed to the current method.

4.2 Research Hypotheses

The research hypotheses are derived from the research questions in Chapter 3. The results of this experiment are based on two themes of measurement. To show improvement, we use a mental model change measurement. To further the research potential within the defense community, we use a perceived usefulness measurement. In this section we will first look at the measures of the hypotheses and then we restate the hypotheses in terms of the measures.

Hypotheses H_1 and H_2 are designed to test the effects associated with the change in an automotive maintenance technician's mental model from the current troubleshooting method to the use of the LockTel Framework coupled with the current method. Hypotheses H_3 and H_4 test the perceived usefulness of the LockTel Framework according to an automotive maintenance technician.

The hypotheses were derived based on previous research work on Concept Map Assessment, Measuring Shared Mental Models, Mental Model Analysis, and Measuring Perceived Usefulness of Information Technology (Adams et al., 1992) (Alavi & Leidner,

2001) (Billinghamurst & Weghorst, 1995) (Brandt et al., 2003) (Connon-Bowers et al., 1993) (Davis, 1989) (Gery, 2001) (Hoeft et al., 2003) (Kraoger & Wenzel, 1997) (Lim et al., 1996) (Scheper & Faber, 1994) (Vankatesh, 2000) (Williams, 1998).

The hypotheses will be tested using nonparametric ANOVA, Factorial ANOVA SAS GLM PROC, statistical analysis methods used to test differences between two groups.

In this chapter the following symbols will be used in describing the experimental conditions:

$\sim L$ = Current Tool

L = Current Tool + LockTel

T = Time Constraint

U = Time Unconstrained

R = Relevant Nodes

I = Irrelevant Nodes

P = Percentage of Relevant Nodes

u = Perceived Usefulness

c = Questionnaire Score

For example, L_{RT} = Measures the number of Relevant Nodes for the LockTel + Current Method under a time constraint.

H1: Subjects will show a positive change in their mental model when performing troubleshooting tasks using the LockTel Framework with the current tool as compared to subjects performing troubleshooting tasks using the current tool alone.

H1a: The concept maps of subjects using the LockTel Framework with current tool in an unconstrained condition will be comprised of more nodes than those of subjects using the current tool alone in an unconstrained condition.

$$H1a_o : L \leq \sim L$$

$$H1a_a : L > \sim L$$

H1b: The concept maps of subjects using the LockTel Framework with the current tool will be comprised of more relevant nodes than those of subjects not using the current tool alone.

$$H1b_o : L_R \leq \sim L_R$$

$$H1b_a : L_R > \sim L_R$$

H1c: The percentage of relevant nodes for subjects using the LockTel Framework with the current tool will be equal to or greater than those for subjects using the current tool alone.

$$H1c_o : L_p < \sim L_p$$

$$H1c_a : L_p \geq \sim L_p$$

H2: Subjects performing troubleshooting tasks in a time constrained condition will show a minimal change in their mental models as compared to subjects performing troubleshooting tasks under normal conditions.

$$H2_o : L_U \neq L_T$$

$$H2_a : L_U = L_T$$

H3: The LockTel Framework will be perceived as being useful in seeking relevant knowledge while performing a maintenance troubleshooting task.

$$H3_o : \bar{u}_L > c$$

$$H3_a : \bar{u}_L < c$$

4.3 Methodology

The experimental method used to determine the effects of the LockTel treatment and Time Constraint is a 2x2 factorial design. The two independent variables are performance support method and time as illustrated in Table 4.1.

Table 4.1 Experiment Design

2 x 2 Factorial Design		Time	
		Unconstrained	Constrained
Performance Support Method	Current Tool		
	Current Tool + LockTel		

4.3.1 Tasks

The subjects were required to complete two tasks, one prior to developing their second concept map and then another prior to the completion of their third concept map. The order in which a subject completed their tasks was based upon when they signed in and the table of random numbers that assigned them into a group. The two tasks had the same level of difficulty.

The tasks were generated from the fault symptom troubleshooting process of the High-Mobility Multipurpose Wheeled Vehicle (HMMWV) Electronic Technical Manual (ETM). The first fault symptom was ‘the vehicle will not start and the engine does not crank normally.’ This fault will require a subject to troubleshoot the starter circuit using the diagnostic flowcharts located in the ETM. This process requires the use of the technical

manual and the troubleshooting procedures located in the technical manual. Subjects have the option to use flowcharts of other alternate test procedures. The fault was inducted into the charging system by creating an open circuit starting system that caused the vehicle not to start. When the subject locates the open circuit, the task is complete.

The second fault symptom was ‘the engine will not start but cranks normally.’ The fault required the subjects to test the fuel system prior to testing the starter circuit. This fault required the subjects to use the ETM, its troubleshooting procedures, and alternate test procedures when necessary. This fault was introduced into the fuel system at the fuel solenoid by disconnecting the wire at the solenoid. When the subject locates the disconnected wire, the task is complete.

Prior to the experiment, with the assistance of subject matter experts located at the U.S. Army Ordnance Center and School, the fault symptoms were validated through a pilot experiment.

4.3.2 Procedure

The experiment was conducted over a two-day period. On both days, half of the subjects reported for participation in the experiment at 8 a.m. and signed in. At that time, each subject was assigned a group number based on the subject number space they signed in on the Subject Sign-in Sheet, Appendix K. The group assignments were determined using the random number generator in MS Excel. The group assignment matrix can be found in Appendix I. The sequence of events for the experiment, except as listed in the next paragraph, were: subject sign-in, subject assignment to a group, subject completes personal data form, subject completes the Consent to Participate in a Research Study Form,

introduction presentation, instruction on how to build a concept map using the TPL-KATS concept mapping tool, develop an initial concept map for practice using the concept mapping tool, perform the first task under one of the four conditions, create their second concept map, perform the second task, create their third concept map, complete a post-experiment questionnaire (for those subjects in a LockTel condition), then receive an out briefing.

The sequence of events was changed from day to day to counterbalance the experiment. On the first day the conditions were scheduled in sequential order: 1, 2, 3, and then 4. On the second day the conditions were scheduled 3, 4, 1 and then 2. The order of the tasks was also different from day to day. On the first day the tasks were completed in order, 1 then 2, and on the second day the tasks were reversed, 2 then 1.

4.3.3 Mental Model Analysis

The mental model analysis was accomplished by using the TPL-KATS semi-automated concept mapping tool. TPL-KATS produces a concept map scoring matrix that produces a score of 1 for each linkage between concepts. The matrix that results from each concept map lists all possible pairs of the concepts. When pairs are connected, an arc results at the intersection point. The list of the fifteen concepts and the ten propositions that were used in the experiment are listed in Appendix F.

The experiment was conducted over a two-day period and all four conditions were administered each day (see Appendix A for the treatment schedule). On the first day the conditions were conducted in sequence order and the second day the order changed to 3, 4, 1, and then 2 to mitigate any order effects.

During the experiment, each subject developed three concept maps using the TPL-KATS semi-automated concept mapping tool. The first was a practice map for subjects to

become familiar with the concept mapping tool. Maps 2 and 3 were used to depict the subject knowledge of where they retrieve information from while completing a troubleshooting task.

4.3.4 Mental Model Change Measurement

To capture the subjects' mental model, we used a semi-automated cognitive mapping tool from the University of Central Florida, TPL-KATS, which was developed in partnership with the U.S. Department of Federal Aviation Administration and the U.S. Department of Defense (Hoeft, et al., 2003). These maps will be derived by subjects from a selected list of concepts and propositions as shown in Appendix F. These lists contain previously identified concepts and propositions for both the current method and the current method coupled with the LockTel Framework. The concept list also includes concepts that are not relevant to the tasks being performed to aid in counterbalancing the experimental design. To measure the mental model differences between groups, we used the capture mapping tool output matrices to analyze the concept map differences conditions. Figure 4.1 shows the TPL-KATS mapping board.

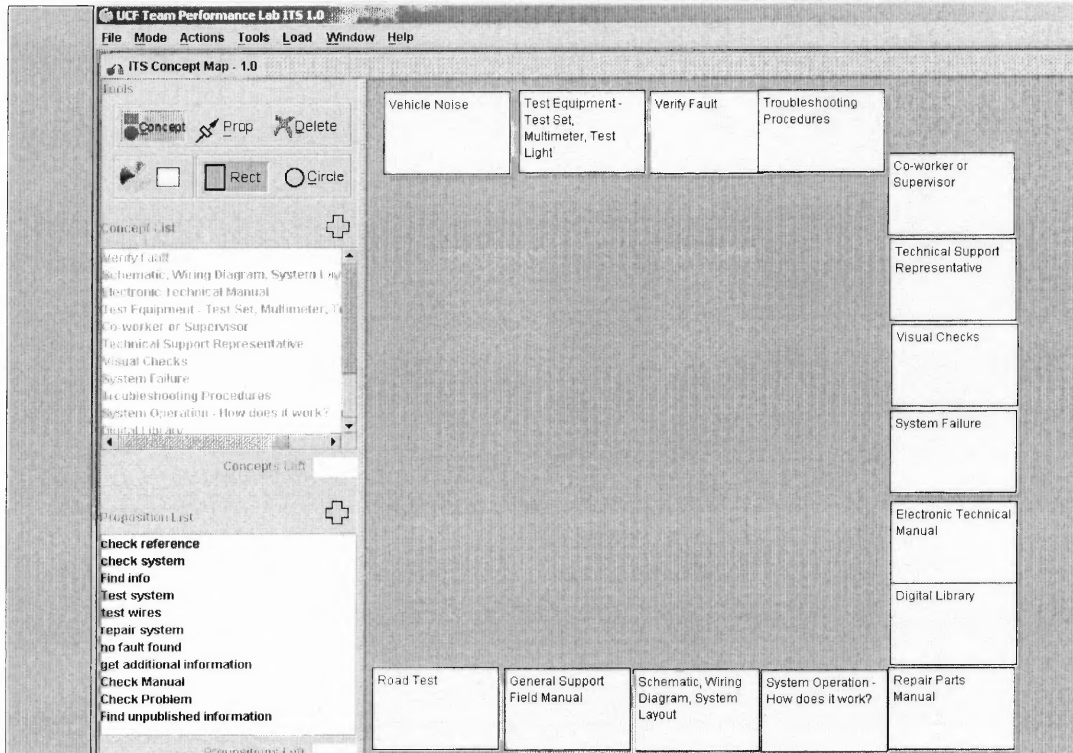


Figure 4.1 TPL-KATS Concept Mapping Tool.

The differences between conditions are based on analyses of paired group subject mean node results. Each subject map produces a matrix that represents the linked concepts. These linkages between concepts and propositions are represented by an output matrix of arcs and nodes. The results of each subject map of a paired group are joined using the union of concept map method. The outcome of the union for a subject pair is represented by a single node and arc, where nodes and arcs are duplicated. To analyze the results between conditions, the mean node results each condition are compared.

4.3.5 Perceived Usefulness Measurement

In the Army, the first step in a soldier's acceptance of a project for future development is its perceived usefulness. Based on this premise, if the LockTel Framework is perceived to be

useful, it will have a good chance for further development within the Army research community.

The experimental method used to determine perceived usefulness is taken from the Adams, et al., (1992) article on perceived usefulness. Because this study is only interested in the perceived usefulness of the LockTel Framework, it will use only the perceived usefulness portion of the Technology Acceptance Model (TAM) used in the determination of information technology future usage.

The questionnaire was administered after the experimental tasks and the concept maps were completed. The questionnaire was administered only to the subjects receiving the LockTel treatment to elicit their perceived usefulness of the LockTel Framework. The questionnaires are attached as Appendix E.

4.3.6 Data Capture

The data capture portion of the experiment was conducted in six (6) phases for those subjects receiving the LockTel treatment and five (5) for those in the no-LockTel condition and the combination of all phases took not longer than two and one half hours (2.5 hours) in duration for each pair group. The experiment was conducted at a U.S. Army maintenance training center. The U.S. Army provided the subjects as well as the facilitators and the equipment to conduct the experiments. The following is a brief description of the phases.

Phase 1 - The sign-in, introduction to the experiment, and the completion of a subject consent form. The Subject Sign-in Sheet and the Subject Consent Form are attached as Appendix K and Appendix B, respectively.

Phase 2 - The subjects received training on the use of the TPL-KATS concept mapping tool and how to build a concept map and completed an initial concept map for practice.

Phase 3 – The subjects participating in the LockTel treatment received an introduction to the LockTel Framework. The introduction was conducted as a group, in a classroom setting, using a Microsoft Power Point presentation with video and animation segments explaining the Live, Virtual, and Constructive Environments for Performance Support. See Appendix C for the slides used in the introduction presentation.

Phase 4 - The subjects were presented with the first of two faults selected for the experiment. The order of the faults was based on which day the subjects participated in the experiment. While performing the tasks, the subjects' actions were recorded using a video camera. Half of the subjects performed their tasks under a time-constrained condition. This manipulation provided analytical data on the impacts of performing a task in a time-constrained condition. After completing the task, the subjects constructed their second concept map.

Phase 5 - The subjects completed a second troubleshooting task under the same conditions as their first task. The subjects were presented with the second of the two faults selected for the experiment. During the performance of this task the subjects' actions were also recorded using a video camera. The subjects, who performed their task under a time-constrained condition in phase 4, also performed this task under a time constraint. After completing this task, the subjects constructed their third and final concept map.

Phase 6 - Consisted of a post-experiment questionnaire to measure perceived usefulness for those subjects who received the LockTel treatment and in this phase a debriefing was also conducted. The post-experiment questionnaire is attached as Appendix E.

4.4 Experiment Results

This section describes the results of an experiment which tests the effects of the LockTel Framework on ground vehicle maintenance technicians performing troubleshooting tasks. The LockTel Framework, described in chapter 3, is a method that segments knowledge retrieval for maintenance technicians into three separate computer-aided performance support environments, live, virtual, and constructive. The analysis performed was compared against a set of hypotheses to determine if the LockTel Framework improves the mental models of its users while they are retrieving knowledge to perform a troubleshooting task. The analysis also evaluates the LockTel Framework's usefulness, an important indicator for project continuation within the defense acquisition program.

The experiment took place in the summer of 2004 and involved military ground vehicle maintenance technician trainees undergoing their advanced individual training at a national military training center in the United States.

The data was collected using the TPL-KATS concept mapping tool by collecting two concept maps from each subject to determine the changes in mental models from one group to another and a post questionnaire for those subjects receiving the LockTel Framework treatment to determine its perceived usefulness. The analysis of the data, using statistical procedures in SAS, is presented in this chapter.

4.4.1 Subjects

The subjects in the experiments consist of seventy-eight randomly selected military automotive maintenance technician trainees that are attending advanced individual training at a U.S. Army military training site. All subjects have a basic understanding of electrical troubleshooting and have completed the Army's maintenance technician basic skill and knowledge training.

4.4.2 Subject Background Information

A total of seventy-eight individuals participated in the experiment, resulting in thirty-nine pairs. To determine the background and experience levels of the participants, they completed a pre-experiment questionnaire, found in Appendix H. All participants completed courses in basic skills and knowledge, electrical systems, and troubleshooting. This section analyzes the results from the pre-experiment questionnaire. Figure 4.2 shows the distribution of participants per treatment.

Table 4.2 Number of Participants Assigned to Treatments

		Time	
		Unconstrained	Constrained
Performance Support Method	Current Tool	20	22
	Current Tool + LockTel	20	16

4.4.3 Subject Pre-Experiment Evaluation

The range of educational years for individuals was from eleven to fourteen years, with most having completed the twelfth grade. The range of experience, in terms of months of automotive work experience prior to joining the military, range from zero to forty-eight months with most having no prior experience. The military occupation specialty (MOS) comprises of three major groups: 63B/W, 63H/D/45D and 63Y. Table 4.3 shows the results of the Subject Personal Information Survey. The results confirm the homogeneity of the subjects.

Table 4.3 Personal Data

	PERSONAL DATA		
	<12 years	12 years	>12 years
Education	8	58	12
	<19	19-21	>21
Age	14	43	22
	63B/W	63H/D/45D	63Y
MOS	4	45	29
	Yes	No	
Automotive School	7	71	
	None	≤12	>12
Experience	64	6	8

4.4.4 Experiment Hypothesis Analysis

This section describes the evaluation of the data collected. The evaluation involves factor analysis, nonparametric ANOVA, t-Test, and Cronbach's Alpha. The results were computed against the hypotheses described in chapter 5.

The data analysis for the experiment is based on the 2x2 factorial design for H1 and H2. The data collected from the concept maps are analyzed using factorial and non-parametric ANOVA statistical method of analysis. H3 and H4, testing the perceived

usefulness of the LockTel Framework, are analyzed using the one sample t-test statistical method of analysis.

The first of the experimental results are focused on analyzing the data captured from the subjects' concept maps within different treatments. Each concept map was scored using a Concept Scoring Matrix. An example of this matrix is illustrated in Table 4.4. The "1" indicates that there is a linkage between two concepts and the "0" indicates that there is no linkage between a set of concepts. The total number of linkages (1's) is added to get a total number of linkages for each of the concept maps. The experiment was conducted in subject pairs and every subject constructed their own concept map. The two concept maps for the pair were combined using a union of concept map technique. The means of all concept maps for each treatment were calculated to determine the differences between the concept maps of each treatment, resulting in the test data for hypothesis H₁ and H₂.

Table 4.4 Concept Map Scoring Matrix

		CONCEPT			
		1	2	3	4
CONCEPT	1	X	1	1	0
	2	0	X	1	1
	3	1	0	X	1
	4	0	0	0	X

4.4.5 Analysis Performance Support Method Variable

Hypothesis 1 tests the difference in the subject's mental model between two conditions, ~L and L. The Hypothesis is subdivided into three hypotheses that test the difference in the

means of concept map nodes between groups, the difference in relevant nodes between groups, and the quality of nodes by representing the means percent of the relevant nodes in each condition.

For the analysis, the individual concept maps were combined using a union of matrices technique. For H1a, H1b, and H2 we used the SAS factorial ANOVA Test.

H1: Subjects will show a positive change in their mental model when performing troubleshooting tasks using the LockTel Framework with the current tool as compared to subjects performing troubleshooting tasks using the current tool alone.

H1a: The concept maps of subjects using the LockTel Framework with current tool in an unconstrained condition will be comprised of more nodes than those of subjects using the current tool alone in an unconstrained condition.

H1b: The concept maps of subjects using the LockTel Framework with the current tool will be comprised of more relevant nodes than those of subjects not using the current tool alone.

H1c: The percentage of relevant nodes for subjects using the LockTel Framework with the current tool will be equal to or greater than those for subjects using the current tool alone.

The results of the factorial ANOVA are shown in Table 4.5.

Table 4.5 Factorial ANOVA results

VARIABLE	n	Model p	R-Square	LockTel $p=$	Time $p=$	Result
Nodes	39	0.0034	0.270571	0.0017	0.2771	H1a: $p = 0.0017$
Relevant Nodes	39	0.0031	0.273898	0.0011	0.4936	H1b: $p = 0.0011$
Percent of Relevant Nodes	37	0.0922	0.130857	0.4863	0.0347	H1c: $p = 0.0922$

Table 4.6 provides the mean of nodes calculations for each of the four conditions.

Table 4.6 Means of Nodes

		Time	
		Unconstrained	Constrained
Performance Support Method	Current Tool	8.20	8.82
	Current Tool + LockTel	15.25	10.50

H1a: The analysis tool independent variable Current Tool + LockTel shows a significant effect at the $p = 0.0017$ level and a mean score of 8.20 and 15.25 (Table 4.5) for Current Tool Unconstrained and Current Tool + LockTel Unconstrained, respectively.

The results shown in Table 4.6 support H1a and indicate that this variable is statistically significant at $\alpha = 0.05$ level. The mean score for those using the LockTel Framework 15.25 is notably better than the Current Tool 8.20 and indicates that using the LockTel Framework significantly increases the number of nodes in an automotive technician's mental model.

Table 4.7 provides the mean of relevant nodes calculations for each of the four conditions.

Table 4.7 Means of Relevant Nodes

		Time	
		Unconstrained	Constrained
Performance Support Method	Current Tool	6.75	7.64
	Current Tool + LockTel	12.70	9.19

H1b: The analysis tool independent variable Current Tool + LockTel of relevant nodes shows a significant effect at the $p = 0.0011$ level and a mean score of relevant nodes of 6.75 and

12.70 (table 4.7) for Current Tool Unconstrained and Current Tool + LockTel Unconstrained, respectively.

The results shown in table 4.7 supports H1b and indicate that this variable is statistically significant at $\alpha = 0.05$ level. The mean score for those using the LockTel Framework of 12.70 is notably better than those using the Current Tool of 6.75 and indicates that using the LockTel Framework significantly increases the number of relevant nodes in an automotive technician's mental model.

Table 4.8 provides the mean percentage of relevant nodes for each of the four conditions.

The purpose of this table is to show the quality differences between groups.

Table 4.8 Relevant Node Percentage

		Time	
		Unconstrained	Constrained
Performance Support Method	Current Tool	80%	90%
	Current Tool + LockTel	84%	89%

H1c: The analysis tool independent variable shows no significant difference in the level of mean scores for relevant nodes as reflected in Table 4.8.

H1c: The analysis tool variable Performance Support Method shows that there is no significant difference in quality of mental models captured using the TPL-KATS concept mapping tool. The percent of quality between groups ≥ 10 resulting and the model $p = 0.0922$.

Thus, in H1, subjects will show a positive change in their mental model when performing a troubleshooting task using the current tool coupled with the LockTel

Framework over performing a troubleshooting task while using the current tool alone was supported and the null hypothesis was rejected at $p = 0.0017$.

Hypothesis 2 involves the analysis of two groups to compare the change in mental models of subjects while performing tasks under a time constraint.

H2: Subjects performing troubleshooting tasks in a time constrained condition will show a minimal change in their mental models as compared to subjects performing troubleshooting tasks under normal conditions.

Table 4.9 provides the mean of nodes for each of the four conditions. The purpose of this table is to show the effects of time constraint on the mental model of automotive technicians in the Current Tool + LockTel treatment.

Table 4.9 Mean of Constrained Nodes

		Time	
		Unconstrained	Constrained
Performance Support Method	Current Tool	8.20	8.82
	Current Tool + LockTel	15.25	10.50

H2: The analysis tool independent variable Performance Support Method shows a significant effect at the $p = 0.0277$ level and a mean score of nodes of 15.50 and 10.50 (table 4.9) for Current Tool + LockTel Unconstrained and Current Tool + LockTel Constrained, respectively.

Thus, in H2, subjects performing troubleshooting tasks in a time constrained condition showed a significant change in their mental models as compared to subjects performing troubleshooting tasks under normal conditions, so null hypothesis was accepted and the hypothesis was not supported.

4.4.6 Analysis Perceived Usefulness Variable

The second set of data that was collected from the post questionnaires is designed to determine the perceived usefulness of the LockTel Framework thus providing results to test hypothesis H3 and H4. The post questionnaire analyzing the perceived usefulness was only administered to the subjects receiving the LockTel Treatment.

The post-experiment questionnaire, Appendix E, was evaluated using the SAS hypothesis test. Hypothesis 3 involves testing the perceived usefulness of the LockTel Framework. For this hypothesis, \bar{X} indicates the average answer score for all perceived usefulness questions. The hypothesis H3 is:

H3: The LockTel Framework will be perceived as being useful in seeking relevant knowledge while performing a maintenance troubleshooting task.

$$H3_o : \bar{X}_u > 4$$

$$H3_a : \bar{X}_u < 4$$

Table 4.10 reflects the SAS hypothesis test results for the post questionnaire question relating to perceived usefulness and is organized by the constructs U1 (Makes Job Easier), U2 (Useful), and U3 (Increases Productivity).

Table 4.10 t-Test Results

Usefulness Question	Mean	Std Error	t-Statistic	Prob > t
U1a - Q3	Mean = 3.11	0.20	t = -4.583	<.0001
U1b - Q4	Mean = 3.03	0.21	t = -4.676	<.0001
U2a - Q2	Mean = 3.13	0.20	t = -4.263	<.0001
U2b - Q5	Mean = 3.05	0.21	t = -4.444	<.0001
U3a - Q6	Mean = 3.05	0.20	t = -4.839	<.0001
U3b - Q9	Mean = 3.24	0.24	t = -3.143	= 0.0015
\bar{X}	Mean = 3.10	0.03	t = -28.182	<.0001

H3: The results of the SAS analysis tool show that $H3_a : \bar{X}_u < 4$ and that the results are significant for questions 2, 3, 4, 5 and 6 at the $p < .0001$ and for question 9 at $p = 0.0015$ as reflected in Table 4.9. There were thirty-six participants that completed the questionnaire.

The results shown in Table 5.6 support H3 and indicate that these findings are statistically significant at alpha = 0.05 level. All questions show a mean score of < 4 , indicating that the LockTel Framework is perceived as being useful.

4.4.7 Summary of the Hypothesis Analysis

Table 4.11 shows a summary of the hypotheses results of the experiment.

Table 4.11 Experiment Hypotheses Results

Hypotheses		Result
H1	Subjects will show a positive change in their mental model when performing troubleshooting tasks using the LockTel Framework with the current tool as compared to subjects performing troubleshooting tasks using the current tool alone.	Supported
H1a	The concept maps of subjects using the LockTel Framework with current tool in an unconstrained condition will be comprised of more nodes than those of subjects using the current tool alone in an unconstrained condition.	Supported $p = 0.0017$
H1b	The concept maps of subjects using the LockTel Framework with the current tool will be comprised of more relevant nodes than those of subjects not using the current tool alone.	Supported $p = 0.0011$
H1c	The percentage of relevant nodes for subjects using the LockTel Framework with the current tool will be equal to or greater than those for subjects using the current tool alone.	Supported $p = 0.0922$
H2	Subjects performing troubleshooting tasks in a time constrained condition will show a minimal change in their mental models as compared to subjects performing troubleshooting tasks under normal conditions.	Supported $p = 0.0277$
H3	The LockTel Framework will be perceived as being useful in seeking relevant knowledge while performing a maintenance troubleshooting task.	Supported $p < .0001$

4.5 Discussion

The main motivation for this research is the development of a new method, not a technology, which will serve as an enabler to enhance the capabilities of automotive technicians both in industry and the military. An Electronic Performance Support System is said to be a computer-mediated system that is intended to provide on-the-job access to task-based information, learning, and the transfer of knowledge to enable improvements in productivity (Cole and Fisher, 1997). An observation made over the past four years, within the automotive service technology industry, is that “we have the technology, now all we need to

know is how to use it.” Technicians do not realize the power of the technology they have available to them and what they need to know to be able to take advantage of the technology that is at their disposal. This dissertation introduces the segmentation of knowledge into three computer-support environments for performance support through the LockTel Framework. It allows an enabler to enhance current performance support system’s functionality and usability. This chapter reviews the results of the research and outlines its contributions.

4.5.1 The LockTel Framework

The LockTel Framework was built upon Hubal and Helm’s (1998) Advanced Learning Environment research. Their concept uses blended learning environments to optimize training effectiveness and efficiencies in individual training courses and events. Their work identifies the relationships between the live, virtual, and constructive environments for training and their benefits when blended in a signal training event. Their work was the first to present a relationship between computed-aided environments and knowledge acquisition while focusing on the service technology community. It also implies the transferability of computer-aided environments for learning to performance support. Although the live, virtual, and constructive environments for training are not directly extendable to performance support, they serve as a foundation for the development of terms that are usable for the knowledge management and performance support communities. This dissertation provides a construct for extending the advance learning environments to performance support environments and deriving some usable meanings for live, virtual, and constructive environments outside the training community

4.6 Conclusions

The LockTel Framework provides a validated construct for capturing, storing, mapping and retrieving knowledge for use in performance support systems for automotive maintenance technicians. The terms are simple to understand and use. The subjects who received the LockTel treatment quickly understood the terms and employed them while performing a troubleshooting task. The terms were perceived as flexible enough to allow for the blending and traversing between environments. These terms associate themselves well with the constructivist point of view for learning and they also reflect knowledge management terms, such as declarative, conceptual, and procedural knowledge.

To test the construct of Virtual, Live, and Constructive Environments for Performance Support, the LockTel Framework, we examined the change in the automotive technician's mental model in such a way that we were able to evaluate how an automotive technician used knowledge resources while completing a troubleshooting task. Through the use of the University of Central Florida's concept mapping tool, we were able to quantifiably assess their mental model and show the effects of the LockTel Framework on their ability to find knowledge that brings them closer to the solution state.

This construct not only proved to be valuable in retrieving knowledge to complete a task but also for use in obtaining basic concepts and knowledge on a specific system or subsystem. This aspect of the experiment could be further extended to a rehearsal situation.

4.7 Contributions

The contributions provided by this dissertation are focused primarily on providing an enabling method for automotive technicians to retrieve knowledge from a computer-mediated performance support system while completing a task. The introduction of the LockTel Framework provides a methodology for multicapable mechanics to obtain data, information, knowledge, and in some cases, wisdom, from a variety of sources. It provides an alternative method for knowledge retrieval by segmenting knowledge retrieval into three environments: live, virtual, and constructive. This segmentation not only provides the knowledge seeker with alternative paths to seek out and retrieve knowledge but also provides a way for knowledge owners and brokers to capture, store, and deliver knowledge within a given domain.

At the mega level, the construct of live, virtual, and constructive environments for performance support could serve as a catalyst for transforming both virtual and physical communities from an information-based society to a knowledge-based society. It can also provide a schema for knowledge capture, storage, and retrieval within the automotive industry.

At the macro level the LockTel Framework can provide performance support system developers with a framework that will aid in them categorizing data, information, and knowledge for storage and retrieval and provide a framework for knowledge sharing within groups of professionals such as Communities of Practice and knowledge centered organizations.

At the micro level the LockTel Framework could set the stage for knowledge capture and mapping collaboration efforts between training and performance support communities

and provide a means for automotive technicians to retrieve knowledge from computer-mediated performance support tools. Finally, the operationalization of this framework would immediately change an automotive technician's mental model of where to obtain knowledge to solve problems or perform a task.

CHAPTER 5

FUTURE RESEARCH

The findings of this research prove that the LockTel Framework improves the mental model of automotive technicians while performing troubleshooting tasks. The next step is to develop a prototype system that is built to maximize the benefits for the LockTel Framework. This prototype system should be built upon a socio-technical framework that supports the capture, storage, delivery and mapping of knowledge within a community of practice and be designed to support geographically dispersed workgroups. This prototype should explore use of the LockTel Framework in hypothetical training and performance support situations.

Another future research direction for the LockTel Framework is to develop a model that combines the Live, Virtual, and Constructive Environment for Learning and the Live, Virtual and Constructive Environment for Performance Support into one construct, the LockMar Model. This model could be developed to support operational systems that are also used as training and rehearsal platforms.

In addition to the above, a need exists to develop a process to capture, store, and distribute tacit knowledge via information systems. The question is, “can we through the use of simulations, and simulated environment begin to deliver tacit knowledge to technicians while engaged in performing a task?” The LockTel Framework coupled with augmented reality and object linking of the live and virtual environments may provide for the development of a data capture model that can potentially deliver tacit knowledge through distributive information systems.

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APPENDIX A

EXPERIMENT PREPARATION CHECKLIST AND PROTOCOL

This appendix consists of the experiment preparation checklist and the protocol that was used during the experiment. The preparation checklist was used to coordinate and control activities for the thirty days prior to the experiment and during the conduct of the experiment. The protocol includes an experiment schedule.

EXPERIMENT PREPARATIONS AND PROTOCOL

Live, Virtual, and Constructive Environments for Performance Support Study

1. Overview

The study will be conducted during the month of August 2004 at the U.S. Army Ordnance Center and School, Aberdeen Proving Grounds, Maryland. The subjects will be randomly selected from ground vehicle maintenance soldiers attending Advance Individual Training at the school. A total of eighty (80) subjects will be selected to participate in the experiment.

1.1 Location, Equipment, Infrastructure

The study will take place at the U.S. Army Ordnance Center and School, Aberdeen Proving Grounds, Maryland (410-278-9843). The contact is Mr. Mark Wells and Mr. Richard Hoy

1.1.1 Supplies Provided by the U.S. Army Ordnance Center and School

- 10 – U.S. Army Maintenance Support Devices
- 2 – Printers (made available)
- 10 – HMMWVs
- 10 – HMMWV Electronic Test Sets (STE-ICE)
- 10 – Electronic Technical Manuals for HMMWV
- 10 – Mechanics Tool Boxes
- 2 – LCD projector
- 2 – Classrooms
- 1 – Maintenance Garage that with 10 Bays or space available for 10 HMMWVs
- 11 – Stopwatches

1.1.2 Equipment to be borrowed from New Jersey Institute of Technology

- 10 video camera with tripod
- 1 tape recorder

1.1.3 Equipment from Home

- 4 Video camera with tripod
- 1 Laptop Computer

- TPL-KATS software – 12 copies w/administrator’s ID and password
- Concept Mapping Tutorial
- HMMWV Electronic Technical Manual Software
- LockTel Framework Training Presentation

1.1.4 Supplies to be Purchased from Best Buy and Office Max

- 12 Video Tapes (VHS or Super 8, etc, that match camera’s)
- Rewriteable CDs (100) – 1 for each participant
- Portable CD Writer
- Audio cassettes – 4
- Pencils – 50 (Sharpened)
- 1.2 Personnel Needs
- 10 – Observers/Facilitators - Aberdeen
- 2 – Subject Matter Experts – Aberdeen (Can also serve a Observe/Facilitator)
- 2 - Study Preparations Checklist

2.1 Preparation for One Month before Event

- Request 10 Observer/Facilitators from Aberdeen
- Request 2 Subject Matter Experts
- Request vehicle HMMWVs, 10 ea from Aberdeen
- Request video cameras with tripod (if available), 10 ea, NJIT
- Request tape recorder, 1 ea from NJIT
- Request stopwatches, 11 ea from Aberdeen
- Request facilities: (Aberdeen)
- Maintenance garage with 10 bays
- 2 Classrooms with 20 chairs
- Request 10 computers (SPORTs or MSDs) and 2 printers (APG)

2.1 Preparation for One Week before Event

- Check vehicle availability, 10 HMMWVs
- Check video camera availability 10 ea

- Check tape recorder availability
- Check stopwatch availability, 11 ea
- Check maintenance garage reservation, garage with 10 bays
- Check computers and printers request status, 10 computers, 2 printers
- Visit experiment site and conduct pilot
- Refine protocols for experiment
- Recruit experiment personnel, (get names)
- Finalize dates of experiment
- Setup equipment pickups
- Request facilitators and subject matter experts resumes
- Set sequence of events (when participants and helper should arrive)
- Develop schematic for experiment layout
- Refine questionnaires
- Develop sign-in roster with name, age, years of service, and years as a maintenance technician, Primary Military Occupational Specialty (MOS), Secondary MOS, and/or Alternate MOS.

2.2 Preparation for Three Days before Event

- Make last minute coordination with the Ordnance Center and School on participants, subject matter experts, and facilitators.
- Confirm equipment availability – Aberdeen
- Confirm facilities availability – Aberdeen
- Confirm support personnel availability
- Pick-up equipment from NJIT
- Label R/W CD with subject and study codes
- Publish protocols
- Practice supervising/conducting experiment
- Make copies:
 - Protocols (20)
 - Consent to participate in a research study forms (100)
 - Questionnaires (100 ea)

- Sign-in Roster (20 ea)
- Pack for movement to Aberdeen

2.3 Preparation for One Day before Event

- Load car
- Travel to Aberdeen not later than 0900 to arrive not later than 1200
- Pickup equipment from Aberdeen
- Setup experiment equipment in place and test the operation of equipment
- Load TPL-KATS software
- Load HMMWV ETM software
- Train support staff
- Conduct staff rehearsal
- Ensure all materials are on hand:
 - Consent Forms
 - Sign-in Rosters
 - Video Tapes
 - Audio Tapes
 - Pencils
- Secure sensitive equipment for the evening

2.4 Preparation for Day of Event

- Setup and test equipment
- Rewind tapes
- Provide each facilitator with a stopwatch
- Ensure equipment batteries are charged and power supplies are available.
- Ensure facilities are open and accessible not later than 0730
- Depart for experiment site at 0700 from hotel

Note to facilitators/experimenters: the words for you to say are in bold within each heading. It is of utmost importance that you follow these scripts exactly.

This study is to be conducted in eight (8) separate sessions, with four (4) periods for each of the two days. Half of the groups in each session will work under a time constraint while

completing the task. All participants will start and stop each session under the direction of the lead experimenter, John Lacontora. At the beginning of each session all participants will meet as a group, be provided with an introduction to the session and be provided training for that session, if necessary, at that time.

3.1 Preliminaries

Experimenters - Meet in maintenance garage bay area in Wheel Vehicle Training Building, Edgewood, MD at 0730 hrs each day.

Participants - Sign-in and meet in classroom at 0800 hrs, 1000 hrs, 1230 hrs, and 1430 hrs – 10 participants per session, each day, for two days

3.2 Experiment Schedule:

DAY 1:

TIME	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4
0800	Sign-in, Introduction, and Consent	Sign-in, Introduction, and Consent	Sign-in, Introduction, and Consent	Sign-in, Introduction, and Consent
0830	Initial Concept Mapping			
0900	Perform Task 1 & New Concept Map			
0930	Perform Task 2 & New Concept Map			
1000	Complete Survey & Debriefing	Initial Concept Mapping		
1030		Perform Task 1 Constrained & New Concept Map		
1100		Perform Task 2 Constrained & New Concept Map		
1130		Complete Survey & Debriefing	Initial Concept Mapping	
1200			LockTel Training	
1230			Perform Task 1 & New Concept Map	
1300			Perform Task 2 & New Concept Map	
1330			Complete Survey & Debriefing	Initial Concept Mapping
1400				LockTel Training
1430				Perform Task 1 Constrained & New Concept Map
1500				Perform Task 2 Constrained & New Concept Map
1530				Complete Survey & Debriefing

DAY 2:

TIME	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4
0800	Sign-in, Introduction, and Consent	Sign-in, Introduction, and Consent	Sign-in, Introduction, and Consent	Sign-in, Introduction, and Consent
0830	Initial Concept Mapping			
0900	LockTel Training			
0930	Perform Task 2 & New Concept Map			
1000	Perform Task 1 & New Concept Map			
1030	Complete Survey & Debriefing	Initial Concept Mapping		
1100		Perform Task 2 Constrained & New Concept Map		
1130		LockTel Training	Initial Concept Mapping	
1200		Perform Task 1 Constrained & New Concept Map	Perform Task 2 & New Concept Map	
1230		Complete Survey & Debriefing	LockTel Training	
1300			Perform Task 1 & New Concept Map	
1330			Complete Survey & Debriefing	Initial Concept Mapping
1400				Perform Task 1 Constrained & New Concept Map
1430				LockTel Training
1500				Perform Task 2 Constrained & New Concept Map
1530				Complete Survey & Debriefing

3.3 Setup and Operational Testing

- Final setup and testing: (Complete by 0800 hrs for classroom and bay area by 0830 hrs)
- Setup table for sign-in
- Position vehicles
- Place MSD at vehicles
- Turn-on computers and test software
- Position and focus cameras
- Position and test audio recorders
- Position LCD projector and screen, test and focus
- Verify setup against schematic
- Use time stamp on video equipment (if equipped)

3.4 Reception and Sign-in

Direct the subjects to the introduction classroom as they arrive at the wheel vehicle training facility. Have subject sign-in on the sign-in sheet as they enter the classroom and provide them with their subject number.

3.5 Introduction and Consent to Participate Session

Note to session facilitator: All participants will be seated in classroom not later than the start time of each session. Each session will start promptly at the scheduled time. All presenters will be taped.

Start video – scan subjects, classroom, and presenter/experimenter.
Handout consent forms and data collection form

GOOD (MORNING or AFTERNOON)

MY NAME IS JOHN LACONTORA, I'M A RETIRED ARMY MAINTENANCE OFFICER AND A Ph.D. CANDIDATE AT NEW JERSEY INSTITUTE OF TECHNOLOGY.

**WHILE SERVING AS AN NCO I ATTENDED WHEEL TRACK VEHICLE MAINTENANCE SCHOOL AT FORT KNOX KENTUCKY AND TANK TURRET REPAIRMAN TRAINING HERE IN ABERDEEN, MARYLAND.
THANK YOU FOR VOLUNTEERING TO PARTICIPATE IN THIS STUDY. THE STUDY IS SCHEDULE TO LAST APPROXIMATELY 2 HOURS.**

YOU WERE JUST HANDED A NEW JERSEY INSTITUTE OF TECHNOLOGY CONSENT TO PARTICIPATE IN A RESEARCH STUDY FORM. PLEASE TAKE A FEW MINUTES TO READ THE FORM.

PRINT YOUR NAME AFTER THE WORD "I" IN THE RESEARCH STUDY SECTION.

BEFORE YOU SIGN THE FORM LET ME HIGHLIGHT A FEW ITEMS ON THE FORM.

There are no perceived risks associated with this study outside the normal caution and warnings associated with performing troubleshooting process on a HMMWV

Every effort will be made to maintain confidentiality of the study records. If the findings of this study are published you will not be identified by name.

You have the right to refuse or withdraw from this study at any time with no adverse consequence.

Are there any questions on the consent form?

PLEASE SIGN AND DATE THE FORM IN THE PARTICIPANT'S SIGNATURE SECTION AND PASS THE FORM TO THE FRONT OF THE ROOM.

Collect consent forms

THE STUDY YOU ARE PARTICIPATING IN IS DESIGNED TO PROVIDE VALUABLE DATA FOR FUTURE RESEARCH IN DEVELOPMENT OF PERFORMANCE SUPPORT SYSTEMS

IN THIS STUDY WE WILL ASK YOU TO PERFORM SOME TROUBLESHOOTING TASKS. WHILE YOU PERFORM THESE TASKS YOU WILL BE REQUIRED TO SAY WHAT YOU'RE THINKING WHILE YOU ARE COMPLETING THE TASK. THIS IS CALLED THINKING ALOUD.

Have subjects practice thinking out loud

PICK A PARTNER AND PRACTICE THINKING ALOUD. THINK ALOUD ABOUT HOW YOU WOULD FIND THE NUMBER OF WINDOWS YOU HAVE IN YOUR BARRACKS. DON'T PLAN WHAT TO SAY OR SPEAK AFTER THE THOUGHT, BUT RATHER LET YOUR THOUGHTS SPEAK, AS THOUGH YOU WERE REALLY THINKING OUT LOUD.

Have subjects practice

YOU HAVE 2 MINUTES EACH. I WILL TELL YOU IN 2 MINUTES TO SWITCH.

START

After 2 minutes

IT'S TIME TO SWITCH

IN THIS STUDY WE WILL ALSO BE USING A CONCEPT MAPPING TOOL DEVELOPED BY THE UNIVERSITY OF CENTRAL FLORIDA.

Provide concept map training presentation

Have subjects move to respective areas

3.5.1 Data Session - No LockTel - Unconstrained

THE STUDY WILL CONSIST OF FIVE PHASES. THE FIRST PHASE IS THE INTRODUCTION TO THE EXPERIMENT AND CONCEPT MAP DEVELOPMENT TRAINING WHICH YOU COMPLETE EARLIER.

THE SECOND PHASE IS THE DEVELOPMENT OF YOUR FIRST CONCEPT MAP.

IN THE THIRD PHASE YOU WILL PERFORM A TROUBLESHOOTING TASK AND DEVELOP YOUR SECOND CONCEPT MAP.

IN THE FOURTH PHASE YOU WILL PERFORM A SECOND TROUBLESHOOTING TASK AND COMPLETE YOUR THIRD CONCEPT MAP.

THE FIFTH AND FINAL PHASE OF THE EXPERIMENT WILL CONSISTS OF COMPLETING A QUESTIONNAIRE AND A DEBRIEFING.

ARE THERE ANY QUESTIONS.

Provide student with an overview and an example of a concept map and ask them if they have any questions

YOU WILL NOW COVER DOWN ON ONE OF THE TEN HMMWV'S WHERE YOU WILL CREATE A CONCEPT MAP ON HOW YOU WOULD PERFORM A TROUBLESHOOTING TASK ON THE STARTING AND CHARGING SYSTEM OF A HMMWV.

Have subjects randomly cover down on one of the ten HMMWV stations. Have subjects stand in front of each vehicle facing the center of the bay area.

CONSTRUCT A CONCEPT MAP USING THE COMPUTER LOCATED AT YOUR STATION. CREATE THE CONCEPT MAP USING THE CONCEPTS PROVIDED OF HOW YOU WOULD COMPLETE THE TROUBLESHOOT TASK ON A

HMMWV STARTING AND CHARGING SYSTEM. THE FAULT YOU WILL BE TROUBLESHOOTING IS, THE VEHICLE WILL NOT START.

YOU WILL HAVE APPROXIMATELY 15 MINUTES TO COMPLETE YOUR FIRST CONCEPT MAP.

Subject will work on building a concept map. Facilitators will only answer question on how the concept mapping tool works. Do not answer questions on how the concepts fit together.

After 15 minutes:

PLEASE STOP BUILDING YOUR CONCEPT MAP.

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS "SUBJECT ____, CONCEPT MAP 1. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

Ask facilitators to have the subject practice "Thinking Aloud."

Have facilitators use the Practice – Think Aloud handout practice with subjects.

AT THIS TIME YOU WILL COMPLETE A TROUBLESHOOTING TASK MAY USE THE ELECTRONIC TECHNICAL MANUAL AND THE TOOLS PROVIDED. YOU FACILITATOR WILL GIVE YOU A DA 2404 WITH THE FAULT SYMPTOM. MAKE SURE YOU THINK OUT-LOUD

YOU WILL HAVE 20 MINUTES TO COMPLETE THE TASK. DURING THE TASK YOU MUST ENSURE YOU THINK ALOUD.

ARE YOU READY?

BEGIN...

After 20 minutes

PLEASE STOP

AT THIS TIME YOU WILL CREATE YOUR SECOND CONCEPT MAP BASED ON THE KNOWLEDGE AND EXPERIENCE YOU GAINED WHILE COMPLETING THE TROUBLESHOOTING TASK.

YOU DO NOT HAVE TO USE ALL THE CONCEPTS. PLACE THE CONCEPTS YOU DON'T WANT TO USE IN THE BOTTOM RIGHT HAND CONNER. PLEASE USE THE PROPOSITIONS PROVIDED.

CREATE NEW PROPOSITIONS WHEN THE SUPPLIED PROPOSITIONS DO NOT COVER WHAT YOU ARE TRYING TO DO OR WHEN YOU WANT TO USE A PROPOSITION TWICE.

WILL HAVE APPROXIMATELY 15 MINUTES TO CREATE YOUR SECOND CONCEPT MAP.

ARE THERE ANY QUESTIONS?

BEGIN.

After they complete the second concept map:

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS "SUBJECT ____, CONCEPT MAP 2. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME WE WILL YOU WILL COMPLETE YOUR SECOND TROUBLESHOOTING TASK. ONCE AGAIN MAKE SURE YOU SPEAK ALOUD WHILE PERFORMING THE TASK. THIS WILL ALLOW YOUR FACILITATOR TO RECORD THE ACTIONS YOU TAKE WHILE COMPLETING THE TASK.

YOU WILL HAVE APPROXIMATELY 20 MINUTES TO COMPLETE THE TASK.

DO YOU HAVE ANY QUESTIONS?

BEGIN

After 20 minutes ask the subjects to stop.

Have subjects make a new concept map

AT THIS TIME I WOULD LIKE YOU TO CAPTURE A YOUR THIRD CONCEPT MAP GIVEN WHAT YOU LEARNED IN COMPLETING THE PREVIOUS TASK.

DO YOU HAVE ANY QUESTIONS?

After the subject's have completed their third concept map have them move to the classroom.

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS "SUBJECT ____, CONCEPT MAP 3. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME I WOULD LIKE YOU TO MOVE TO THE CLASSROOM FOR THE COMPLETION A SURVEY AND TO RECEIVE AN OUTBREIF.

Handout surveys and have subject complete them.

Provide subject with an out briefing

3.5.2 Data Session - No LockTel - Constrained

THE STUDY WILL CONSIST OF FIVE PHASES. THE FIRST PHASE IS THE INTRODUCTION TO THE EXPERIMENT AND CONCEPT MAP DEVELOPMENT TRAINING WHICH YOU COMPLETED EARLIER.

THE SECOND PHASE IS THE DEVELOPMENT OF YOUR FIRST CONCEPT MAP.

IN THE THIRD PHASE YOU WILL PERFORM A TROUBLESHOOTING TASK AND DEVELOP YOUR SECOND CONCEPT MAP.

IN THE FOURTH PHASE YOU WILL PERFORM A SECOND TROUBLESHOOTING TASK AND COMPLETE YOUR THIRD CONCEPT MAP.

**THE FIFTH AND FINAL PHASE OF THE EXPERIMENT WILL CONSISTS OF COMPLETING A QUESTIONNAIRE AND A DEBRIEFING.
ARE THERE ANY QUESTIONS?**

YOU WILL NOW COVER DOWN ON ONE OF THE TEN HMMWV'S WHERE YOU WILL CREATE A CONCEPT MAP ON HOW YOU WOULD PERFORM A TROUBLESHOOTING TASK ON THE STARTING AND CHARGING SYSTEM OF A HMMWV.

Have subjects randomly cover down on one of the ten HMMWV stations. Have subjects stand in front of each vehicle facing the center of the bay area.

BEFORE WE GET STARTED ON TROUBLESHOOTING THE HMMWV, I LIKE YOU TO CONSTRUCT A CONCEPT MAP USING THE COMPUTER LOCATED AT YOUR STATION. CREATE CONCEPT MAP USING THE CONCEPTS PROVIDED OF HOW YOU WOULD COMPLETE THE TROUBLESHOOT TASK ON A HMMWV STARTING AND CHARGING SYSTEM. THE SYMPTOM IS THAT THE VEHICLE WILL NOT START.

DOES ANYONE HAVE ANY QUESTION ON BUILDING A CONCEPT MAP?

YOU WILL HAVE APPROXIMATELY 15 MINUTES TO COMPLETE YOUR FIRST CONCEPT MAP.

Subject will work on building a concept map. Facilitators will only answer question on how the concept mapping tool works. Do not answer questions on how the concepts fit together.

After 15 minutes:

PLEASE STOP BUILDING YOUR CONCEPT MAP.

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS “SUBJECT ____, CONCEPT MAP 1. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

Ask facilitators to have the subject practice “Thinking Aloud.”

Have facilitators use the Practice – Think Aloud handout practice with subjects.

AT THIS TIME YOU WILL COMPLETE A TROUBLESHOOTING TASK MAY USE THE ELECTRONIC TECHNICAL MANUAL AND THE TOOLS PROVIDED. YOU FACILITATOR WILL GIVE YOU A DA 2404 WITH THE FAULT SYMPTOM. MAKE SURE YOU THINK OUT-LOUD

YOU WILL HAVE 10 MINUTES TO COMPLETE THE TASK. ARE YOU READY? BEGIN...

After 10 minutes

PLEASE STOP

AT THIS TIME YOU WILL CREATE YOUR SECOND CONCEPT MAP BASED ON THE KNOWLEDGE AND EXPERIENCE YOU GAINED WHILE COMPLETING THE TROUBLESHOOTING TASK. YOU WILL FIND THAT THE CONCEPTS FOR CREATING YOUR CONCEPT MAP HAVE BEEN PLACE ON THE BOARD FOR YOU. YOU DO NOT HAVE TO USE ALL THE CONCEPTS. PLACE THE CONCEPTS YOU DON’T WANT TO USE IN THE BOTTOM RIGHT HAND CONNER. PLEASE USE THE PROPOSITIONS PROVIDED. CREATE NEW PROPOSITIONS WHEN THE SUPPLIED PROPOSITIONS DO NOT COVER WHAT YOU ARE TRYING TO DO OR WHEN YOU WANT TO USE A PROPOSITION TWICE.

WILL HAVE APPROXIMATELY 15 MINUTES TO CREATE YOUR SECOND CONCEPT MAP.

ARE THERE ANY QUESTIONS

BEGIN.

After they complete the second concept map:

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS “SUBJECT ____, CONCEPT MAP 2. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME WE WILL YOU WILL COMPLETE YOUR SECOND TROUBLESHOOTING TASK. ONCE AGAIN MAKE SURE YOU SPEAK ALOUD WHILE PERFORMING THE TASK. THIS WILL ALLOW YOUR FACILITATOR TO RECORD THE ACTIONS YOU TAKE WHILE COMPLETING THE TASK.

YOU WILL HAVE APPROXIMATELY 10 MINUTES TO COMPLETE THE TASK.

DO YOU HAVE ANY QUESTIONS?

BEGIN

After 10 minutes ask the subjects to stop.

Have subjects make a new concept map

AT THIS TIME I WOULD LIKE YOU TO CAPTURE A YOUR THIRD CONCEPT MAP BASED ON YOU'RE THE KNOWLEDGE AND EXPERIENCE GAINED COMPLETING THIS TASK.

DO YOU HAVE ANY QUESTIONS?

After the subject's have completed their third concept map have them move to the classroom.

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS “SUBJECT ____, CONCEPT MAP 3. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME I WOULD LIKE YOU TO MOVE TO THE CLASSROOM FOR THE COMPLETION A SURVEY AND TO RECEIVE AN OUTBREIF.

Handout surveys and have subject complete them.

Provide subject with an out briefing

3.5.3 Data Session - LockTel - Unconstrained

THE STUDY WILL CONSIST OF SIX PHASES. THE FIRST PHASE IS THE INTRODUCTION TO THE EXPERIMENT AND CONCEPT MAP DEVELOPMENT TRAINING.

THE SECOND PHASE IS DEVELOPMENT OF YOUR FIRST CONCEPT MAP.

IN THE THIRD PHASE YOU WILL PERFORM A TROUBLESHOOTING TASK AND DEVELOP OF YOUR SECOND CONCEPT MAP.

IN THE FOURTH PHASE YOU WILL RECEIVE TRAINING ON THE LOCKTEL METHOD.

IN THE FIFTH PHASE YOU WILL PERFORM YOUR SECOND TROUBLESHOOTING TASK USING THE LOCKTEL METHOD AND COMPLETE YOUR THIRD CONCEPT MAP.

IN THE SIXTH AND FINAL PHASE OF THE EXPERIMENT YOU WILL BE COMPLETING A QUESTIONNAIRE AND RECEIVE A DEBRIEFING ON THE EXPERIMENT.

ARE THERE ANY QUESTIONS?

Provide student with an overview and an example of a concept map and ask them if they have any questions

YOU WILL NOW COVER DOWN ON ONE OF THE TEN HMMWV'S WHERE YOU WILL CREATE A CONCEPT MAP ON HOW YOU WOULD PERFORM A TROUBLESHOOTING TASK ON THE STARTING AND CHARGING SYSTEM OF A HMMWV.

Have subjects randomly cover down on one of the ten HMMWV stations. Have subjects stand in front of each vehicle facing the center of the bay area.

CONSTRUCT A CONCEPT MAP USING THE COMPUTER LOCATED AT YOUR STATION. CREATE THE CONCEPT MAP USING THE CONCEPTS PROVIDED OF HOW YOU WOULD COMPLETE THE TROUBLESHOOT TASK ON A HMMWV STARTING AND CHARGING SYSTEM. THE FAULT YOU WILL BE TROUBLESHOOTING IS, THE VEHICLE WILL NOT START.

YOU WILL HAVE APPROXIMATELY 15 MINUTES TO COMPLETE YOUR FIRST CONCEPT MAP.

Subject will work on building a concept map. Facilitators will only answer question on how the concept mapping tool works. Do not answer questions on how the concepts fit together.

After 15 minutes:

PLEASE STOP BUILDING YOUR CONCEPT MAP

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS "SUBJECT ____, CONCEPT MAP 1. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

Ask facilitators to have the subject practice “Thinking Aloud.”

Have facilitators use the Practice – Think Aloud handout practice with subjects.

AT THIS TIME YOU WILL COMPLETE A TROUBLESHOOTING TASK MAY USE THE ELECTRONIC TECHNICAL MANUAL AND THE TOOLS PROVIDED. YOU FACILITATOR WILL GIVE YOU A DA 2404 WITH THE FAULT SYMPTOM. MAKE SURE YOU THINK OUT-LOUD YOU WILL HAVE 20 MINUTES TO COMPLETE THE TASK. ARE YOU READY? BEGIN...

After 20 minutes

PLEASE STOP

AT THIS TIME YOU WILL CREATE YOUR SECOND CONCEPT MAP BASED ON THE KNOWLEDGE AND EXPERIENCE YOU GAINED WHILE COMPLETING THE TROUBLESHOOTING TASK. YOU WILL FIND THAT THE CONCEPTS FOR CREATING YOUR CONCEPT MAP HAVE BEEN PLACE ON THE BOARD FOR YOU. YOU DO NOT HAVE TO USE ALL THE CONCEPTS. PLACE THE CONCEPTS YOU DON'T WANT TO USE IN THE BOTTOM RIGHT HAND CONNER. PLEASE USE THE PROPOSITIONS PROVIDED. CREATE NEW PROPOSITIONS WHEN THE SUPPLIED PROPOSITIONS DO NOT COVER WHAT YOU ARE TRYING TO DO OR WHEN YOU WANT TO USE A PROPOSITION TWICE.

YOU WILL HAVE APPROXIMATELY 15 MINUTES TO CREATE YOUR SECOND CONCEPT MAP.

ARE THERE ANY QUESTIONS?

BEGIN.

After they complete the second concept map:

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS “SUBJECT ____, CONCEPT MAP 2. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME WE WILL MOVE BACK INTO THE CLASSROOM.

Present to LockTel Framework training

After the training

AT THIS TIME WE WILL MOVE BACK TO THE MAINTENANCE BAY.

PLEASE RETURN TO THE SAME STATION YOU WERE AT PRIOR TO THE TRAINING.

AT THIS TIME WE WILL YOU WILL COMPLETE YOUR SECOND TROUBLESHOOTING TASK USING THE LOCKTEL METHOD FROM THE TRAINING YOU JUST RECEIVED. ONCE AGAIN MAKE SURE YOU SPEAK ALOUD WHILE PERFORMING THE TASK. THIS WILL ALLOW YOUR FACILITATOR TO RECORD THE ACTIONS YOU TAKE WHILE COMPLETING THE TASK.

YOU WILL HAVE APPROXIMATELY 20 MINUTES TO COMPLETE THE TASK.

DO YOU HAVE ANY QUESTIONS?

BEGIN

After 20 minutes ask the subjects to stop.

Have subjects make a new concept map

AT THIS TIME I WOULD LIKE YOU TO CAPTURE A YOUR THIRD CONCEPT MAP BASED ON YOU'RE THE KNOWLEDGE AND EXPERIENCE GAINED COMPLETING THIS TASK.

DO YOU HAVE ANY QUESTIONS?

After the subject's have completed their third concept map have them move to the classroom.

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS "SUBJECT ____, CONCEPT MAP 3. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME I WOULD LIKE YOU TO MOVE TO THE CLASSROOM FOR THE COMPLETION A SURVEY AND TO RECEIVE AN OUTBREIF.

Handout surveys and have subject complete them.

Provide subject with an out briefing

3.5.4 Data Session - LockTel - Constrained

THE STUDY WILL CONSIST OF SIX PHASES. THE FIRST PHASE IS THE INTRODUCTION TO THE EXPERIMENT AND CONCEPT MAP DEVELOPMENT TRAINING.

THE SECOND PHASE IS DEVELOPMENT OF YOUR FIRST CONCEPT MAP. IN THE THIRD PHASE YOU WILL PERFORM A TROUBLESHOOTING TASK AND DEVELOP OF YOUR SECOND CONCEPT MAP.

IN THE FOURTH PHASE YOU WILL RECEIVE TRAINING ON THE LOCKTEL METHOD.

IN THE FIFTH PHASE YOU WILL PERFORM YOUR SECOND TROUBLESHOOTING TASK USING THE LOCKTEL METHOD AND COMPLETE YOUR THIRD CONCEPT MAP.

IN THE SIXTH AND FINAL PHASE OF THE EXPERIMENT YOU WILL BE COMPLETING A QUESTIONNAIRE AND RECEIVE A DEBRIEFING ON THE EXPERIMENT.

ARE THERE ANY QUESTIONS?

Provide student with an overview and an example of a concept map and ask them if they have any questions

YOU WILL NOW COVER DOWN ON ONE OF THE TEN HMMWV'S WHERE YOU WILL CREATE A CONCEPT MAP ON HOW YOU WOULD PERFORM A TROUBLESHOOTING TASK ON THE STARTING AND CHARGING SYSTEM OF A HMMWV.

Have subjects randomly cover down on one of the ten HMMWV stations. Have subjects stand in front of each vehicle facing the center of the bay area.

CONSTRUCT A CONCEPT MAP USING THE COMPUTER LOCATED AT YOUR STATION. CREATE THE CONCEPT MAP USING THE CONCEPTS PROVIDED OF HOW YOU WOULD COMPLETE THE TROUBLESHOOT TASK ON A HMMWV STARTING AND CHARGING SYSTEM. THE FAULT YOU WILL BE TROUBLESHOOTING IS, THE VEHICLE WILL NOT START.

YOU WILL HAVE APPROXIMATELY 15 MINUTES TO COMPLETE YOUR FIRST CONCEPT MAP.

Subject will work on building a concept map. Facilitators will only answer question on how the concept mapping tool works. Do not answer questions on how the concepts fit together.

After 15 minutes:

PLEASE STOP BUILDING YOUR CONCEPT MAP

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS “SUBJECT ____, CONCEPT MAP 1. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

Ask facilitators to have the subject practice “Thinking Aloud.”

Have facilitators use the Practice – Think Aloud handout practice with subjects.

AT THIS TIME YOU WILL COMPLETE A TROUBLESHOOTING TASK MAY USE THE ELECTRONIC TECHNICAL MANUAL AND THE TOOLS PROVIDED. YOU FACILITATOR WILL GIVE YOU A DA 2404 WITH THE FAULT SYMPTOM.

**MAKE SURE YOU THINK OUT-LOUD.
YOU WILL HAVE 10 MINUTES TO COMPLETE THE TASK.**

ARE YOU READY?

BEGIN...

After 10 minutes

PLEASE STOP

AT THIS TIME YOU WILL CREATE YOUR SECOND CONCEPT MAP BASED ON THE KNOWLEDGE AND EXPERIENCE YOU GAINED WHILE COMPLETING THE TROUBLESHOOTING TASK. YOU WILL FIND THAT THE CONCEPTS FOR CREATING YOUR CONCEPT MAP HAVE BEEN PLACE ON THE BOARD FOR YOU. YOU DO NOT HAVE TO USE ALL THE CONCEPTS. PLACE THE CONCEPTS YOU DON'T WANT TO USE IN THE BOTTOM RIGHT HAND CONNER. PLEASE USE THE PROPOSITIONS PROVIDED. CREATE NEW PROPOSITIONS WHEN THE SUPPLIED PROPOSITIONS DO NOT COVER WHAT YOU ARE TRYING TO DO OR WHEN YOU WANT TO USE A PROPOSITION TWICE.

WILL HAVE APPROXIMATELY 15 MINUTES TO CREATE YOUR SECOND CONCEPT MAP.

ARE THERE ANY QUESTIONS?

BEGIN

After they complete the second concept map:

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS “SUBJECT ____, CONCEPT MAP 2. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME WE WILL MOVE BACK INTO THE CLASSROOM.

Present to LockTel Framework training

After the training

AT THIS TIME WE WILL MOVE BACK TO THE MAINTENANCE BAY. PLEASE RETURN TO THE SAME STATION YOU WERE AT PRIOR TO THE TRAINING

AT THIS TIME WE WILL YOU WILL COMPLETE YOUR SECOND TROUBLESHOOTING TASK USING THE LOCKTEL METHOD FROM THE TRAINING YOU JUST RECEIVED. ONCE AGAIN MAKE SURE YOU SPEAK ALOUD WHILE PERFORMING THE TASK. THIS WILL ALLOW YOUR FACILITATOR TO RECORD THE ACTIONS YOU TAKE WHILE COMPLETING THE TASK.

YOU WILL HAVE APPROXIMATELY 10 MINUTES TO COMPLETE THE TASK.

DO YOU HAVE ANY QUESTIONS?

BEGIN

After 10 minutes ask the subjects to stop.

Have subjects make a new concept map

AT THIS TIME I WOULD LIKE YOU TO CAPTURE A YOUR THIRD CONCEPT MAP BASED ON YOU'RE THE KNOWLEDGE AND EXPERIENCE GAINED COMPLETING THIS TASK.

DO YOU HAVE ANY QUESTIONS?

After the subject's have completed their third concept map have them move to the classroom.

FACILITATORS PLEASE SAVE YOUR SUBJECTS CONCEPT MAP AS "SUBJECT ____, CONCEPT MAP 3. IN THE SUBJECT NAME PROMPT USE SUBJECT ____.

AT THIS TIME I WOULD LIKE YOU TO MOVE TO THE CLASSROOM FOR THE COMPLETION A SURVEY AND TO RECEIVE AN OUTBREIF.

Handout surveys and have subject complete them.

Provide subject with an out briefing

APPENDIX B

CONSENT TO PARTICIPATE IN A RESEARCH STUDY FORM

Appendix C contains the Consent to Participate in a Research Study Form that was approved by the Institutional Review Board and was completed by all the subjects who participated in the experiment.

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF STUDY: Virtual, Live, and Constructive Environments for Performance Support

RESEARCH STUDY:

I, _____, have been asked to participate in a research study under the direction of John M. Lacontora. Other professional persons who work with him as study staff may assist to act for him.

PURPOSE:

The purpose of this experiment is to test the effectiveness of an enhanced electronic technical manual for a military ground vehicle.

DURATION:

My participation in this study will last approximately two and one half hours.

PROCEDURES:

I have been told that, during the course of this study, the following will occur:

I will be trained in maintenance troubleshooting techniques.

I will be questioned on how I would normally perform a diagnostic and repair process in writing and then through an interview process.

I will perform a diagnostic task using an Electronic Technical Manual (ETM) and a diagnostic task using an ETM with some modifications.

I am required to fill out a questionnaire and participate in a debriefing session at the conclusion of the experiment.

PARTICIPANTS:

I will be one of about 80 participants to participate in this study.

EXCLUSIONS:

I will inform the researcher if any of the following apply to me: N/A

RISK/DISCOMFORTS:

I have been told that the study described above may involve the following risks and/or discomforts:

There are no known risks or discomforts.

There also may be risks and discomforts that are not yet known.

CONFIDENTIALITY:

Every effort will be made to maintain the confidentiality of my study records. Officials of NJIT will be allowed to inspect sections of my research records related to this study. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

PAYMENT FOR PARTICIPATION:

I have been told that I will receive \$0 compensation for my participation in this study.

CONSENT AND RELEASE:

I fully recognize that there are risks that I might be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by New Jersey Institute of Technology's insurance policy for any injury or loss I might sustain in the course of participating in the study.

RIGHT TO REFUSE OR WITHDRAW:

I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

INDIVIDUAL TO CONTACT:

If I have any questions about my treatment or research procedures that I discuss them with the principle investigator. If I have any addition questions about my rights as a research subject, I may contact:

Richard Greene, M.D., Ph.D., Chair, IRB (973) 596-3281.

SIGNATURE OF PARTICIPANT:

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

Subject's Name: _____

Signature: _____

Date: _____

SIGNATURE OF INVESTIGATOR OR RESPONSIBLE INDIVIDUAL:

To the best of my knowledge, the participant,

_____,

has understood the entire content of the above consent form, and comprehends the study. The participants and those of his/her parent/legal guardian have been accurately answered to his/her/their complete satisfaction.

Investigator's Name: _____

Signature: _____

Date: _____

APPENDIX C

THE LOCKTEL FRAMEWORK INTRODUCTION PRESENTATION

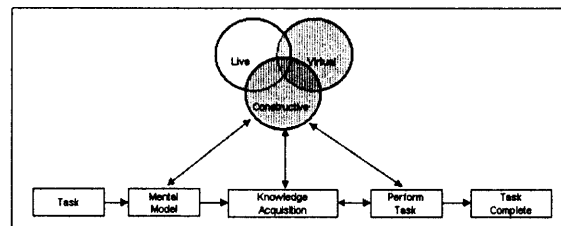
Appendix C contains the LockTel Framework introduce presentation. Slides 3, 4 and 5 also contained video and audio segments that clarify the material being presented.

LockTel Framework Introduction

John M. Lacontora
NJIT

Slide 1 - LockTel Framework

LockTel Framework



- ☑ The LockTel Framework segments knowledge retrieval into three environments: Live, Virtual, and Constructive for automotive technicians retrieving knowledge while using a computer-mediated performance support system (Lacontora and Mendonça (2003).

Slide 2 - LockTel Framework

Introduction: *Live, Virtual, and Constructive Environments for Performance Support*

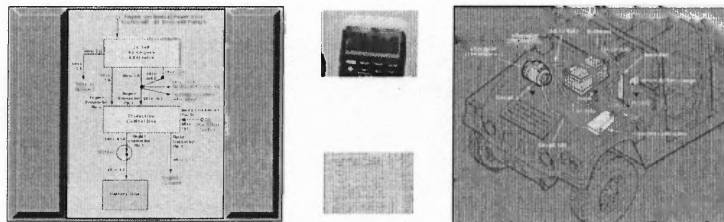
- ☑ **Live Environment** – A computer-aided performance support environment that enables a user to solve problems where system information is not available through collaboration with external resources.



Slide 3 - LockTel Framework

Introduction: *Live, Virtual, and Constructive Environments for Performance Support*

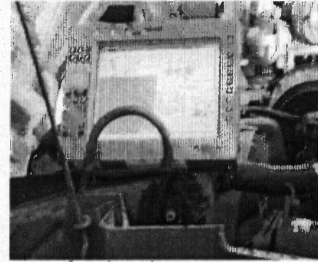
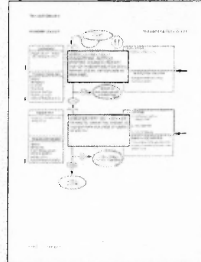
- ☑ **Virtual Environment** – Conceptual or high-level understanding of a given system or function.



Slide 4 - LockTel Framework

Introduction: *Live, Virtual, and Constructive Environments for Performance Support*

- ☑ **Constructive Environment** – Techniques, processes and procedures associated with completing a task.



Slide 5 - LockTel Framework

LockTel for Performance Support

- Within the LockTel Framework, a technician interacts with the live, virtual, and constructive environments to gain *declarative knowledge, conceptual knowledge, and procedural knowledge* relevant to executing a vehicle maintenance task.

Slide 6 - LockTel Framework

APPENDIX D
CONCEPT MAP TRAINING MATERIALS

Appendix D, consist of 34 slides developed at the University of Central Florida to train users on how to create a concept map and were modified to meet the needs of this study.

Concept Mapping Made Easy

John M. Lacontora
NJIT

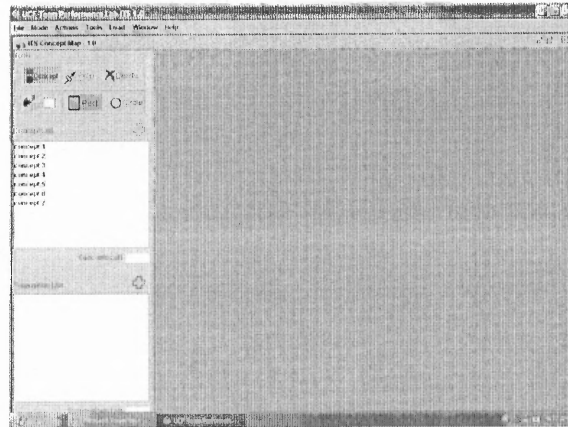
Slide 1 - Concept Map Training

Instructions

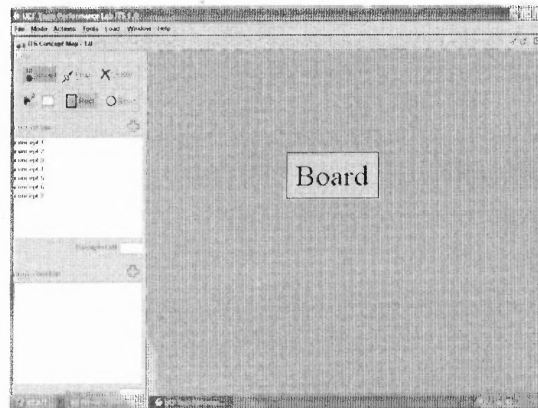
- You will be completing an troubleshooting task and afterward you will be asked to create a concept map.
- This tutorial will explain to you the basics of the how to create a concept map for this experiment
- Please feel free to ask the researcher any questions you may have throughout this study.

Slide 2 - Concept Map Training

Game Playing Screen

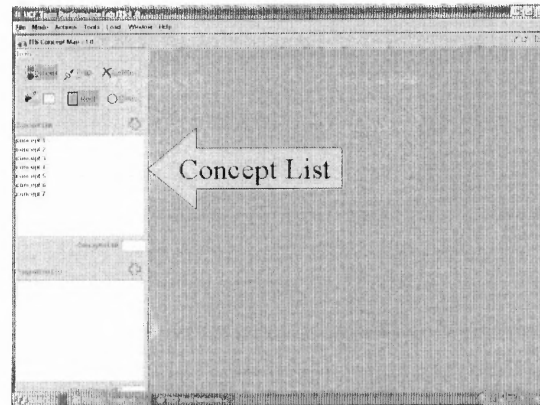


Slide 3 - Concept Map Training



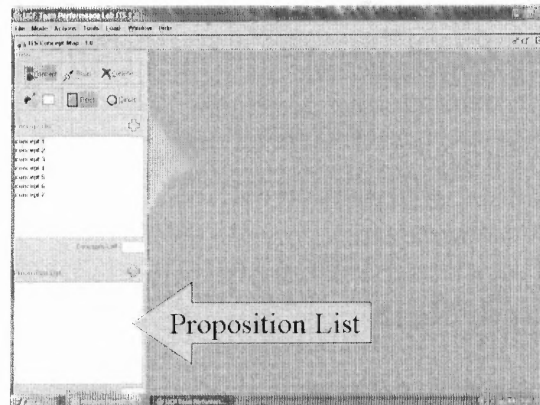
The lavender right hand side of the screen is the Board.
In this area, you will create the concept map.

Slide 4 - Concept Map Training



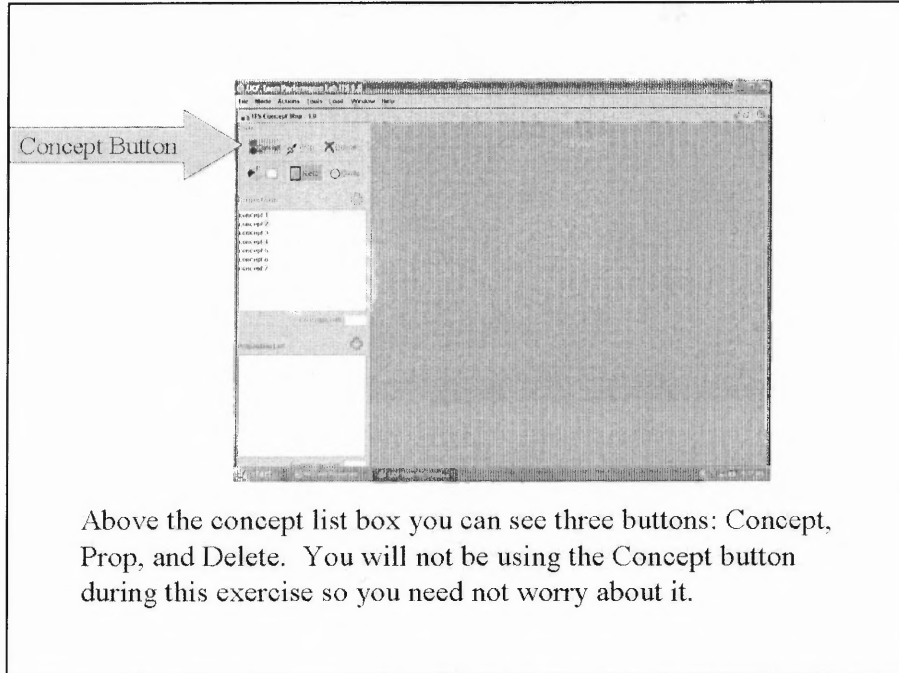
On the gray left hand side of the screen you can see the Concept List box. This shows you all available concepts. A scroll bar is available to view the entire list if necessary.

Slide 5 - Concept Map Training

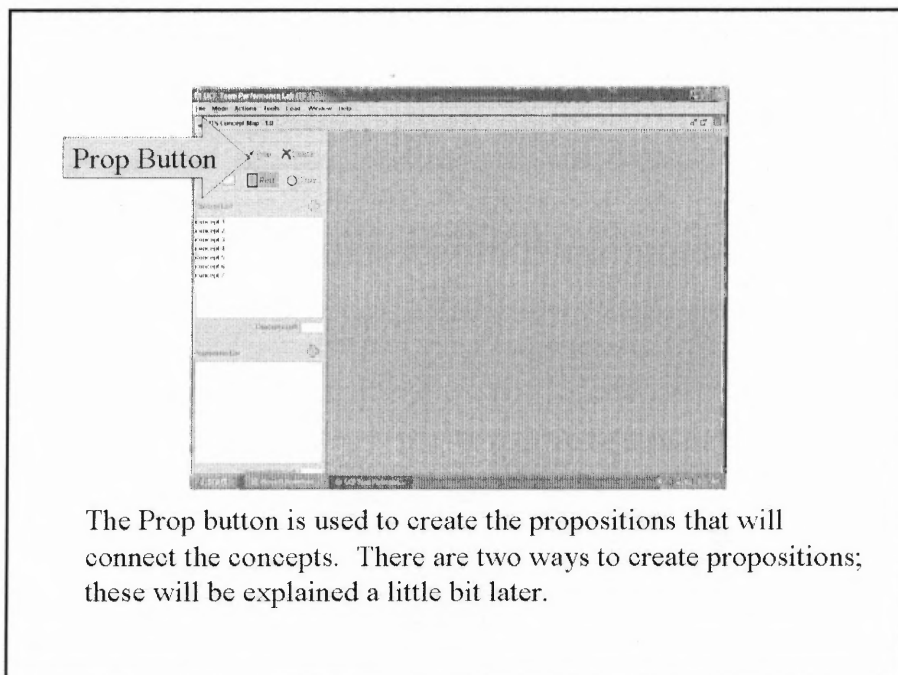


On the gray left hand side of the screen you can also see the Proposition List box. Currently this list is empty. During this exercise you will create the propositions that will connect the concepts to one another.

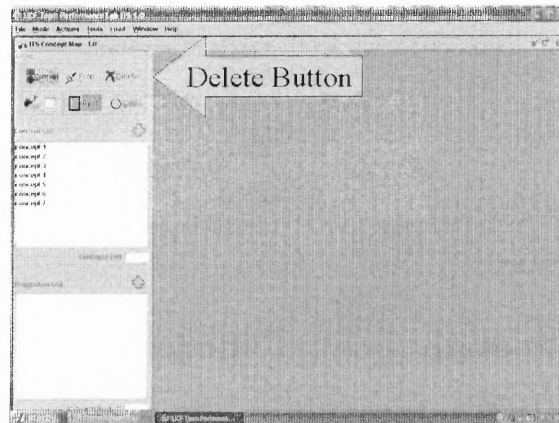
Slide 6 - Concept Map Training



Slide 7 - Concept Map Training

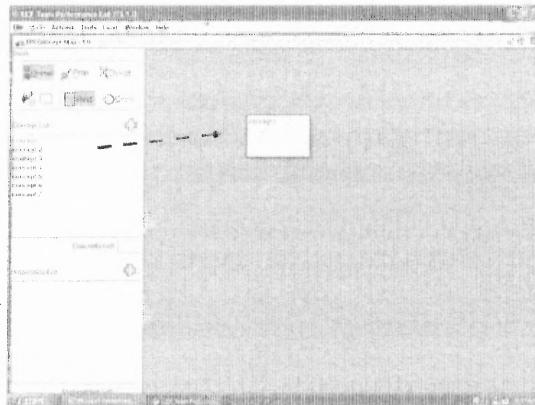


Slide 8 - Concept Map Training



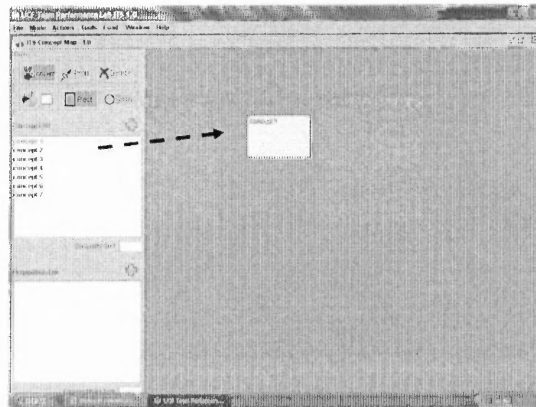
The Delete button is used to delete propositions from the game. To do this you click on the Delete button and then double-click on the proposition you wish to delete. There is no Undo option so you should make deletions cautiously.

Slide 9 - Concept Map Training



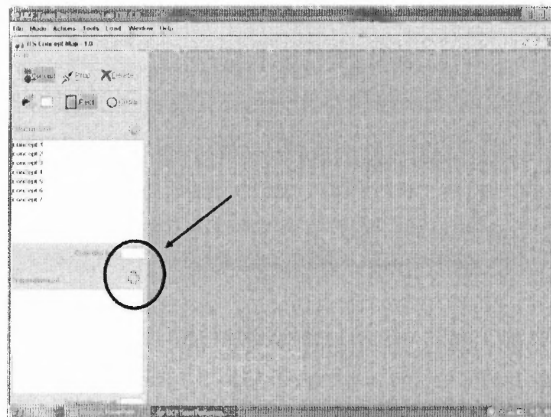
In order to use the concepts, you must bring them over to the Board. To do this, click on the concept in the Concept List and drag the concept over to the Board.

Slide 10 - Concept Map Training



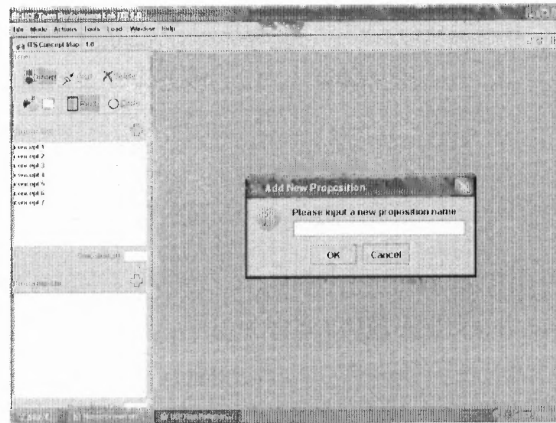
You will see the concept appear on the Board as shown. You will also see that the name in the Concept List has been shaded, showing that concept is in use already.

Slide 11 - Concept Map Training



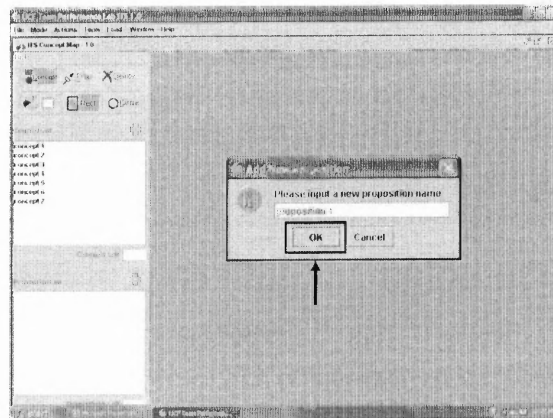
Using propositions is a little bit more difficult. The first way to create a proposition is to click on the little green cross directly above the Proposition List box.

Slide 12 - Concept Map Training



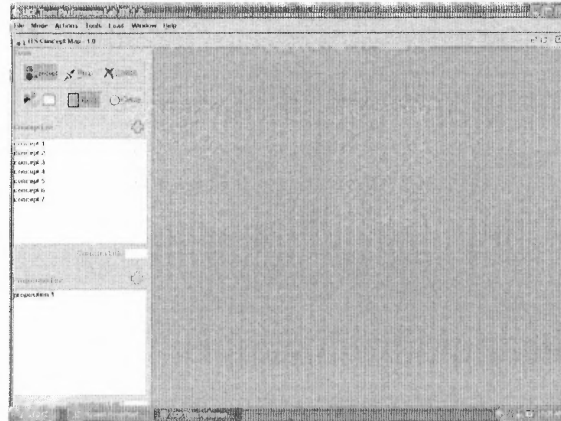
An Add New Proposition box will appear on the Board. This allows you to name your proposition.

Slide 13 - Concept Map Training



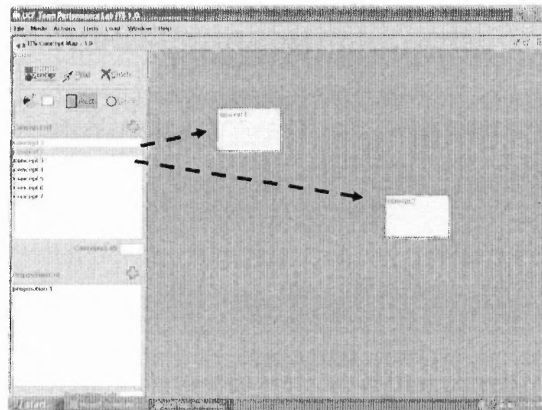
Type in the name of the proposition you wish to create and click on the OK button.

Slide 14 - Concept Map Training



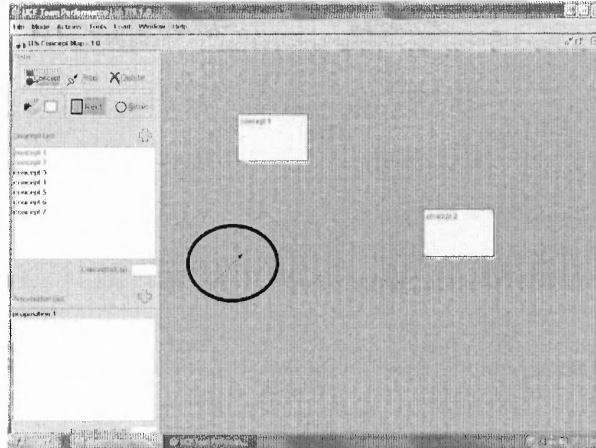
You can see that the proposition is now in the Proposition List and can be used at any time. However, you cannot simply click on a proposition and move it onto the Board like you can the concepts.

Slide 15 - Concept Map Training



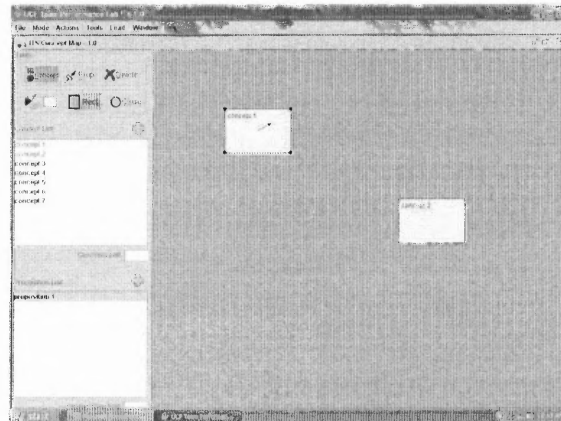
Because propositions can only be used to connect concepts to one another, you must first place your concepts on the Board.

Slide 16 - Concept Map Training



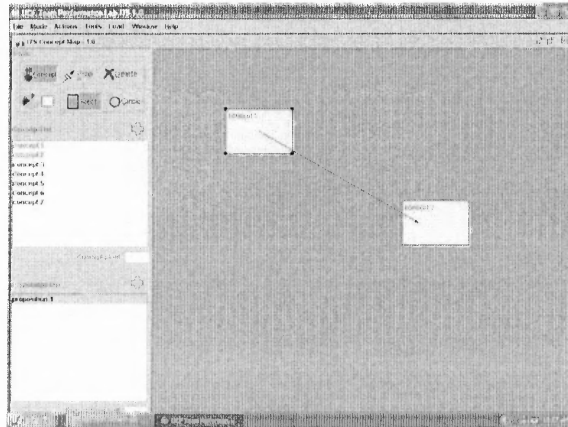
In order to use the proposition, you will now click and drag the proposition onto the Board. As you drag the proposition, an arrow follows the mouse. This lets you know that you are moving the proposition onto the Board.

Slide 17 - Concept Map Training



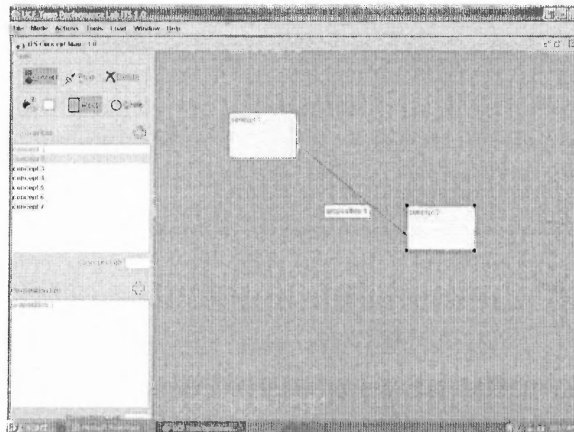
You must drag the proposition to the first concept and release the mouse button. When you do this, you will see the concept become selected (the corners become black and the arrow appears inside the concept rectangle).

Slide 18 - Concept Map Training



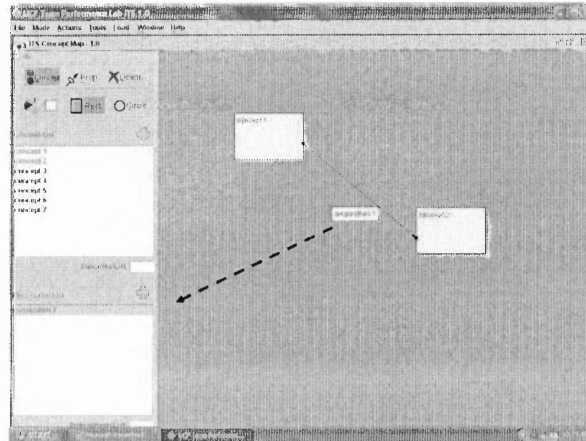
You then need to move the mouse to the second concept. You will see that the arrow follows the mouse around the Board. To complete the connection, you will need to click on the second concept.

Slide 19 - Concept Map Training



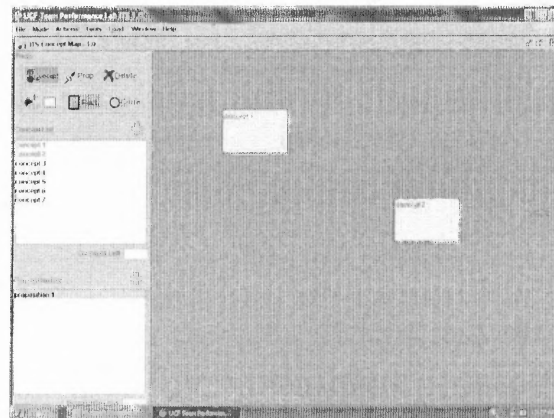
Once you have clicked on the second concept, you will see that the proposition name appears between the two concepts and proposition 1 becomes shaded in the Proposition List showing that it is in use on the Board.

Slide 20 - Concept Map Training



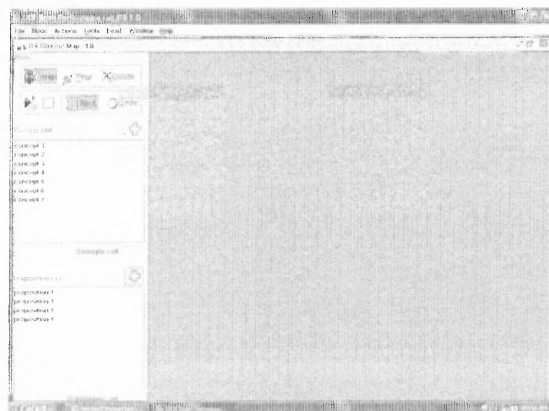
Similar to the concepts, you can remove a proposition from the Board simply by clicking on the proposition name and dragging it back to the Proposition List.

Slide 21 - Concept Map Training



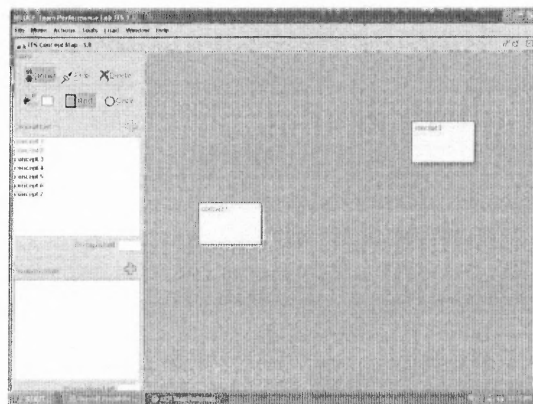
The proposition will appear back in the Proposition List and can be used at any time during the exercise. Each proposition can only be used once, however you can duplicate propositions such that they have the same name.

Slide 22 - Concept Map Training



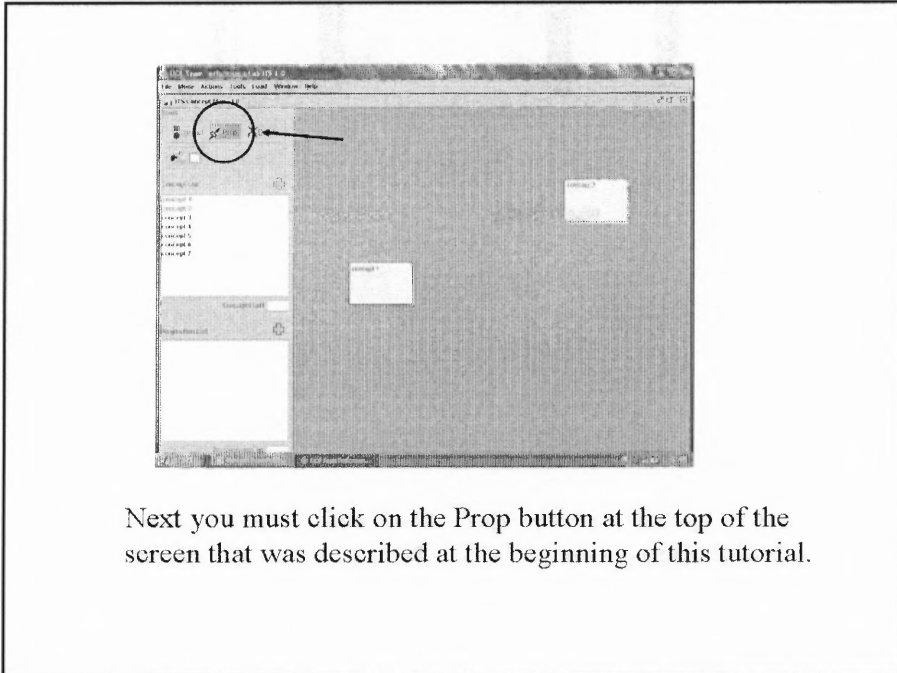
Here you can see that 4 proposition 1's are in the Proposition List. This allows you free range in how you connect the concepts together with propositions.

Slide 23 - Concept Map Training



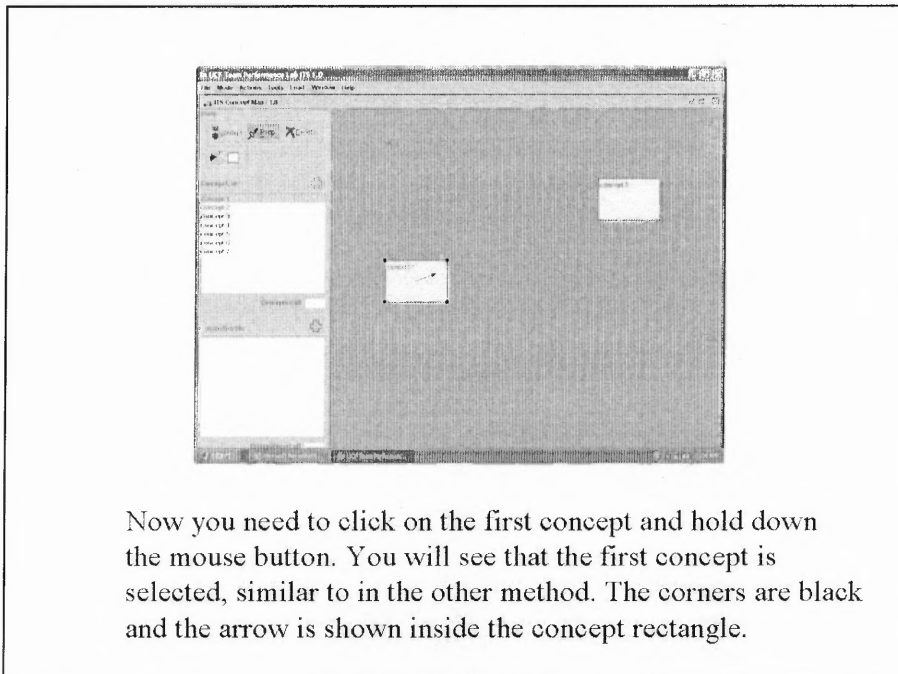
As already mentioned, there is a second way to create propositions. In this method, the first step is to move the Concepts onto the Board.

Slide 24 - Concept Map Training



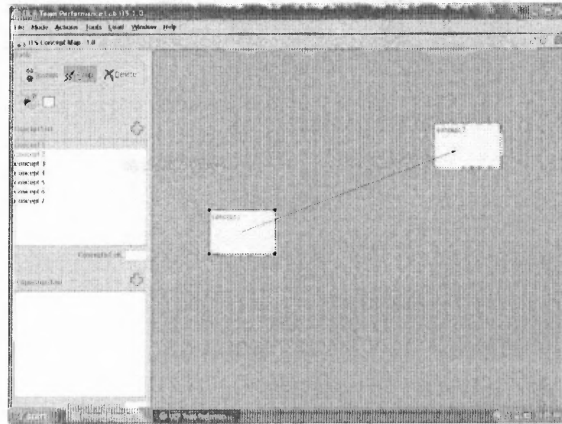
Next you must click on the Prop button at the top of the screen that was described at the beginning of this tutorial.

Slide 25 - Concept Map Training



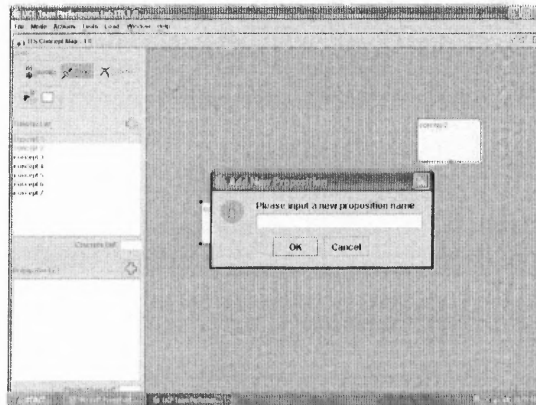
Now you need to click on the first concept and hold down the mouse button. You will see that the first concept is selected, similar to in the other method. The corners are black and the arrow is shown inside the concept rectangle.

Slide 26 - Concept Map Training



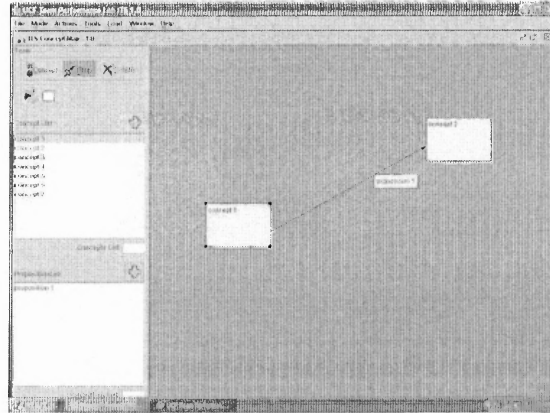
This time, you need to drag the arrow over to the other concept and then let the mouse button go when you are over the second concept.

Slide 27 - Concept Map Training



This action will bring up the Add New Proposition box. From here, you follow the same instructions. By entering the proposition name, the proposition will appear both on the Board and in the Proposition List.

Slide 28 - Concept Map Training

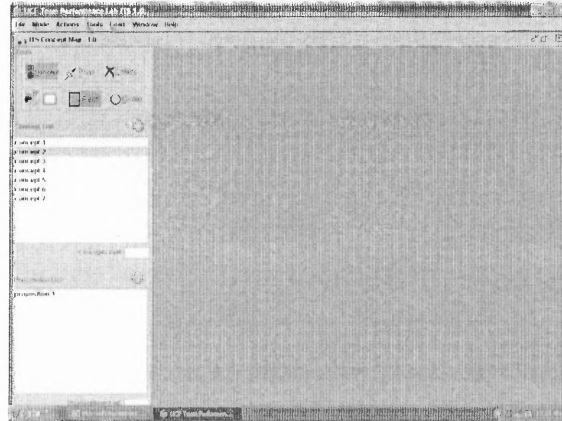


Here you see that in fact the proposition is on the Board and is shaded in the Proposition List.

Slide 29 - Concept Map Training

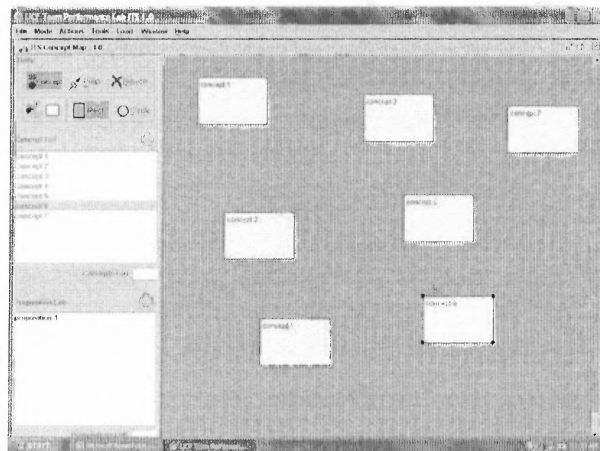
You now have the basic information regarding the creation of the concept map on the Board. You should be able to move the concepts onto the Board and create propositions to connect those concepts. Next you will be given some additional information to help in your concept map exercise.

Slide 30 - Concept Map Training



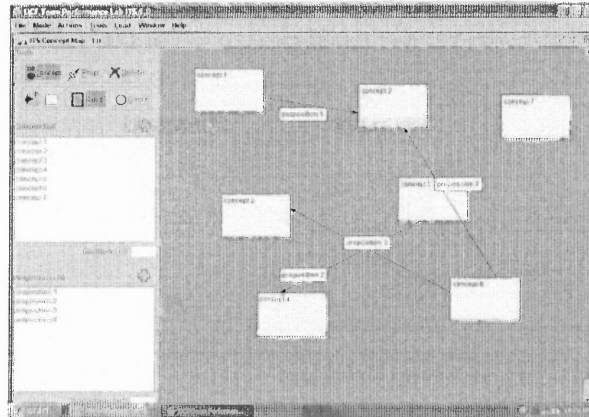
You can create your concept map in any way that you see fit. One common method that people use it to place all the concepts on the Board first.

Slide 31 - Concept Map Training



Here you can see that all concepts have been moved onto the Board. In addition, you can see that a scroll bar has appeared to the right-hand side of the Board. The Board will expand to fit all the concepts used.

Slide 32 - Concept Map Training



Once all the concepts are on the Board, you can then create propositions to explain the relationships between the concepts. You are not required to connect all concepts to one another, however you are required to place all concepts on the Board.

Slide 33 - Concept Map Training

Conclusion

- This completes your training on using the Concept Map program.
- If you have any questions please direct them to your researcher now. If you have further questions during the actual game, the researcher will still be available for help.
- Please let the researcher know that you have completed the training session and are ready to move on.

Slide 34 - Concept Map Training

APPENDIX E

POST EXPERIMENT QUESTIONNAIRE

Appendix E contains the post experiment questionnaire which is designed to determine the LockTel Framework's perceived usefulness and task validity.

**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT
POST QUESTIONNAIRE**

SUBJECT IDENTIFICATION NUMBER: _____

1. I understood the task.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

2. Using LockTel would make it easier to do my job.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

3. Using LockTel in my job would enable me to accomplish tasks more quickly.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

4. Using LockTel would enhance my effectiveness on the job.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

5. I would find LockTel useful in my job.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

6. Using LockTel would improve my job performance.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

7. I feel the task was too difficult.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

8. I have already troubleshot a starting and charging system for my job.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

9. Using LockTel in my job would increase my productivity.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

10. I feel there wasn't enough time to complete the task.

Strongly Agree						Strongly Disagree
1	2	3	4	5		6 7

CONCEPT AND PROPOSITION LIST
Virtual, Live, and Constructive Environments for Performance Support

The concepts that are associated with Automotive Troubleshooting consist of the following:

CONCEPTS

Verify Fault	Troubleshooting Procedures
Schematic, Wiring Diagrams, etc	System Operation – How does it work
Electronic Technical Manual	Digital Library
Test Equipment, Test Set, etc.	Repair Parts Manual
Co-worker or Supervisor	General Support Field Manual
Technical Support Representative	Road Test
Visual Checks	Vehicle Noise
System Failure	

The propositions associated with an automotive troubleshooting task are:

PROPOSITIONS

Check Referenced	Repair System
Check System	No Fault Found
Find Information	Get Additional Information
Test System	Check Manual
Test Wires	Check Problem
Find Unpublished Information	

APPENDIX F

CONCEPT AND PROPOSITION LIST

Appendix F contains the list of Concepts and Propositions that were used t by the subjects to construct their concept maps during the experiment.

APPENDIX G

THINK ALOUD PRACTICE SHEET

Appendix G contains the Think Aloud Practice Sheet. All participants will work with the experiment facilitators to practice thinking aloud prior to starting their first troubleshooting task.

Virtual, Live, and Constructive Environments for Performance Support

PRACTICE SHEET – Thinking Aloud

Note to facilitator: Do these practice tasks until the subjects can give verbal reports “without confounding them with explanations and justifications.” Accept 5-10 seconds of silence before telling the subject, “keep talking.”

□ AS STATED BY MR. LACONTORA, IN THIS STUDY WE ARE INTERESTED IN WHAT YOU SAY TO YOURSELF AS YOU PERFORM THE TROUBLESHOOTING TASKS. WE WILL ASK YOU TO THINK ALOUD WHILE YOU PERFORM THE TWO TROUBLESHOOTING TASKS. WHAT I MEAN BY “THINK ALOUD” IS THAT I WANT YOU SAY OUT LOUD EVERYTHING THAT YOU RECALL SAYING TO YOURSELF SILENTLY. I DON'T WANT YOU TO TRY TO PLAN OUT WHAT YOU SAY OR TRY TO EXPLAIN TO ME WHAT YOU ARE SAYING. JUST ACT AS IF YOU ARE ALONE IN THE ROOM SPEAKING TO YOURSELF. IT IS MOST IMPORTANT THAT YOU KEEP TALKING. IF YOU ARE SILENT FOR ANY LENGTH OF TIME I WILL REMIND YOU TO KEEP TALKING. DO YOU UNDERSTAND WHAT I WANT YOU TO DO?

GOOD.

□ THE FIRST PRACTICE TASK IS TO MULTIPLY TWO NUMBERS IN YOUR HEAD. I WANT YOU TO MULTIPLY THESE TWO NUMBERS IN YOUR HEAD AND TELL ME WHAT YOU ARE THINKING AS YOU GET AN ANSWER. SO, THINK ALOUD WHILE YOU MULTIPLY 27 TIMES 7!

Note to facilitator: Whether or not the answer is correct is unimportant.

GOOD!

Note to facilitator: You may use other multiplication problems (e.g., $23*5$, $19*30$) if you think the subject needs more practice in giving the protocol.

□ NOW I WILL GIVE YOU A PRACTICE TASKS BEFORE WE PROCEED WITH THE ACTUAL STUDY. I WANT YOU TO DO THE SAME THING FOR EACH OF THESE TASKS. I WANT YOU TO THINK ALOUD, AS YOU DID BEFORE, WHILE YOU THINK ABOUT PERFORMING THE TASK. THEN, AFTER YOU HAVE COMPLETED THE TASK, I WILL ASK YOU TO REPORT ALL THAT YOU CAN REMEMBER ABOUT YOUR THINKING. ANY QUESTIONS? HERE IS YOUR NEXT PROBLEM.

"HOW MANY WINDOWS ARE THERE WHERE YOU LIVE?"

APPENDIX H
SUBJECT PERSONAL DATA FORM

Appendix H contains the Subject Personal Data Form. All subjects must complete this form during the sign-in phase of the experiment.

**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT EXPERIMENT**

SUBJECT PERSONAL DATA FORM

SUBJECT # _____

AGE _____

UNIT OF ASSIGNMENT _____

MOS: PRIMARY _____ **SECONDARY** _____

ALTERNATES _____

EDUCATION: HIGHEST GRADE COMPLETED _____

MAJOR: _____

NUMBER OF COLLEGE CREDITS _____

MAJOR: _____

**DID YOU ATTEND AN AUTOMOTIVE TECHNICAL
SCHOOL? YES/NO** _____

**EXPERIENCE: WERE YOU AN AUTOMOTIVE MECHANIC OR
TECHNICIAN PRIOR TO JOINING THE MILITARY?
YES/NO** _____ **HOW MANY MONTHS?** _____

GENERAL INFORMATION:

WHERE DID YOU GROW UP?

CITY _____ **STATE** _____

APPENDIX I

SUBJECT RANDOM ASSIGNMENT MATRIX AND GROUP ORDER SCHEDULE

Appendix I contains the subject random assignment matrix and the group order schedule that was generated using the MS Excel random number generator.

Day 1

Subject#	Group	Random No.
1	1	0.09
2	1	0.15
3	3	0.62
4	4	0.83
5	2	0.34
6	4	0.81
7	3	0.54
8	2	0.35
9	3	0.51
10	3	0.72
11	1	0.00
12	1	0.22
13	3	0.76
14	4	0.95
15	4	0.91
16	4	0.89
17	4	0.93
18	2	0.47
19	3	0.49
20	2	0.28
21	1	0.05
22	2	0.30
23	3	0.49
24	1	0.18
25	1	0.07
26	4	0.86
27	4	0.84
28	2	0.42
29	4	0.84
30	2	0.44
31	2	0.41
32	1	0.21
33	1	0.11
34	2	0.26
35	3	0.60
36	3	0.56
37	1	0.10
38	2	0.48
39	3	0.60
40	4	0.99

Task 1 precedes Task 2

Day 2

Subject#	Group	Random No.
1	4	0.76
2	1	0.03
3	2	0.29
4	3	0.45
5	1	0.17
6	2	0.18
7	3	0.62
8	1	0.14
9	3	0.66
10	3	0.67
11	2	0.35
12	2	0.35
13	4	0.73
14	3	0.65
15	1	0.06
16	3	0.51
17	3	0.65
18	2	0.23
19	4	0.68
20	1	0.12
21	3	0.36
22	4	0.74
23	4	1.00
24	3	0.64
25	1	0.18
26	4	0.79
27	1	0.07
28	1	0.02
29	2	0.31
30	2	0.25
31	2	0.22
32	1	0.01
33	4	0.78
34	2	0.22
35	2	0.32
36	4	0.87
37	3	0.50
38	4	0.73
39	4	0.92
40	1	0.06

Task 2 precedes Task 1

APPENDIX J

SUBJECT GROUP ASSIGNMENT FORM

Appendix J contains the Subject Group Assignment Form. This form was used to assign subjects to a group based on the Random Assignment Matrix in Appendix I.

**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT**

GROUP ROSTER

DAY #

PAGE 1 OF 2

Group 1			
Number Subjects	Name	Subject #	
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Group 2			
Number Subjects	Name	Subject #	Task
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT**

GROUP ROSTER

DAY #

PAGE 2 OF 2

Group 3			
Number Subjects	Name	Subject #	
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Group 4			
Number Subjects	Name	Subject #	
1			
2			
3			
4			
5			
6			
7			
8			
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10			

APPENDIX K

SUBJECT SIGN-IN SHEET AND SUBJECT ROSTER

Appendix K contains the experiment Subject Sign-in Sheet and Subject Roster. The form was used to record subjects as they sign-in and to assign subject numbers for the experiment. This form also captures the subject's unit of assignment.

**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT
SIGN-IN SHEET AND SUBJECT ROSTER**

PAGE 1 OF 4

Subject #	Name	Unit of Assignment	Signature
1			
2			
3			
4			
5			
6			
7			
8			
9			
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12			
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**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT
SIGN-IN SHEET AND SUBJECT ROSTER**

PAGE 2 OF 4

Subject #	Name	Unit of Assignment	Signature
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
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**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT
SIGN-IN SHEET AND SUBJECT ROSTER**

PAGE 3 OF 4

Subject #	Name	Unit of Assignment	Signature
51			
52			
53			
54			
55			
56			
57			
58			
59			
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61			
62			
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**LIVE, VIRTUAL, AND CONSTRUCTIVE ENVIRONMENTS
FOR PERFORMANCE SUPPORT
SIGN-IN SHEET AND SUBJECT ROSTER**

PAGE 4 OF 4

Subject #	Name	Unit of Assignment	Signature
76			
77			
78			
79			
80			
81			
82			
83			
84			
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