THE EFFECT OF LESSONS-LEARNED SHARING PROCESSES FOR ORGANIZATIONAL LEARNING ON DECISION-MAKING PERFORMANCE

by

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Dissertation submitted to the Faculty of the

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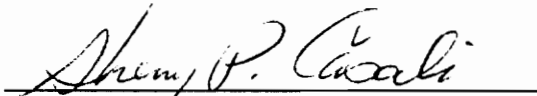in partial fulfillment of the requirements for the degree of

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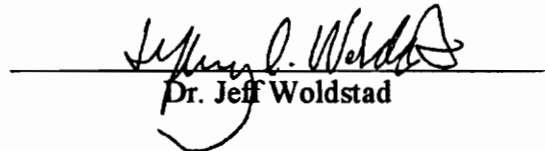## INDUSTRIAL AND SYSTEMS ENGINEERING

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(ABSTRACT)

The aim of this research was to operationalize and validate a lessons-learned sharing process for supporting organizational learning. I validated the process by measuring and evaluating the effects of the process on decision-making (i.e., management) performance. The research results provide tangible evidence about the effects of a lessons-learned sharing process to support organizational learning. A lessons-learned sharing process does improve decision-making performance as measured by decision quality.

A three phase research process was used. The first phase consisted of a task analysis at an industrial site. The results of the task analysis served as the basis for an experiment.

The second phase was a laboratory experiment. Sixty students participated in the experiment. The experiment involved twenty groups of three subjects. One subject completed a task and constructed a lesson learned based on feedback from his or her decisions. The next two subjects used different parts of the lesson learned to solve the same problem. The factors studied in the experiment were the content (no lesson learned, a lesson learned containing only recommendations, and a lesson learned containing the original set of decisions, results, and recommendations) and structure (informal or formal). Both quantitative and qualitative data were collected. The quantitative results of the experiment show: 1) having a lesson learned was better than not having a lesson learned; 2) a formal or structured lesson learned had a greater effect on decision quality than an

informal or unstructured lesson learned; and 3) the formal or structured lesson learned produced an higher-quality lesson learned. The qualitative results show: 1) subjects want explanations for the recommendations in the lesson learned; 2) the accuracy and consistency of a lesson-learned content needs to be ensured because people may use the lesson learned as an answer without further work; and 3) prompts for eliciting the information in a lesson learned need to be developed. Subjects used the lesson learned in six different ways when solving the problem. The problem consisted of making a set of decisions for a manufacturing shift.

The third phase of the research involved a follow-up at the original industrial site. The purpose of this second field study was to gain an insight into how the experimental findings related to a field setting. Implications are discussed for the theory of organizational learning and users of lessons-learned sharing processes in organizations.

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I thank the committee for their guidance, feedback, and support throughout the research process. I need to especially thank two members of my committee, Dr. Sherry Casali and Dr. Betty Koball. Both of these members used their own time to be a member the dissertation committee. I greatly appreciate their sacrifice for the betterment of myself. I also thank Dr. Casali for the opportunity to work with her on the "Risk Perception" project, one of the most gratifying projects I worked on while at Management Systems Laboratories (MSL) at Virginia Tech. I thank Dr. Koball for allowing the human side of life to enter the discussion of the role of research and teaching. The discussions over the Friday lunches and her quotes on her board put research into perspective. I will miss those conversations. Throughout my time at Virginia Tech, she helped me understand the research process and the various tools available to a researcher. I am or will become a better researcher because of her.

I thank Dr. Brian M. Kleiner for helping ensure I understood the relationship between my research and management systems engineering, more accepted research methods, and the organizational world research is intended to help improve. He asked the right questions to push me to make my assumptions and connections to management systems engineering explicit. I thank Dr. Jeff Woldstad for his helping me focus the methodology. His input during the pre-proposal and proposal meeting helped move the dissertation to a much more explicitly defined direction. I can't overstate his contribution.

As part of my graduate school experience, I was employed at MSL. There are many people I became friends with from MSL who have helped me develop. I thank Tom Carolyn and Jim Hughes for our impromptu research discussions, which allowed me to think aloud. I thank Will Guerrero for recognizing that graduate students are professionals who can make significant contributions. His concern for people was a

who endured our first years of marriage being in graduate school. Her support throughout the journey made the trip more enjoyable. I thank her for reminding me why I went to graduate school and to take the jump into academic life. With her by my side, I was able to succeed. Thank you.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.   SCOPE OF MY RESEARCH

In this chapter, I define the scope of my research.

I take nine different views to define the scope of my research. The first view is the problem statement, which describes what problem this research is attempting to solve (Leedy, 1989). The second view is the research question motivating this research. The third view is the operationalized research question. The operationalized research question puts the research question in practical terms. The conceptual model is the fourth view. The conceptual model is a picture of how the conceptual elements of the research problem fit together or affect each other. My conceptual model is constructed from and reinforced through the review of the body of knowledge contained in Chapter 2. The fifth view is the delimitations on the scope of the research. The delimitations identify what the problem is not and are limits imposed on the study. The sixth view is the research purpose, which describes why I'm doing this research project. The seventh view is the research objective, which defines the outcome or what can be learned from this research. The eighth view is the research hypothesis. Sub-problems and outputs are the ninth view. Sub-problems are components of the research that partition the problem and conceptual model into a closed set of pieces. Outputs are the tangible results of the research, which relate one-to-one to the sub-problems. I use the sub-problems and outputs to segment the problem statement and therefore the body of knowledge. In addition to the nine views, I describe the contributions of the research and the process I used to develop the research. Finally, I define the terms relevant to this research.

Premises are discussed in Chapter 2. I develop from the body of knowledge four premises to serve as the foundation to the body of knowledge review. I offer the premises as propositions or facts to define, support, or put boundaries around the problem statement.

1.1.	**PROBLEM STATEMENT**

In this research, I'll operationalize a lessons-learned sharing process for supporting organizational learning. I'll validate the process by measuring and evaluating the effects of the process on decision-making (i.e., management) performance.

By operationalize I mean to translate the theoretical concepts of organizational learning into a lessons-learned sharing process that I can investigate and validate. A process is valid if the process is "able to effect or accomplish what is designed or intended" (Webster, 1981), that is, is able to achieve the outcomes. The outcomes of organizational learning are enhanced organizational knowledge; management performance (problem solving or decision making, consistent interpretation, and reduced uncertainty); task performance (organizational actions and performance); and organizational survival. I'll focus on the effects on decision-making performance.

One problem in organizational learning is the sharing or transfer[1] (storage, retrieval, and interpretation) of information and knowledge from one problem-solving or learning experience to another; i.e., sharing lessons learned. A lesson learned is "a catchall phrase describing what has been learned from experience" (Juran, 1988, p. 306). A lesson learned contains a description of the goals, conditions, steps to accomplish the goal, results of the steps, and an explanation of what worked and didn't work and why (Anderson, 1993; Argyris & Schon, 1978; Duncan & Weiss, 1979; Juran, 1988).

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[1] I view the concepts of sharing and transferring to be closely related, with sharing being broader than transferring. To share is "to participate in, use, or experience in common" (American Heritage Dictionary, 1985, p. 1127), whereas to transfer is "to convey or shift from one person or place to another" (American Heritage Dictionary, 1985, p. 1286). To transfer has the connotation of physically moving an object from one place to another as in moving dollars from a checking to savings account when we transfer money. Some authors use the term transfer. I view other authors' use of the term transfer to be in agreement with my use of the term sharing. For example, when the authors speak of transferring knowledge from one individual to another they don't mean for the knowledge from the first person to be missing after the transfer.

This research proposes a lessons-learned sharing process (within the context of the data-to-information chain and management system model to be described shortly) to be central to sharing lessons. A lessons-learned sharing process acquires data through measurement, updates organizational memory, and distributes lessons learned to a decision maker. The aim of the process is to support organizational learning.

Organizational learning is a process of storage, retrieval (distribution), and interpretation of information and knowledge developed by individuals or groups of individuals in an organization as a result of problem solving (Huber, 1991; Duncan & Weiss, 1979; Simon, 1991; Fiol & Lyles, 1985). The problem in organizational learning is making the information and knowledge gained through experience readily available to problem solvers or decision makers (Juran, 1988). (Note: I use the term decision maker and problem solver interchangeably to mean the same thing. Problem solving is making a series of connected decisions to resolve a problem.) We want to have the capability "to map the experience of the past into actions appropriate to [the current situation]" (Cohen & Sproull, 1991, p. i). Organizational learning includes the updating of organizational memory. We update organizational memory with the purpose of improving management (i.e., decision making), which in turn improves performance (i.e., the work processes and thereby the products and services of the organization).

1.2. RESEARCH QUESTION

What is the effect of a lessons-learned sharing process on decision-making performance?

The effects I'll measure and evaluate are related to the outcomes of organizational learning, e.g., management or decision-making performance. Two related sub-questions are:

1. How do I measure organizational learning? and
2. What are the design characteristics for a lessons-learned sharing process?

I developed the above research question by first asking the broad research question: What is the relationship between management tools and organizational learning? I further refined this question based on an understanding of organizational learning and management tools. A lessons-learned sharing process uses management tools, or data-to-information converters. By addressing the research question, I'm beginning to define the relevant dimensions of the data and information components of organizational learning that Daft and Huber (1987) identified as a research need.

1.3. OPERATIONALIZED RESEARCH QUESTION

When a manager is solving a new problem, what effect does the information from a formal data-to-information process for sharing lessons-learned have on the manager's decisions and actions?

To improve organizational performance, we must improve the problem-solving actions of the individuals. We can use elements of prior solutions to current problems as a way of enhancing organizational performance (Levinthal, 1991). Organizations should capture lessons learned to help people solve problems in the future and not repeat the mistakes of the past. "Unless the implications of experience can be transferred from those who experienced it to those who did not, the lessons of history are likely to be lost through turnover of personnel" (Levitt & March, 1988, p. 328). Simon (1991) discusses the importance of capturing the organization's experience and knowledge: "It is usually important to specify where in the organization particular knowledge is stored, or who has

4

learned it. Depending on its actual locus, knowledge may or may not be available at the decision points where it would be relevant" (p. 126). A knowledge-sharing process would enable knowledge gained by organizational members to be "transmitted to others or stored in ways that will permit it to be recovered when relevant" (Simon, 1991, p. 126).

Nutt (1993) in his analysis of 168 decision cases found subjects use three tactics 82% of the time in the design stage of decision making. The three tactics are idea, template, and cyclical search. In using the idea tactic, the decision maker uses pre-existing ideas. The decision maker uses the template tactic by exporting and adapting the practices of other individuals and organizations. In cyclical search, the decision maker redefines his or her needs based on what was learned from earlier proposals. I view these tactics as the sharing of lessons learned because each tactic uses knowledge gained through past experience to help solve the current problem.

This research focuses on improving the process of using lessons learned from our experiences. Examples of sharing lessons learned and other organizational learning methods are: sharing the lessons of a quality improvement method at one organizational unit to another unit (e.g., Radford Community Hospital and Carilion Health System); complying with regulations for different sites with similar conditions throughout a government complex; technology transfer between industries and sites (e.g., Technology Information Exchange workshops); benchmarking activities; and success and failure in engineering design (e.g., Petroski, 1992). I was involved with Radford Community Hospital in the planning stages of a re-engineering effort. The senior managers were concerned about how to share what was learned in their efforts to other hospitals in the Carilion Health System. I discuss the Technology Information Exchange workshops in the body of knowledge review.

Petroski (1992, p. 210) quotes Barry LePatner, who was testifying to the Congressional House Investigations and Oversight Committee of the House Science and Technology Committee, on the use of knowledge about lessons learned:

> Good judgment is usually the result of experience. And experience is frequently the result of bad judgment. But to learn from experience of others requires those who have the experience to share the knowledge with those who follow.

In an interview with Meen and Keough (1992, p. 72), Senge supports the idea of capturing and using lessons learned: "With a body of public knowledge, the lessons of the past become part of a 'living library' that can be continually expanded, refined, and if need be, thrown out altogether to fit a changing world. It is this continual process of building the knowledge base of an organization that will, I believe, eventually be seen as the central task of management in a learning organization."

"...learning builds on past knowledge and experience—that is on memory. Organizational memory depends on institutional mechanism (e.g., policies, strategies, and explicit models) used to retain knowledge" (Stata, 1989, p. 64).

Capturing lessons learned is one "mechanism not only to converge on a shared model, but also to communicate to younger, less experienced managers the organization's stored experience and knowledge" (Stata, 1989, p. 67).

Juran defines three merits to using lessons learned in quality planning efforts:

> "[Lessons-learned] make available to any user the collective experience and memories of numerous individuals, organized in ways that permit ready retrieval.
>
> [Lessons-learned] are of a repetitive nature. They can be used over and over again for an indefinite number of planning cycles.
>
> [Lessons-learned] are impersonal. They avoid the problems created when one person gives orders to another person" (1988, p. 307).

I'm studying a lessons-learned sharing process in which management tools can be used. By studying the process, I can gain an understanding of the management tools needed to support the process. That is, I will have addressed the call for management tools to support organizational learning: "the challenge, then, is to discover new management tools and methods to accelerate organizational learning" (Stata, 1989, p. 64). I'm looking at the process in which the management tools will be used.

1.4.	**CONCEPTUAL MODEL**

The three figures I use to represent the conceptual model for this research consider the sharing of lessons learned between domains of responsibility viewed as (1) PDSA cycles, (2) management systems, and (3) problem-solving or learning experiences.

I use three figures to emphasize different concepts of a lessons-learned sharing process. The first figure emphasizes the production of a lesson learned. The second figure emphasizes the concept of sharing a produced lesson learned between management domains through a process using management tools. The third figure integrates the second figure, or management domain model, into the theoretical work on organizational learning.

Figure 1, the first conceptual model, shows two plan-do-study-act cycles (PDSA) connected through a lessons-learned sharing process. The sharing process shares lessons learned from one cycle's study step to the other cycle's plan step. Each cycle can represent a work shift or a project, with the shift or project beginning in the plan step.
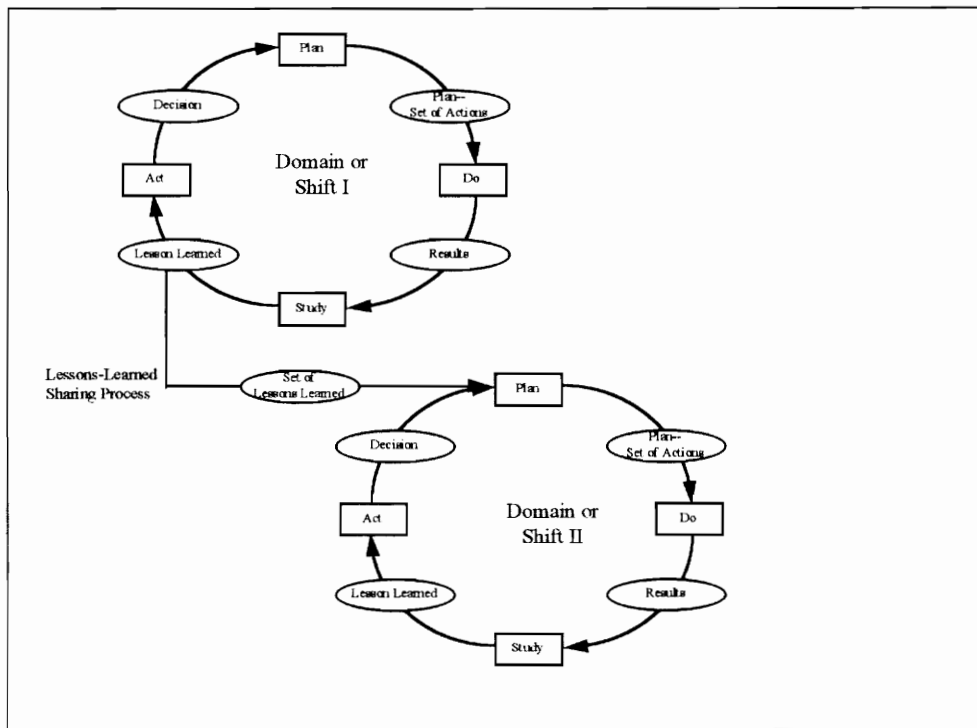
Figure 1. Conceptual model of a lessons-learned sharing process between PDSA cycles.

Figure 2, the second conceptual model, shows a lesson learned being shared between management domains (i.e., domains A and B in Figure 2). A management domain is considered to be a system and is represented using the management system model (MSM). The MSM contains three components and three interfaces. A "who manages" component acts on the "what is managed" component (i.e., task in Figure 2) through the "decision to action" interface. The "measurement to data" interface collects data from the "what is managed" component. The "what is used to manage" component (i.e., organizational memory in Figure 2) uses the data to produce and portray information. The portrayed information is perceived by the "who manages" component to make decisions. "Information portrayal to perception" is the third interface. The "what is used to manage" component includes management tools, which embody the data-to-information chain.

8

I use the notation {management domain, cycle} to distinguish the components and interfaces of the two different domains and cycles. To illustrate the concept of Figure 2, I'll walk through two cycles. The first cycle begins with a decision and ends with the update of organizational memory. The first "who manages" {A} during the first cycle {c1} makes a decision {A, c1} that leads to an action {A, c1} on a task {A, c1} all within the first cycle {c1}. Measurement {A, c1} on the task performance produces data {A, c1}. The second cycle {c2} begins with the updating of organizational memory. Organizational memory is updated with a lesson learned.

The contents of organizational memory at the beginning of cycle {c2} are shared between management domains {A} and {B}. The information portrayal of both domains {A} and {B} at the beginning of the second cycle {c2} is a set of lessons learned in domain {A} to be shared with domain {B} and, therefore, is the same for each domain. The second cycle begins when the second "who manages" {B} uses this information {B, c2} to make a decision {B, c2} leading to an action {B, c2}. The action on task {B, t2} produces a lesson learned through measurement and data. Organizational memory is updated to represent its new state at the beginning of the third cycle {c3}.
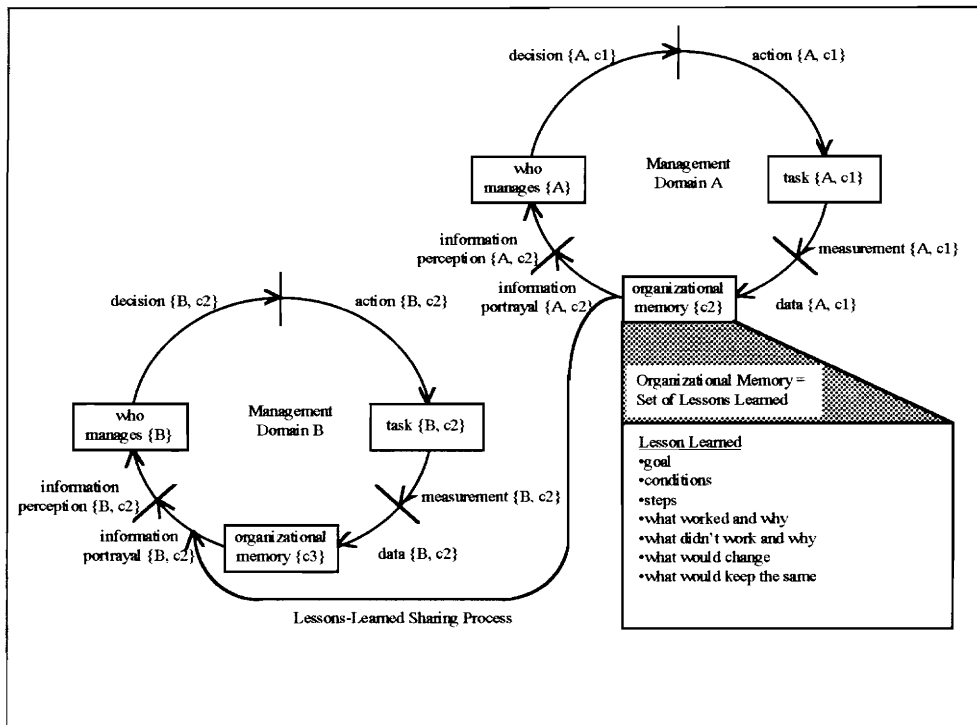
Figure 2. Conceptual model of a lessons-learned sharing process between management domains.

Figure 3 is the third conceptual model of this research. I use this model to integrate the two previous models with the organizational learning concepts. This third model illustrates the organizational learning process and the data-to-information chain representation of the management system model. The data-to-information chain representation of the MSM emphasizes the "what is used to manage" component. The chain converts data from a source into information for a decision maker to make a decision to affect an object of the operation. The data-to-information chain and MSM is repeated throughout the organizational learning process. Both the MSM and the organizational learning process are cycles. One cycle is illustrated as a sine wave type cycle (learning process) and the other cycle typically illustrated as a closed loop cycle (MSM).

The four functions of organizational learning, as I define organizational learning, are shown as (1) problem-solving or learning experience, (2) storage and refinement, (3)

10

retrieval, and (4) interpretation (Huber, 1991; Duncan & Weiss, 1979; Simon, 1991; Fiol & Lyles, 1985). In Figure 3, I include the retrieval and interpretation functions in a single box because these are carried out by the "who manages" component. I add a box for organizational memory, a key component of organizational learning. One repetition on the learning process overlays one loop from "what is managed" to "what is managed" of the MSM. The decision maker, or "who manages," performs the retrieval and interpretation functions of organizational learning. The decision maker retrieves and interprets lessons learned to support a problem-solving experience. Measurement on one problem-solving experience produces data. The lessons are collected and stored in memory. The lessons-learned sharing process for this research performs the organizational learning functions of storage, refinement, and retrieval to support a problem solver in interpreting and applying a lesson learned to a problem-solving experience. The chain converts data into information to be used in another problem-solving experience.
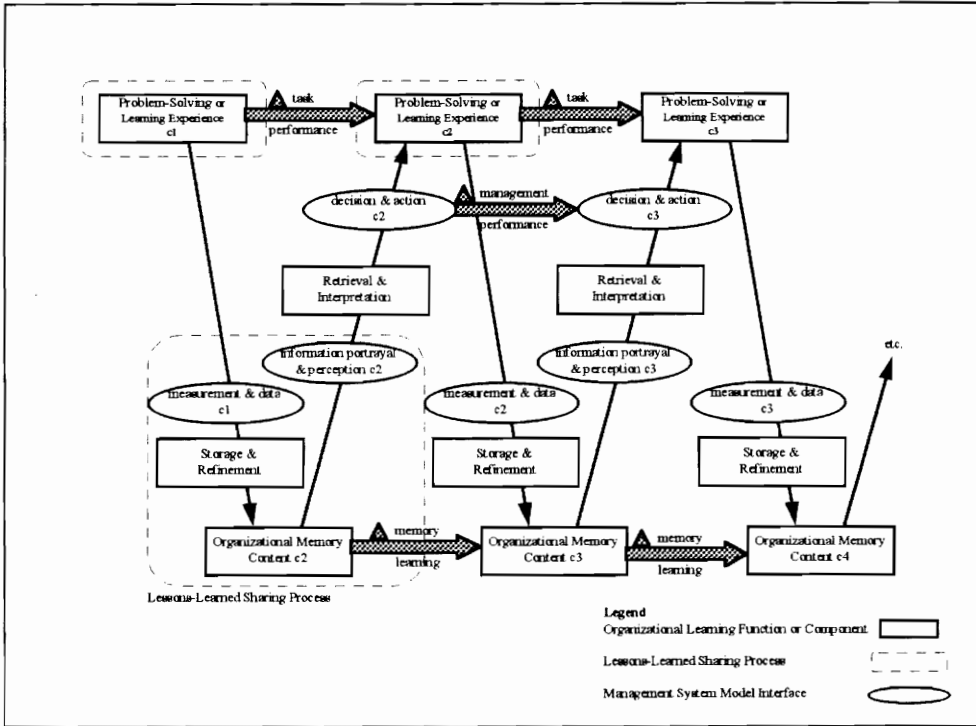
Figure 3. Conceptual model of a lessons-learned sharing process to support organizational learning.

1.5.	**RESEARCH DELIMITATIONS**

I'm focusing on the effect of the lessons-learned sharing process on organizational learning.

1. I delimit the focus of this research on the effect of the lessons-learned sharing process on organizational learning. I will not develop a tool or test an existing one.

2. I define the lessons-learned sharing process as: (1) collecting a lesson learned from a problem-solving experience, (2) storing the lesson with other lessons, and (3) making the lessons available to a subsequent problem solver or decision maker.

3. I'm not studying the cognitive development of organizational members. I'm studying a lessons-learned sharing process to communicate or share lessons learned.

4. I'm focusing on explicit knowledge, or knowledge that can be easily communicated between individuals. I'm not focusing on tacit knowledge.

1.6.	**RESEARCH PURPOSE**

The purpose of the research is to demonstrate how a lessons-learned sharing process is useful to improving decision-making performance through the use of lessons learned. The use of lessons learned supports the decision maker in making better decisions, i.e., management performance.

The goal of a lessons-learned process is to increase organizational learning by sharing lessons learned from one problem-solving experience to another. An organizational member needs to learn from the experience of other members. In this research, I focus on a formal sharing process or "the mechanisms by which learning is perpetuated and institutionalized in organizations" (Shrivastava, 1983, p. 7). I will evaluate the process's ability to allow an organizational member to use past knowledge and experience.

13

1.7.	**RESEARCH OBJECTIVE**

The objective of this research is to provide tangible evidence of the effects of a lessons-learned sharing process to support organizational learning.

Juran (1988) identifies the lack of a quantifiable return on investment for a lessons-learned system as an obstacle to developing lessons learned. One assumption of total quality management (TQM) is that lessons learned help improve performance. Juran (1988) discusses lessons learned as a major planning tool. Deming (1986) emphasizes the need for a theory to record and learn from history or experience. The theory I use is the organizational learning theory. In this research, I will provide evidence that will either support or fail to support this assumption.

1.8.	**RESEARCH HYPOTHESIS**

Related to the research question is the research hypothesis: a lessons-learned sharing process will support the aim of organizational learning or improving management performance through knowledge based on experience.

This research hypothesis is not a null hypothesis tested with statistics. This hypothesis focuses on the research problem and provides the direction to the experiment and testable hypotheses (Leedy, 1989).

1.9.	SUB-PROBLEMS AND OUTPUTS

I divide the research and the conceptual model into a closed set of sub-problems. By solving these sub-problems I solve the research problem. The outputs are the tangible results relating one-to-one to the sub-problems.

In the body of knowledge I review the parts of the conceptual model. The following sub-problems partition my conceptual model:

1. Understand organizational learning.
2. Understand data-to-information chains.
3. Understand the relationship between data-to-information chains and organizational learning.

The following are the outputs of the sub-problems:

1. A conceptual framework of organizational learning.
2. A conceptual framework of data-to-information chains.
3. A conceptual framework, theory, and empirical evidence of a data-to-information chain as a sharing mechanism to support organizational learning.

1.10.	THE CONTRIBUTION OF THE RESEARCH

This research contributes to the body of knowledge on organizational learning and management tools. Both organizational learning and management tools are critical to understanding the management system model (MSM) and to accomplishing total quality management (TQM).

The contribution of this research is to develop "research-based guidelines for increasing the effectiveness of organizational learning" (Huber, 1991, p. 108). I will do this through the study of the data-to-information components of a lessons-learned sharing process. I will attempt to answer Daft and Huber's (1987) question: "How do organizations acquire and handle a large volume of data when it is needed for learning to take place?"

I make three contributions by doing this research:

1.   Define organizational learning using the systems approach.

2.   Define the data and information parameters to support organizational learning. This contribution is made by integrating the individual learning theory into organizational learning. Using the empirically tested model of individual learning (Anderson, 1993), the depth to the theory of information processing for organizational learning is increased.

3.   Design, develop, demonstrate, and evaluate a data-to-information process to support organizational learning.

1.10.1. This Research and MSE

This research contributes to management systems engineering (MSE) in the conceptual and methodological domains of MSE; that is, in both the content studied (i.e., data-to-information chain and organizational learning) and the process used to study the content (i.e., engineering process under the purview of the systems approach).

This research's conceptual domains are management systems engineering and organizational learning[2]. The methodological domains for this research can be thought of as the engineering process and systems approach. The explicit contributions this research makes to MSE are:

1. Demonstrating the philosophy of MSE by employing the engineering process and systems approach to study, understand, and improve management systems. I use the systems approach in describing organizational learning. The holistic perspective is used in describing the aim of organizational learning. (See section 2.2.2. of this document.) The systems perspective is used in describing the components and processes of organizational learning as they relate to the aim. (See section 2.2.5., 2.2.6., and 2.2.7.) The generalist perspective is used in using the individual model of learning to provide further refinement of the information components for organizational learning. (See sections 2.2.3, 2.4.3., 2.4.3.1., 2.4.3.2., 2.4.3.3., 2.4.3.4., 2.4.3.5., and 2.4.3.6.)

2. Studying data-to-information chains or management tools within the context of organizational learning.

3. Providing a conceptual model for management tools that facilitates the closing of process loops.

4. Providing a conceptual framework for the storage of knowledge related to the knowledge needed for MSE in the future.

5. Operationalizing the concept of the generalist perspective in a data-to-information process.

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[2] Brinberg and McGrath (1985) define three domains of research: 1) substantive domain: the real-world system or "some content that is of interest"; 2) conceptual domain: the ideas and concepts we use to give meaning and understanding to the real-world system or "some ideas that give meaning to that content"; and 3) methodological domain: the tools we use to collect the data about the real-world system or "some techniques or procedures by means of which those ideas and content can be studied."

17

I will show how the above five contributions support MSE by providing direct quotes from Kurstedt (1993) that describe management systems engineering and explaining how my research addresses the quoted issues. The quotes represent my interpretation of the essence of MSE.

> "Management systems engineering is a structured systems approach, based on engineering principles, to building and using means to help organizations improve their performance." (Kurstedt, 1993, p. 52)

> "For management systems engineers, the objective of all this is to use the engineering process with its functions to get tools to provide the right information to managers for making decisions within their management process with its functions so their management system, or domain of responsibility, will meet its aim." (Kurstedt, 1993, p. 152)

This research contributes to MSE by applying the engineering process under the purview of the systems approach to organizational learning and management tools. Engineering process and systems approach tools such as input/output analysis and flowcharts are used to describe and understand the relationship between organizational learning and management tools. The research focuses on the management tool characteristics to improve organizational decision making, problem solving, and performance through organizational learning; i.e., improve the management process through the use of lessons learned. (Contribution #1)

> "Management tools convert data to information. For management tool design to move from an art to a science, we need a detailed understanding of data, information, and the conversion process for making information from data." (Kurstedt, 1993, p. 156)

> "If the aim of the system was learning or improvement, we'd want to focus on observation to gain data to convert into information to support decision making. Through our decisions, we'd feed back what we learned to the process. And through our conversion of data to information, we'd feed back to the decision maker what the process was doing. Decision making is the key function in the management process." (Kurstedt, 1993, p. 3 of 0.0)

I'm studying the data and information concepts necessary for management tools to support organizational learning. (Contributions #2 and #3)

> "To manage today's uncertain, rapidly-changing organizations, we must evolve the science of building effective tools and the art (skill) for applying them." (Kurstedt, 1993, p. 98)

> "I'm most interested in the effects of changing a management tool or adding a new one." (Kurstedt, 1993, p. 186)

I'm focusing on the characteristics of a management tool to support this effort. That is, a management tool that can be used to acquire, store, and retrieve knowledge we gain about the performance of management tools in a given context. (Contributions #4 and #5)

> "We never closed the cycle. We never took full advantage of how to learn the lessons of our practices and how to use what we learned to do better next time." (Kurstedt, 1993, p. 40-41)

> "When we act on the organization, we change its performance and we should monitor that change and feedback what we've learned to improve our interventions." (Kurstedt, 1993, p. 64)

> "Closed-loop processes promote continuous improvement and organizational learning." (Kurstedt, 1993, p. 3 of 0.0)

> "Knowledge of lessons of the past." (Kurstedt, 1993, p. 84)

This research studies the effect on closing process loops with management tools on the decision making or management process. (Contribution #3)

> "Can he or she logically construct an approach to a problem founded on basic principles stemming from the laws of nature in addition to transferring the experience of solving a similar problem to the problem at hand?" (Kurstedt, 1993, p. 86)

> "The [engineering] process also includes the implementation step to study the results of our design and the follow-up step to use the lessons learned from our study to do better analysis and design." (Kurstedt, 1993, p. 93)

"The generalist perspective emphasizes consistency among the systems and the transferability of lessons learned from one to the other." (Kurstedt, 1993, p. 145)

"If our analogies are solid, we can transfer back the engineering solutions to contribute to management solutions." (Kurstedt, 1993, p. 248)

This research focuses on a management tool that provides a mechanism to share lessons learned from one problem to another. (Contribution #5)

1.11. OVERALL RESEARCH PLAN

I used a process to identify the need for this research.

Figure 4 is the flow-chart representation of the process I used to develop the content issues for this research. This process reflects the research question and the sub-problems and outputs of the conceptual model.
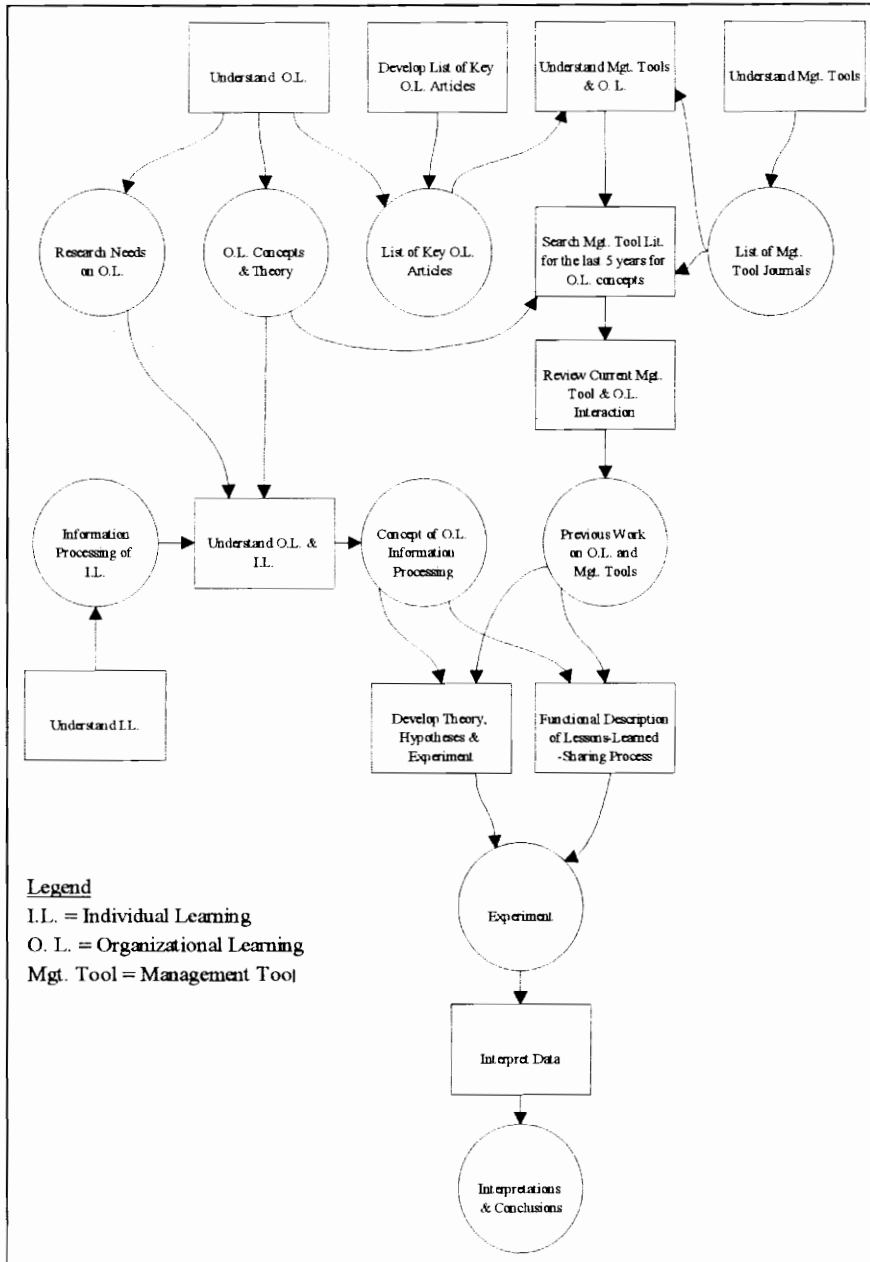
Figure 4. Overall research process.

1.12. DEFINITION OF TERMS

I define the relevant terms of this research.

data-to-information chain: "acquires, stores, retrieves, and manipulates data to compare to reference points (biases) to makes and display information" (Kurstedt, 1993, p. 878).

datum: a specific fact plus meaning (Appleton, 1986).

information: datum or reference compared to a reference (Berube, 1990).

knowledge: more than one piece of information in a pattern from which explicit inferences and predictions can be made; knowledge is represented using if <conditions> then <action> rules.

lesson learned: "a catchall phrase describing what has been learned from experience" (Juran, 1988, p. 306).

lessons-learned sharing process: stores and retrieves lessons learned to support problem-solving and decision-making activities.

management tool: converts data to information to support decision making (Kurstedt, 1993).

organizational knowledge creation: "a process that 'organizationally' amplifies the knowledge created by individuals, and crystallizes it as a part of the knowledge network of the organization" (Nonaka, 1994, p. 17).

organizational learning: a process of storage, retrieval (distribution), and interpretation of information and knowledge developed by individuals or groups of individuals in an

22

organization as a result of problem solving (Huber, 1991; Duncan & Weiss, 1979; Simon, 1991; Fiol & Lyles, 1985).

organizational memory: "stored information from an organization's history that can be brought to bear on present decisions" (Walsh & Ungson, 1991, p. 61).

share: "to participate in, use, or experience in common" (American Heritage Dictionary, 1985, p. 1127).

transfer: "to convey or shift from one person or place to another" (American Heritage Dictionary, 1985, p. 1286).

2.   BODY OF KNOWLEDGE REVIEW

The lessons-learned sharing process I design and evaluate is based on the functions of organizational learning, the functions of the individual model of learning, and the concepts defined in the management tool literature.

This section serves as an introduction to the remaining sections of the body of knowledge review. I use the systems approach as defined by Kurstedt (1993) and a process view in describing the relevant literature. In describing organizational learning, authors focus on different parts of the system; e.g., the aim or components. By using the systems approach and process view we gain an understanding of how these many views are related and complement each other.

The focus of this research is on a formal lessons-learned sharing process (i.e., management tool) for sharing lessons learned. When building management tools we can follow the management systems analysis (MSA) process as defined by Kurstedt (1993). The goal of MSA is "building and using the right tool for the right application" (Kurstedt, 1993, p. 231). MSA has five steps: 1) delimit the domain of responsibility and understand the nature of the work; 2) determine the decision-action pairs; 3) determine the information needed to support the decisions; 4) deduce the data needed to make the necessary information; and 5) determine the indicators needed for the data.

The domain of responsibility for this research is the organizational learning process. I reviewed the body of knowledge on organizational learning because organizational learning is part of the conceptual domain I'm using to improve the substantive domain of organizations (Brinberg & McGrath, 1985). From this review of organizational learning, the concepts, theories, and research needs are identified. The concepts, theories, and research needs are used as the context for the development of the other sub-problem topics. Problem solving is also reviewed in the premises section because problem solving is what organizational learning aims to improve.

24

I review work on lessons-learned sharing processes by using the management tool literature because I define the lessons-learned sharing process through the eyes of the MSM and the data-to-information chain, which is embodied in management tools. I view the lessons-learned sharing process as a "what is used to manage" component of the MSM. The lessons-learned sharing process converts data to information to support decision making through organizational learning. Therefore, when I use the term management tool for organizational learning to mean the "what is used to manage" component I'm referring to a lessons-learned sharing process.

Next, I review the research on management tools or lessons-learned sharing processes as it relates to organizational learning because the relationship between organizational learning and management tools is the conceptual domain I'm using to improve the substantive domain of organizational performance.

Finally, I integrate the body of knowledge into my conceptual model presented in Chapter 1. This conceptual model serves as the graphical representation of the relationship between management tools and organizational learning. The integration and conceptual model leads to a functional description and design of a lessons-learned management tool or lessons-learned sharing process.

Figure 5 shows the relationship of the bodies of knowledge I reviewed.
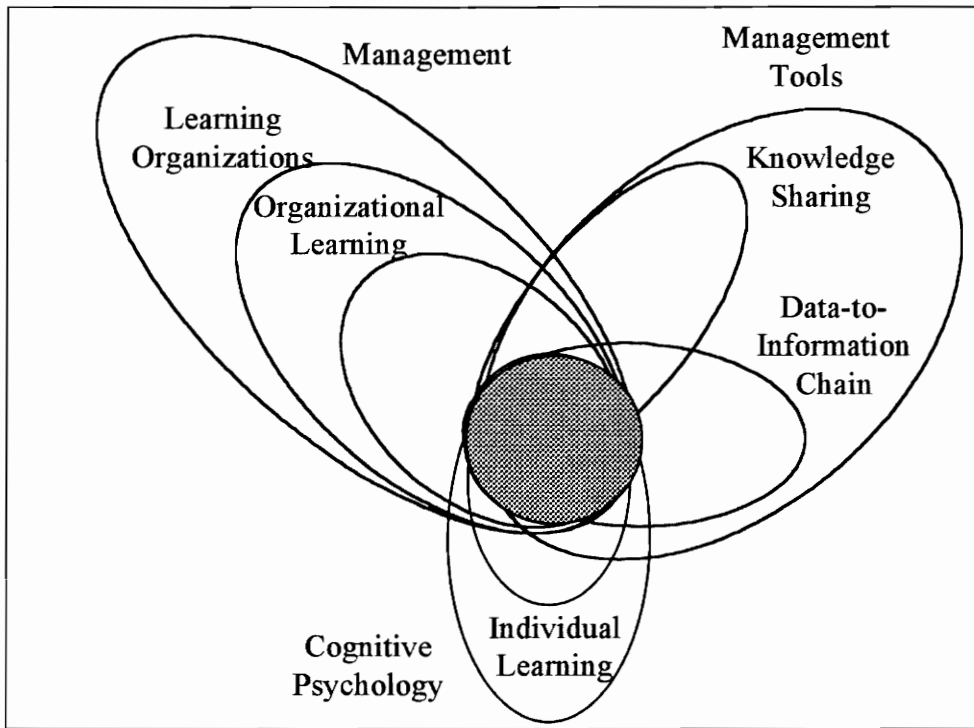
Figure 5. Bodies of knowledge I reviewed.

2.1.   PREMISES USED IN THIS RESEARCH

Premises are offered as fact to define, support, or put boundaries around the problem statement. I make four premises in conducting the research.

I make four premises in this research. I use the premises as the basis for moving forward, that is, I do not test the premises. Rather, I use the body of knowledge to substantiate these assumptions. The four premises describe (1) problem solving as a view of organizational actions, (2) organizational processes as action-outcome relationships, (3) organizational performance as a function of the performance associated with the use of an action-outcome relationship, and (4) organizational learning acts on (i.e., creates and refines) action-outcome relationships through problem-solving activities.

2.1.1. Premise #1: Problem Solving View of Organizational Action.

I take a problem solving view of organizational action (Simon, 1960).
I use problem solving as the foundation to build from. That is, problem solving is viewed as the fundamental activity from which all organizational actions can be viewed. Solving problems is a part of life. How people solve problems, the problem-solving process, must be understood before aids to problem solving can be constructed. The Newell and Simon (1972) information processing model of problem solving provides a model to define this process.

According to this model, problem solving has two stages: (1) a representation stage and (2) a solution stage. In the representation stage, the problem solver interprets the problem, develops a problem representation, and develops a problem space. In the solution stage, the problem solver uses an evaluation function to move through the problem space to a solution. When solving a problem, a person is first presented with a task under a given set of circumstances representing the problem statement. The problem solver interprets the problem statement to construct a problem representation and from this the problem space. The problem representation contains the initial states and goal of the task. The problem space includes the initial states, goal and subgoals, possible intermediate states, operators which move the problem solver from state to state, and constraints on the problem.

In the solution stage, the problem solver moves through the problem space evaluating each state-to-state move and identifying operators to perform the movement. An evaluation function determines which move from state to state should be taken to lead to the goal (Simon, 1975). This choice is based upon the knowledge available at the time of decision.

Problem solving can be divided into the content and the process which acts on the content. The content is the problem space represented as production rules and a database of facts. A production rule takes the form of: If <conditions> then <action> (Kieras & Polson, 1985). The <action> is performed after the <conditions> are met. The database is a set of facts relevant to the problem.

The problem solving process is a production system process by which inferences are made by comparing the production rules and database (Simon, 1975). The process involves comparing the production rules to the database to see if the conditions of a production are satisfied. If a production's conditions are satisfied then it is fired, the <action> is performed. If more than one production's conditions are satisfied, then a conflict resolution function is used to choose the appropriate production to fire. An inference is made when a rule is fired, and this firing adds facts to the database. This cycle is repeated until the problem is solved or no more inferences can be made.

2.1.2.   Premise #2: Organizational Processes are Action-Outcome Relationships.

An organization converts inputs to outputs using transformation processes. These transformation processes are action-outcome relationships (Duncan & Weiss, 1979).

Action-outcome relationships (AORs) are the organization's theories-of-action (Argyris & Schon, 1978). An AOR or theory-of-action describes the action to take in a situation as defined by assumptions, conditions, and a goal or desired outcome. Argyris and Schon (1978) define organizational maps as the shared or public representations of the AORs and "are the actual patterns of activity [which are] guides to future actions" (p. 17).

AORs are the structure used to describe organizational actions in response to environmental conditions and goals. The composition of an AOR is a collection of other AORs and each can be thought of as an organizational routine (Levitt & March, 1988). AORs are the means to which inputs are converted to outputs and are stored in organizational memory. We can model an AOR using the production rule representation, i.e., if <condition> then <action> pair. Figure 6 is a generic production rule for an AOR.

```
IF      <GOAL = _____>
        <CONDITION ATTRIBUTE = VALUE>

        ...
        <CONDITION ATTRIBUTE = VALUE>
THEN
        <ACTION _____>

        ...
        <ACTION _____>
WITH
        <OUTCOME ATTRIBUTE = VALUE>

        ...
        <OUTCOME ATTRIBUTE = VALUE>
```
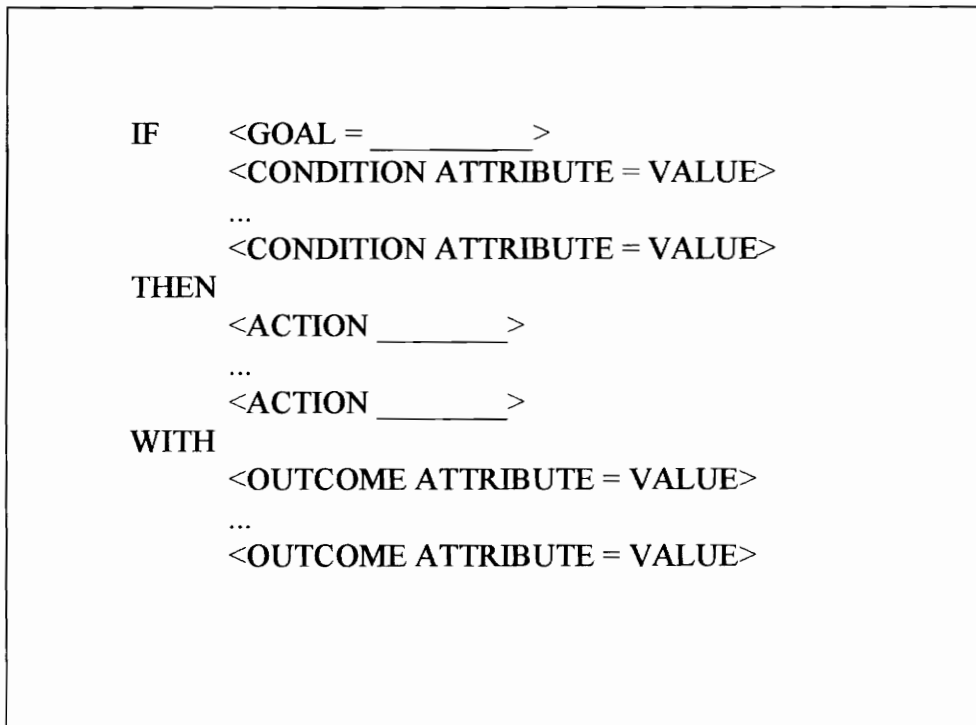
Figure 6. A graphical representation of an action-outcome relationship as a production rule.

2.1.3. Premise #3: Organizational Performance is a Function of the AOR Performance.

Organizational performance is a function of the performance of the transformational processes or the AORs used in response to conditions and goals.

Duncan and Weiss (1979) define three components of organizational effectiveness as related to AORs: 1) AORs achievement of intended goals, 2) specifying changes in AORs needed to respond to changes in environmental conditions which affect the AOR, and 3) AORs are consistent across the organization.

The effectiveness of an action is based on the ability of the decision maker to determine the expected results of the action under the current set of conditions. To use an AOR, knowledge about the AOR must be available to use in the selection and execution of the best AOR to match the conditions of the environment and the execution of the steps. This knowledge is stored in the organization's memory or knowledge base. Therefore, organizational performance is a function of the quality of the organizational knowledge base (Shrivastava, 1983). Knowledge about an AOR must describe the relationship between specific conditions and actions and the expected consequences; the conditions under which a specific action will lead to a consequence; and specify how a change in a condition affects an AOR (Duncan & Weiss, 1979).

"The organization will be limited in its effectiveness to the degree that a decision maker can make use of such knowledge to specify organizational actions which do indeed lead to intended outcomes, and to specify the outcomes needed to lead to more general objectives of the organization. It is our contention that such knowledge is the underlying basis for organizational action and by extension, organizational effectiveness" (Duncan & Weiss, 1979, p. 82).

32

2.1.4.	Premise #4: Organizational Learning Acts on AORs.

> **I take a problem solving and information processing view of organizational learning, therefore, organizational learning is a process by which organizational members improve their problem solving and AORs are the knowledge holders for problem solving.**

From the preceding three premises, the following premise is made in connection to organizational learning:

> organizational learning acts on (creates and refines) action-outcome relationships through problem-solving activities.

AORs are refined by organizational learning. Organizational learning aims to improve AORs. Levitt and March (1988) describe how AORs change as a result of experience based on the interpretation of the actual outcomes or consequences as compared to expected outcomes described by the AOR. The AORs encode what has been learned in the past (Weick, 1991).

2.2.	**WHAT IS ORGANIZATIONAL LEARNING?**

Organizational learning is a process of storage, retrieval (distribution), and interpretation of information and knowledge developed by individuals or groups of individuals in an organization as a result of problem solving (Huber, 1991; Duncan & Weiss, 1979; Simon, 1991; Fiol & Lyles, 1985).

I integrated the works of previous researchers to define the process, aim, and components of organizational learning. The various definitions from which the above definition was derived are given in Table 1. The rest of the body of knowledge review is based on the above definition of organizational learning, that is, the remaining discussion is in the context of organizational learning as sharing data, information, and knowledge about AORs. I use a systems or process view to describe organizational learning. A system exists in an environment and has processes which convert inputs into outputs to stakeholders who receive an outcome from the output. The logic of the organizational learning body of knowledge is influenced by the systems approach of Kurstedt (1993).

Organizational learning is "the process of improving actions through better knowledge and understanding" (Fiol & Lyles, 1985, p. 803). Organizational learning involves creating knowledge from past problem-solving experiences, storing the created knowledge, and retrieving knowledge to solve new problems. Learning occurs when an organization's member detects a deviation from expected results or confirms the actions produced expected results. An explanation for a deviation is sought and incorporated into the organization's theory-in-use. An organization's theory-in-use is the implicit or explicit collective rules guiding the decisions and actions of the organization's individuals or members. These rules describe the action to perform in a given situation under given assumptions to achieve a defined consequence (Argyris & Schon, 1978) and be described by AORs (Duncan & Weiss, 1979).

Both the creation of knowledge and capture of the knowledge in organizational memory is required for organizational learning, that is, if member of the organization learns but doesn't incorporate the new knowledge in the organization's memory, then organizational learning has not occurred (Argyris & Schon, 1978). In essence, a corporate knowledge base is being created through the organizational-learning process. This knowledge base can be used to further aid the organization in solving similar problems as those contained in the knowledge base. This corporate knowledge base or as Senge calls the " 'living library'...can be continually expanded, refined, and if need be, thrown out altogether to fit a changing world" (Meen & Keough, 1992, p. 72).

The aim of organizational learning is to improve organizational actions and performance through knowledge about AORs based on experience. The components of organizational learning are the information and knowledge about AORs, organizational memory, and the organizational learning functions. The functions are problem-solving or learning experience, storage, retrieval (distribution), and interpretation.

Table 1
Definitions of Organizational Learning

Source	Definition or Description of Organizational Learning
Argyris and Schon (1978)	"occurs when members of the organization act as learning agents for the organization, responding to changes in the internal and external environments of the organization by detecting and correcting errors in organizational theory-in-use, and embedding the results of their inquiry in private images and shared maps of organization" (p. 29). "occurs when individuals, acting from their images and maps, detect a match or mismatch of outcome to expectation which confirms or disconfirms organizational theory-in-use" (p. 19) and "consists of restructuring organizational theory of action" (p. 29).
Duncan and Weiss (1979)	"the process within the organization by which organizational members develop knowledge about action-outcome relationships and the effect of the environment on these relationships" (p. 75). "process in the organization through which members of the dominant coalition develop, over time, the ability to discover when organizational changes are required and what changes can be undertaken which they believe will succeed" (p. 78).
Shrivastava (1983)	"Organizational learning entails conversion of individual knowledge and insights into a systematic organizational knowledge base which informs decision making" (p. 18).
Fiol and Lyles (1985)	"the process of improving actions through better knowledge and understanding" (p. 803).
Levitt and March (1988)	"Organizations are seen as learning by encoding inferences from history into routines that guide behavior" (p. 319).
Huber (1991)	"An entity learns, if through its processing of information, the range of its potential behaviors is changed" (p. 89).
Senge (1990)	a learning organization is "an organization that is continually expanding its capacity to create its future" (p. 14).

2.2.1.   Perspectives of Organizational Learning

I use the management systems model (MSM) to view four aspects of organizational learning.

The components and process of organizational learning can be viewed with four aspects: system-structural, interpretive (Daft & Huber, 1987), behavioral, and contextual factors (Fiol & Lyles, 1985). The system-structural is the information processing of data, information, and knowledge about AORs, that is, system structural "emphasizes the acquisition and distribution of information as a resource that is necessary for an organization to learn about its external and internal environments" (Daft & Huber, 1987, p. 5). In this information perspective, data are collected and converted into information to aid decision-making activities, that is, the selection of an AOR in a context. We can view the system-structural issues as the "what is used to managed" component with associated interfaces of the management systems model (Kurstedt, 1993) shown in Figure 7. This perspective focuses on the acquisition and distribution of data and information for organizational learning.

The interpretive perspective focuses on the interpretation of information about AORs to develop understanding for an individual and shared understanding for organizational members. This perspective focuses on developing the meaning (individual and shared) of the data and information for organizational learning. We can view this perspective as the "who manages" components and the information perception and decision interfaces of the MSM. Again, the meaning is on the conditions, goals, assumptions, actions, and results of actions. The system-structural and interpretative perspectives are related through data and information being operated on by these two perspectives.

The behavioral perspective describes the actions people take in response to the data and information. Argyris and Schon (1978) discuss the behavioral perspective of organizational learning. The behavioral perspective is influenced heavily by the contextual

factors. The contextual factors describe the organizational issues such as corporate culture, strategy, structure, and the environment that support or constrain the organizational-learning process (Fiol & Lyles, 1985). As with all systems, an organizational-learning process is contained and operates within an environment. I will not be focusing on the contextual factors. I am focusing on the system-structural and interpretative issues of organizational learning.
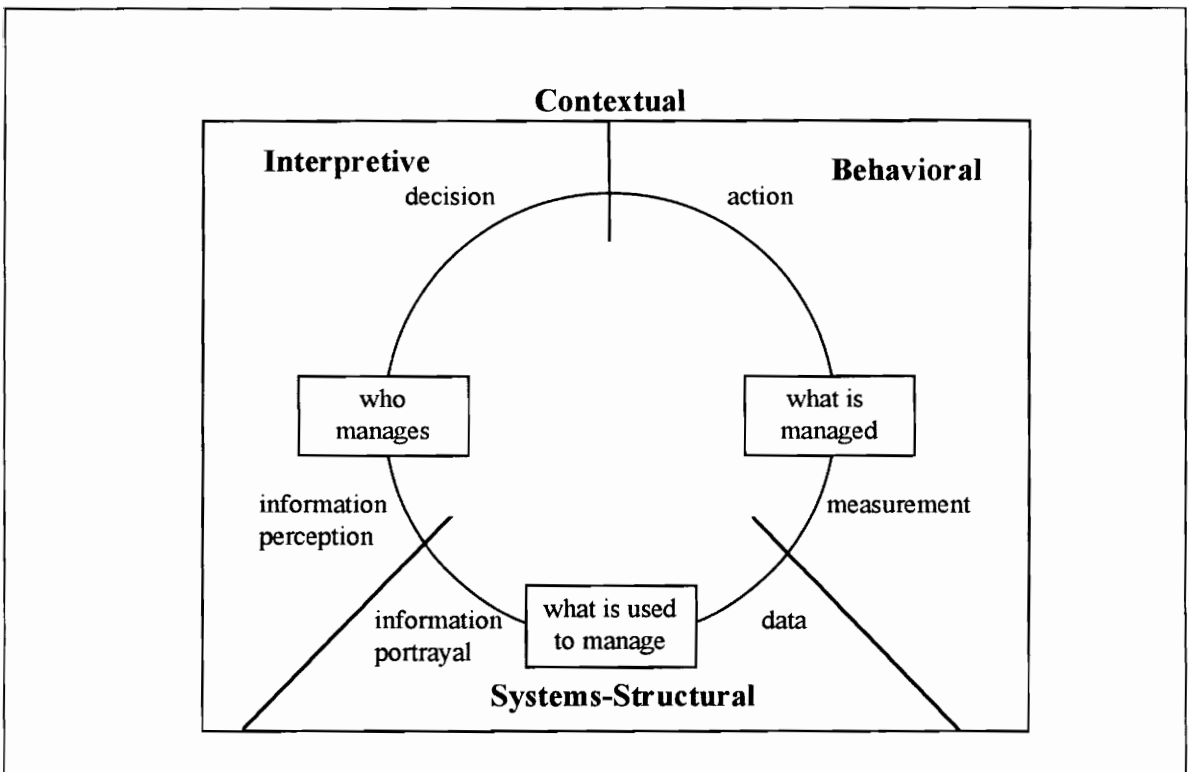
Figure 7. Four aspects of organizational learning mapped onto the Management System Model of Kurstedt (1993).

2.2.2.	The Aim of Organizational Learning

The aim of organizational learning is to improve organizational actions and performance through knowledge about AORs based on experience.

The components of the system work in conjunction to accomplish the system's aim. The aim is related to the outcomes of the system. The outcomes of organizational learning are described later. "Organizational learning means the process of improving actions through better knowledge and understanding" (Fiol & Lyles, 1985, p. 803) and is "the development of insights, knowledge, and associations between past actions, the effectiveness of those actions, and future actions" (p. 811). The aim is accomplished by enhancing AORs or the actions of the organizational members. The enhancement of actions is viewed as changing "the range of [an organization's] potential behaviors" (Huber, 1991, p. 89) or "continually expanding its capacity to create its future" (Senge, 1990, p. 14). Levinthal (1991) describes organizational learning as enhancing an "organization's competence at current activities" (p. 141) and "learning often reduces the variation in performance, as distinct from increasing its expectation" (p. 141).

Creating and using knowledge about AORs implies reducing the uncertainty of an AOR. Daft and Huber (1987) define the aim or essence of organizational learning to be the reduction of equivocality, that is, reducing the uncertainty about the actions to take under a set of conditions to accomplish a goal, "the essence of organizational learning is the reduction of equivocality, not data gathering" (Daft & Huber, 1987, p. 9). With the AOR being the model we use to describe the structure we place on organizational actions, the aim is to learn or reduce uncertainty about (1) the goals to achieve, (2) the actions to accomplish the goal, (3) the expected performance of the steps, and (4) the conditions of the environment as they impact the above three components of an AOR. Therefore, the aim can also be viewed as improving organizational performance by improving and aligning organizational process with the environment (Duncan & Weiss, 1979).

2.2.3.	The Role of Organizational Memory in Organizational Learning

Organizational memory is central to organizational action and learning. Organizational learning operates on organizational memory. Memory is added to, strengthened, and utilized in solving problems. An organization's knowledge is stored in its memory.

Walsh and Ungson (1991) in their review of organizational memory define organizational memory as "stored information from an organization's history that can be brought to bear on present decisions" (p. 61). Organizational memory stores organizational knowledge, i.e., "knowledge which is available to organizational decision makers and which is related to organizational activities" (Duncan & Weiss, 1979, p. 85) with relevance determined by the outcome or goal wanted to achieve. Walsh and Ungson (1991) describe this information as the decisional stimuli and responses, i.e., the conditions, goal, response actions, and performance as described by an AOR. This information is acquired by the process of acquisition or is "stored as a consequence of implementing decisions to which they refer, by individual recollections, and through shared interpretations" (Walsh & Ungson, 1991, p. 61). The content of organizational memory describes the results of making decisions and solving problems or the problem space defined by Newell and Simon (1972).

Walsh and Ungson (1991) define six storage "bins" for organizational memory contents: individuals, culture, transformations, structures, ecology[3], and external archives. For this research, the culture, structures, ecology, and external archives are part of the contextual issues. External archives are not part of the organizational memory but do contain information about organizational actions. External archives include past employees, competitors, government agencies, financial service firms, news media, and business historians. Levitt and March (1988) highlight that the inferences or knowledge we gain from experiences are stored in documents, files, standard operating procedures.

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[3] Ecology is concerned with the human population's environment, spatial distribution, and cultural characteristics.

I'm focusing on the individual and transformation components of organizational memory because (1) individuals are the entities through which we learn and (2) transformations are the means through which work is accomplished or a goal is carried out.

Individuals are the organization's employees and each individual stores her/his history of AOR use in their personal memories. Individuals also use records and files as memory aids. Transformations are the processes that convert inputs to outputs and are depicted in rules or standard operating procedures. Walsh and Ungson (1991) believe "the retrieval of past information from past transformations guides current transformation processes" (p. 65), that is, how we converted inputs into outputs in the past guides how we do it in the future. These transformation processes define "what is to be done, how and when to do it, and where to do it, and they may also include implications for the skills and abilities required of a person to accomplish these tasks (i.e., who)" (Walsh & Ungson, 1991, p. 68).

Walsh and Ungson (1991) define three processes which act on organizational memory: acquisition, retention, and retrieval. These three organizational memory processes are crucial to organizational learning and are discussed in the section on "Organizational Learning as a Process." Retrieval is the process of retrieving information from the six bins to use in a new decision-making environment via an analogy (Neustadt & May, 1986). The retrieval could be automatic and effortless or purposeful requiring a conscious effort.

Walsh and Ungson (1991) ask a central question about organizational memory and for this research on organizational learning: "Of what consequence is it to organizations that they are able to preserve knowledge of past events and bring it to bear on present decisions?" (p. 70). Organizational memory is central to organizational learning because organizational learning requires the description of the actions and associated results to be incorporated into organizational memory to help decision makers or problem solvers in the future.

2.2.4.   Research Issues of Organizational Memory and Organizational Learning

I identify research issues about the relationship between organizational memory and organizational learning.

I discuss the important issues of organizational memory as they relate to organizational learning. Organization's must resolve two key issues for organizational memory use: (1) the ability to acquire the decision-response information and (2) the ability to recall or activate the past cases to the present decision-making or problem solving environment (Walsh & Ungson, 1991). This research provides the overarching theory or process for addressing the two issues. Huber (1991) in defining gaps in knowledge about organizational learning and memory believes organizational memory, including computer-based memory, as part of organizational learning needs to investigated. However, we first need to know the information needed and the data elements which makeup the information, i.e., the data-to-information chain described by Kurstedt (1993).

The effectiveness of organizational memory in relation to organizational learning depends on the ability to demonstrate and use the results of learning (Huber, 1991). That is, knowledge must be stored and retrieved from organizational memory to support organizational learning. Huber (1991) defines four variables for the effectiveness of organizational memory: membership attrition; information distribution and organizational interpretation of information; norms and methods for information storing; and methods for locating and retrieving stored information. Levitt and March (1988) describe the availability of organizational memory contents as a function of the frequency of use, recency of use, and its organizational proximity. The more recent and frequent AORs being more easily evoked or activated. However, the exact mechanisms or nature of the relationship between recency, frequency, and activation are not explained. We can use the individual model of learning defined by Anderson (1993) to address the activation of an AOR. Finally, Simon (1991) highlights the need for organizational memory to be

43

organized and represented to allow the transfer of relevant knowledge to organizational members. Duncan and Weiss (1979) support the notion that "it is the access to and use of knowledge and not the possession of it that is critical in this concept of organizational knowledge" (p. 86).

2.2.5.   Organizational Learning as a Process

I view organizational learning as a process.

Organizational learning is viewed as a process (Levitt & March, 1988). The functions of the process are: (1) problem-solving or individual-learning experience, (2) storage and refinement of organizational memory, (3) distribution and retrieval of relevant AORs, and (4) interpretation (Huber, 1991). The second and third functions address the three processes of organizational memory defined by Walsh and Ungson (1991). Figure 8 is a high-level flowchart of the organizational learning process.
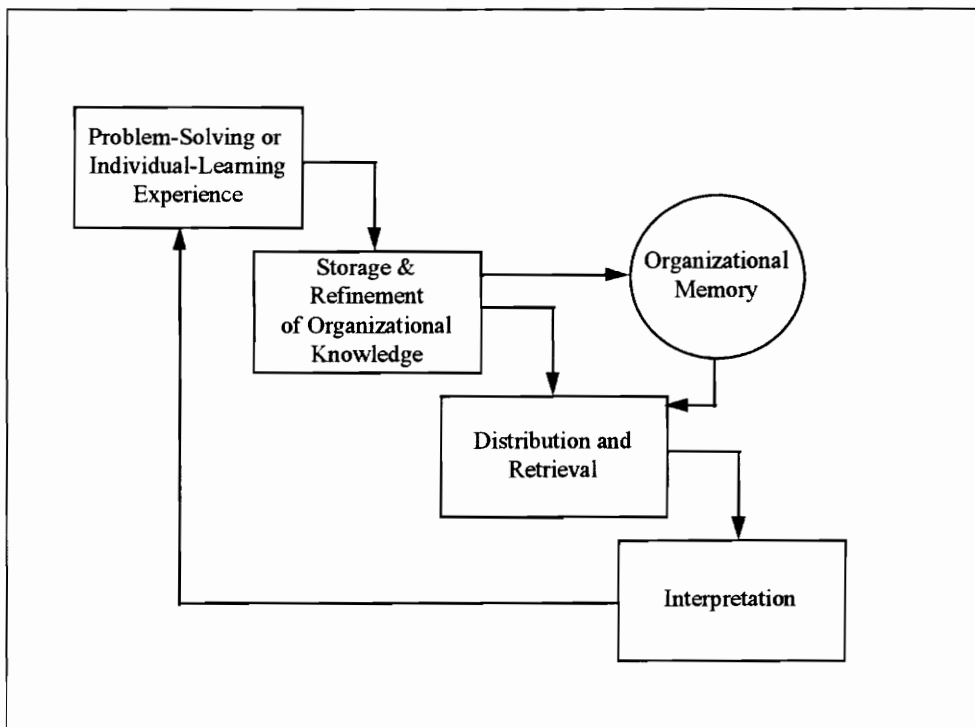
Figure 8. Process view of organizational learning.

Problem-solving or individual-learning experience is the "process by which knowledge is obtained" (Huber, 1991, p. 90). Huber defines this step as knowledge acquisition. However, I use problem-solving or learning-experience to denote the type of experience through which knowledge is gained and reserve the word knowledge acquisition for the

process of placing knowledge into the organization's memory. This definition of knowledge acquisition is in agreement with the cognitive psychology or computer science use of the word. An individual is part of the organizational memory, however, for organizational learning to occur the knowledge must be shared with more than just the single individual. Also, I propose a formal organizational knowledge base to place the knowledge gained from individual experiences and the process of sharing knowledge from an individual to the knowledge base as knowledge acquisition. The renaming of the first function is supported by the notion that organizational learning is the integration of problem-solving or individual-learning experiences (Argyris & Schon, 1978; Simon, 1991). Also, Duncan & Weiss (1979) say organizational learning "must involve an organizational process in which learning done by a given individual can be shared, evaluated, and integrated with that done by others" (p. 89). Furthermore, the use of multiple interpretations from an event are possible by denoting an individual learning experience with the integration of the multiple interpretations as part of the storage and refinement function. I view the first function as an individual plan-do-study-act (PDSA) cycle. Shrivastava (1983) in his analysis of organizational learning systems found organizational learning is a process with individuals being the learning agents.

The first function includes the detection and correction of error and the confirmation of an AOR use by an individual. An AOR use is the act of applying an AOR in a context. Argyris and Schon (1978) define the fundamental learning loop as containing three steps:

1. individuals act from organizational theory-in-use to respond to a stimulus from the environment;
2. the action leads to a result which leads to a match or mismatch of expectations with the actual outcome; and
3. if there is a performance gap, then the theory is disconfirmed, otherwise the theory is confirmed.

Duncan and Weiss (1979) define the role of performance gaps in the refinement of organizational memory. If the results equal the expectations, then the existing knowledge

is validated or updated as being successful in the context. If the results don't meet the expectations, then the individual searches for the cause of the failed expectations. This search focuses on identifying the actions to decrease the performance gap. Using the AOR as the basic structure, we can view the gap as being caused by a lack of knowledge about the components of the AOR used in the given context, that is, in the conditions of the environment, goals to achieve, steps or actions to take, and expected results. Both the lack of complete knowledge about the problem-solving environment and the implementation of the AOR could be causes for the performance gap.

I view the learning loop given in Figure 9 as the learning loop within a problem-solving experience. Organizational members must place what is learned from this loop in organizational memory so others may have access to it. The individual is a component of organizational memory. However, this human is also a barrier organizational learning (Argote & Epple, 1990). For this research, I view the lessons as being placed in a formal, organizational memory.

I make a distinction between individual and organizational learning: individual learning must occur and the results be shared through organizational memory to more than the individual who learned. I will discuss the conditions necessary for organizational learning later.

Individual Act from theory → Interpret response → Response = Expectation? —N→ Detect and Correct Errors

Y

Confirmation → Evaluate & Generalize

Interpretation ← Retrieval/distribution ← Refine Org. Memory
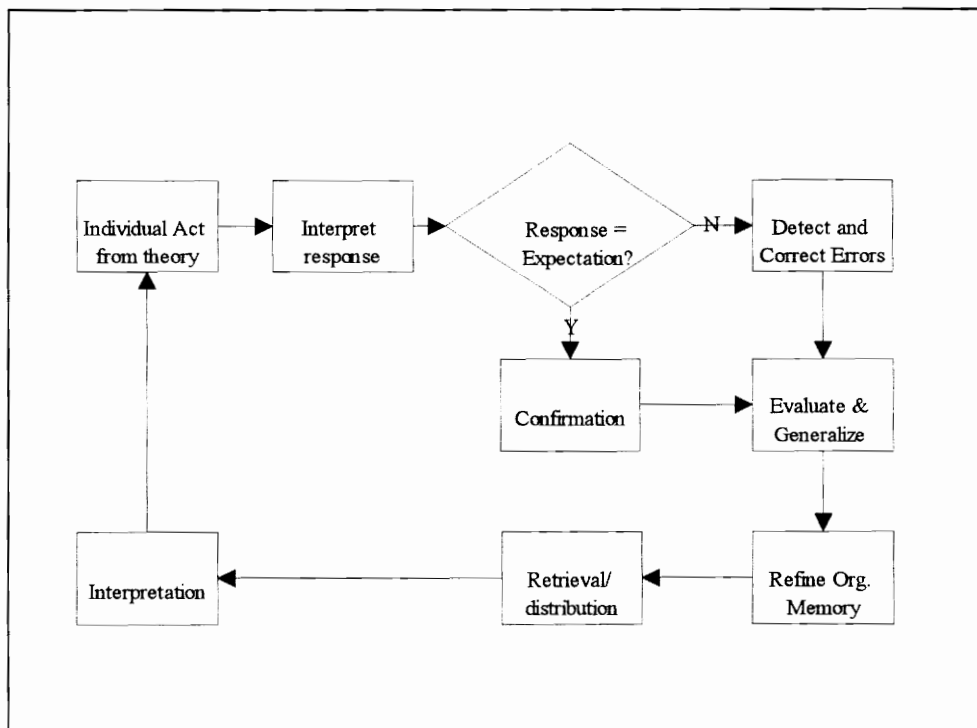
Figure 9. Organizational learning as defined by Argyris and Schon (1978) and Duncan and Weiss (1979).

The second function, storage and refinement of organizational memory, is the process "by which knowledge is stored for future use" (Huber, 1991, p. 90) and organizational memory is refined or updated. This function uses knowledge acquisition as defined by Bylander and Chandrasekaran (1988, p. 65) as "the process that extracts knowledge from a source (e.g., a domain expert or textbook) and incorporates it into a knowledge-based system that solves some problem," to incorporate what we learned from the first function into organizational memory. Organizational memory is refined by adding support to actions that met expectations and reducing or disconfirming actions which didn't meet expectations.

The third function is the distribution and retrieval of the knowledge to use in a problem-solving task. Huber (1991) defines this function as information distribution, "process by which information from different sources is shared and thereby leads to new information

or understanding" (p. 90) and "how units that possess information and units that need this information can find each other quickly and with a high likelihood" (p. 88). However, I include retrieval as part of this process. The difference between distribution and retrieval is the difference between giving and getting the information, respectively. Both distribution and retrieval are needed, that is, the information must be available (distribution) and be retrievable for the particular problem-solving experience. The definitions of both organizational learning and memory highlight the need to use AOR knowledge on a current problem.

The fourth function is the interpretation of information and is defined as the "process by which distributed information is given one or more commonly understood interpretations" (Huber, 1990, p. 90).

2.2.6.	Outputs and Outcomes of Organizational Learning

> The organizational learning process doesn't produce a single final output. I view the outputs of organizational learning as the products of each of the four functions because organizational learning is a cyclic process. The outcomes of organizational learning are enhanced organizational knowledge, problem solving or decision making, actions, and performance; reduced uncertainty; consistent interpretation; and organizational survival.

Outputs of the organizational learning process are:

1. a change in individual memory or lesson learned,
2. refined organizational memory,
3. AORs relevant to a problem, and
4. a mapping of past AORs to the current problem.

A lesson learned is the result of a problem-solving experience. I earlier defined the problem-solving experience as the first function of the organizational learning process. Relevant to the outputs of organizational learning is the lesson learned from solving a problem. Individuals can develop multiple lessons learned from a single problem and these lessons are the function of multiple interpretations (March, Sproull, & Tamuz, 1991). These multiple interpretations are a function of the responsibilities and goals of the individuals solving the problem. That is, multiple individuals involved in a group problem-solving activity can develop a diverse set of lessons learned. One area for research would be the study of tools which help people develop lessons learned from a problem-solving experience. For example, to create alternative AORs scenario-type tools could focus on varying the different components of an AOR and determining the steps to take to respond.

Refined organizational memory is the result of capturing the lesson learned and revising the current contents of memory. Using the AOR as the structure of organizational memory, the revision of an AOR focuses on:

- identifying the new conditions affecting an AOR;
- replacing a previous AOR with a new one to respond to a set of conditions and goals;
- updating the probability or associated uncertainty of an AOR; or
- supporting the AOR as "valid" or disconfirming the AOR (Duncan & Weiss, 1979).

Relevant AORs are the result of a problem solver retrieving AORs relevant to the current problem-solving activity from organizational memory. Relevancy can be determined by the nature or meaning of the goals, conditions, steps, and outcomes of an AOR. The concept of relevancy needs to be researched for organizational learning. For example, when are two problems similar enough to be relevant? What are the dimensions to describe problems in order to determine relevancy?

The mapping or application of relevant AORs is the result of the interpretation function. The problem-solver uses this mapping as an input (descriptive or prescriptive) to the current problem. This mapping is an analogy process.

March, Sproull, and Tamuz (1991) define four outcomes of organizational learning: consistent agreement on interpretation, valid knowledge, improved organizational performance, and organizational survival. These four outcomes are the result of reducing equivocality or uncertainty about the components of an AOR:

> "For an organization to learn, equivocality must be reduced to an acceptable level. Indeed, the essence of organizational learning is the reduction of equivocality, not data gathering" (Daft & Huber, 1987, p. 9).

Milliken defines uncertainty as "an individual's perceived inability to predict something accurately" (1987, p. 136). For organizational learning the prediction is on the expected outcomes of an action in response to conditions and goals, i.e., an AOR. A lack of knowledge about the following AOR components causes uncertainty:

1. the alternatives or response options available;
2. the states of nature or outcomes likely to be connected with each; and
3. the value or utility associated with each alternative-state-of-nature pair (Conrath, 1967).

Duncan and Weiss (1979) in defining organizational learning as "the process within the organization by which knowledge about action-outcome relationships and the effect of the environment on these relationships is developed" (p. 84) highlight the change in knowledge as the outcome of organizational learning.

Table 2 is an input-output analysis showing the outputs and outcomes associated with the four functions of the organizational learning process.

Table 2
Input-Output Analysis of Organizational Learning

Supplier	Input	Process	Output	Customer	Outcome
• Environ-ment • Organiza-tional memory	• Conditions, goals • Espoused or in-use theories • Mapping of AORs to current problem	(1)Problem-Solving or individual learning experience	• Change in individual memory • Lesson learned	• Organiza-tional memory (step 2)	enhanced • knowledge • problem solving or decision making • actions • perfor-mance • organiza-tional survival
• Individual learning experience (step 1)	• Knowledge from step 1 about an AOR, lesson learned	(2)Storage in & refinement of organiza-tional memory	• Refined organiza-tional memory	• Organiza-tional memory (step 3)	• reduction in uncertainty • consistent interpreta-tion
• Organiza-tional memory (step 2)	• AORs from refined organiza-tional memory	(3)Retrieval or distribution	• Relevant AORs	• Individual problem solver (step 4)	
• Retrieved AORs from organiz-ational memory (step 3)	• Relevant AORs	(4)Interpreta-tion	• Mapping of AORs to current problem	• Problem-solving or individual learning experience (step 1)	

2.2.7.	Systems Perspective of the Key Components to Organizational Learning

I view the components of organizational learning using the systems perspective.

Before I discuss the components of organizational learning, I need to place organizational learning in the context of organizational action with organizational memory being central to both. The action of an organization is the result of a decision which involved the identification of the current environment (conditions and goals) and the possible alternative means to accomplish the goals. Organizational learning focuses on learning about the environment and the actions to take. Organizational action requires the use of elements in the organization's memory and learning is the addition to or refinement of elements in the memory.

I use the systems perspective to describe each component and its relationship to the aim of the system (Kurstedt, 1993). I describe the components in their function to accomplishing the aim. The components of organizational learning are the information and knowledge about action-outcome relationships, organizational memory, and the organizational learning functions. The functions are problem-solving or learning experience, storage, retrieval (distribution), and interpretation.

Table 3 presents the systems perspective of the organizational learning components.

Table 3

Systems Perspective of Organizational Learning Components

Component	How the Components Are Related to the Aim of Organizational Learning
Individual problem-solving or learning experience	The organization learns through individuals (Simon, 1991). Therefore an individual must first learn before the organization does; without individual learning organizational learning can't occur.
Organizational memory	Organizational memory stores the organizational knowledge. Individuals act based on the contents in memory; without an organizational memory organizational members can't share knowledge.
Storage and refinement function	Organizations must (1) capture the lessons learned from a problem-solving experience, (2) place the lessons in organizational memory, and (3) update the organizational knowledge base; without storage and refinement of organizational memory then only individual learning has taken place.
Retrieval function	An organizational member must recall the lesson learned; without transfer and use the organization doesn't improve based on the actions of the past.
Interpretation function	A problem solver must draw an AOR from memory and interpret the AOR to fit the current situation; without mapping the lesson learned from the past to the present the problem solver can't use the lesson learned and the organization doesn't improve based on the actions of the past.
AOR or Lesson learned	An AOR is a specific piece of knowledge which defines the steps to take under given goals and conditions. The AOR is the piece of knowledge being operated on by organizational learning.

2.2.8.	Conditions Necessary for Organizational Learning

From the systems perspective of organizational learning, four conditions must be met for organizational learning to occur.

The previous systems perspective of organizational learning leads to the development of conditions necessary for organizational learning to occur. For organizational learning to occur each step in the process must be completed, that is, an individual must have learned, the knowledge must be placed into organizational memory, the information must be distributed and retrieved or used, and interpreted. By the vary nature of retrieving knowledge about an AOR the retriever is interpreting the knowledge. Therefore, by retrieving or using an AOR, interpretation is automatically assumed to take place. However, the "correctness" of the interpretation is another issue. Argyris and Schon (1978) further support the key condition of organizational learning as the integration of individual learning into organizational memory:

> "But in order for organizational learning to occur, learning agents' discoveries, inventions, and evaluations must be embedded in organizational memory. They must be encoded in the individual images and the shared maps of organizational theory-in-use from which individual members will subsequently act. If this encoding does not occur, individuals will have learned but the organization will not have done so" (Argyris & Schon, 1978, p. 19).

Organizational learning "must involve an organizational process in which learning done by a given individual can be shared, evaluated, and integrated with that done by others" (Duncan & Weiss, 1979, p. 89), that is, the knowledge must be shared and accepted by others in the organization or validated by some criteria and viewed as relevant. "Regardless of the method by which an individual finds a new action-outcome relationship or modifies an existing relationship, this change in knowledge must be made public, communicated to and be accepted or legitimized by others before it can be considered a change in organizational knowledge" (Duncan & Weiss, 1979, p. 94).

From the above discussion, conditions for organizational learning include:

1. an individual must have learned, that is, confirmed or disconfirmed an aspect of an AOR (condition, goal, actions, or performance) through experience;
2. an individual must place the lesson learned into organizational memory;
3. organizational members must accept the lesson learned; and
4. organizational members must distribute and retrieve the lesson learned, that is, use the lesson.

Argyris and Schon (1978, p. 20) offer six questions to determine the occurrence of organizational learning:

1. Did individuals detect an outcome which matched or mismatched the expectations derived from their images and maps of organizational theory-in-use?
2. Did they carry out inquire which yielded discoveries, inventions, and evaluations pertaining to organizational strategies and assumptions?
3. Did the results become embodied in the images and maps employed for purposes such as control, decision, and instruction?
4. Did members subsequently act from these images and maps so as to carry out new organizational practices?
5. Were these changes in images, maps, and organizational practices regularized so that they were unaffected by some individual's departure?
6. Do new members learn these new features of organizational theory of action as part of their socialization to the organization?

The six questions map to the above four conditions. Table 4 shows the mapping of Argyris and Schon's questions to the conditions of organizational learning.

Table 4

Mapping of Conditions for Organizational Learning to Questions Defined by Argyris and Schon (1978)

Question	Condition
1. Did individuals detect an outcome which matched or mismatched the expectations derived from their images and maps of organizational theory-in-use?	1. an individual must have learned, that is, confirmed or disconfirmed an aspect of an AOR (condition, goal, actions, or performance) through experience
2. Did they carry out inquire which yielded discoveries, inventions, and evaluations pertaining to organizational strategies and assumptions?	1. an individual must have learned, that is, confirmed or disconfirmed an aspect of an AOR (condition, goal, actions, or performance) through experience
3. Did the results become embodied in the images and maps employed for purposes such as control, decision, and instruction?	2. an individual must place the lesson learned into organizational memory
4. Did members subsequently act from these images and maps so as to carry out new organizational practices?	3. organizational members must accept the lesson learned 4. organizational members must distribute and retrieve the lesson learned, that is, use the lesson
5. Were these changes in images, maps, and organizational practices regularized so that they were unaffected by some individual's departure?	2. an individual must place the lesson learned into organizational memory
6. Do new members learn these new features of organizational theory of action as part of their socialization to the organization?	3. organizational members must accept the lesson learned 4. organizational members must distribute and retrieve the lesson learned, that is, use the lesson

2.2.9. Barriers to Organizational Learning

I identify two sets of barriers to organizational learning. The two sets focus on the problem-solving experience and organizational memory.

Argote and Epple (1990) in their analysis of learning curves in manufacturing organizations found six sources of variances for organizational learning rates: (1) organizational forgetting (e.g., people forget, change in environment making old knowledge obsolete, records or routines are lost or become difficult to access), (2) employee turnover, (3) transfer of knowledge across products, (4) transfer of knowledge across organizations, (5) incomplete transfer within organizations, and (6) other factors (e.g., economies of scale). These six sources of variance plus others form two sets.

The first set focuses on the limited number of and complexity of problem-solving experiences. One barrier is the limited amount of similar experiences to draw lessons from. History may not repeat itself to the same people often enough for a thorough understanding of the problem and resulting lessons (March, Sproull, & Tamuz, 1991). Organizations can use the knowledge-sharing process described in this research to overcome the limited number of experiences barrier. By having a management tool which pulls, from across the organization, the AORs used to respond to similar problems the organization can study a set of lessons learned to develop a general model of actions to take.

Other barriers related to the problem experience include: the problem may be too complex and the meaning of the experience or lesson is difficult to interpret (Levitt & March, 1988). The complexity leads to three barriers of interpretation. The interpretation may be wrong and/or incomplete. Also, a lesson learned may not even be developed from the problem solving experience. March, Sproull, and Tamuz (1991) explain how to extract more meaning from a single problem-solving experience. Developing tools which help people interpret and give meaning to problem-solving experiences to develop lessons

learned is an area which can be studied because an individual's ability to understand a complex situation is limited (Simon, 1991).

The second set of barriers relate to organizational memory. The first barrier is the lesson may not be put into organizational memory. Obviously since the individual is a part of organizational memory by default if an individual learns then it is put into memory. However, turnover of personnel reduces organizational memory. The second barrier is that information is not stored because future use is not anticipated. The transfer of knowledge or lessons from organizational memory to those of need is a barrier (Simon, 1991). For example, an individual solving a problem may not know others in the organization have the knowledge which could help him or her solve the current problem (Huber, 1991). Also, the person with the knowledge may not know others need this knowledge. Finally, the information and knowledge may not be in a form easily retrievable. This research focuses on a knowledge-sharing process which acts as organizational memory to overcome these organizational memory barriers. Figure 10 is a graphical representation of the barriers to organizational learning.

Barriers

Problem-Solving Experiences
•Limited Number
•Complexity/Interpretation
  •Wrong
  •Incomplete
  •Not Completed

Organizational Memory
•Lesson Not Placed In
•Not Easily Retrievable
•Employee Turnover
•Organizational Forgetting
•Sharing
  •Don't Know Others Who Can Help
  •Don't Know Others Need Help
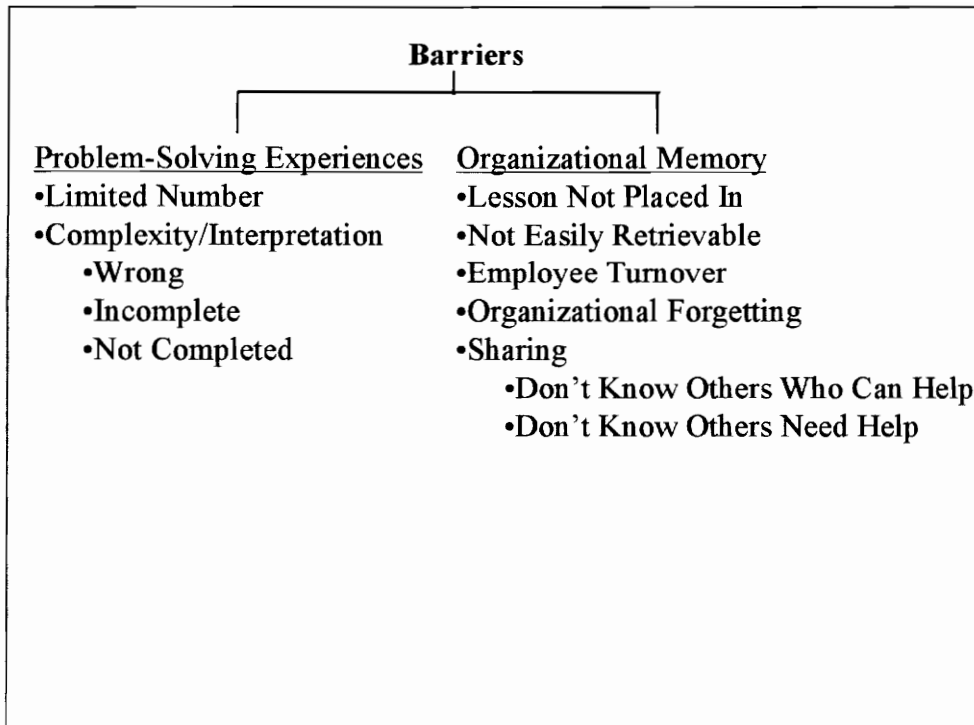
Figure 10. Barriers to organizational learning.

2.2.10. Current State of the Organizational Learning Literature.

The organizational learning does not explicitly address the data, information, and management tools to support organizational learning.

The organizational learning literature is primarily conceptual based on qualitative or anecdotal evidence. Empirical studies of organizational learning exist, such as Argote and Epple (1990); March (1991); Hutchins (1991); Epple, Argote and Devadas (1991); and Argyris and Schon (1978). These provide primarily conceptual issues of organizational learning and anecdotal evidence. Shrivastava (1983) completed a qualitative field investigation of learning systems.

On the information processing side of organizational learning there is need for work. In fact, Daft and Huber (1987) have defined the information processing theory of organizational learning a major need for research. Since management tools are data-to-information converters, i.e., information processors, the information processing issue can be addressed through the role of management tools in organizational learning. Related to Daft and Huber's (1987) call for defining the system-structural component of organizational learning is the need to define the data-to-information chain for organizational learning. The current literature doesn't provide explicit and empirically tested models of the data-to-information chain. I use the information processing model of learning as defined by Anderson (1993) to help define the data-to-information chain. The organizational learning literature doesn't explicitly describe the relationship between the experience with an AOR and the subsequent use of an AOR at another time. That is, the relationship between the use and performance of an AOR in one context, the refining of organizational memory, and subsequent selection of an AOR is not operationally defined.

2.3. DEFINITION OF NEED FOR A LESSONS-LEARNED SHARING PROCESS

A formal lessons-learned sharing process is needed to support organizational learning.

Nonaka (1994) describes a theory of organizational knowledge creation and four modes of knowledge creation. He defines organizational knowledge creation as "a process that 'organizationally' amplifies the knowledge created by individuals, and crystallizes it as a part of the knowledge network of the organization" (p. 17), i.e., the organizational learning process as I have defined. The aim of the process is to "enable individual knowledge to be enlarged, amplified, and justified within an organization" (Nonaka, 1994, p. 21).

The four modes of knowledge creation between individuals are a function of the type of knowledge (tacit or explicit) shared from and to. Explicit knowledge is "transmittable in formal, systematic language" (Nonaka, 1994, p. 16). Tacit knowledge is hard to transfer and is representative of mental models or technical know how. The four modes are:

1) tacit to tacit
2) explicit to explicit
3) tacit to explicit
4) explicit to tacit.

Socialization is the process for transferring tacit knowledge to tacit knowledge between individuals. Methods for socialization include culture or shared experiences, mentors, and on the job training. The second mode, combination, is the transfer of explicit to explicit, by formal methods of information processing. The transfer of tacit to explicit is the externalization mode. The work of Argyris and Schon (1978) address externalization. Also, Senge's (1990) use of systems dynamics for raising hidden assumptions, tacit knowledge, is an example of a method for externalization. The forth mode, internalization, transfers explicit to tacit knowledge. In this mode, the knowledge is transferred via learning by the individual. Nonaka contends one mode is not sufficient for

63

knowledge creation. All four modes must interact. Kim (1993) develops the concept of the link between individual and organizational learning. Part of Kim's theory is the need to specify the transfer mechanism from individual to organizational learning, that is, a mechanism to share or transfer individual learning throughout the organization.

In this research, I focus on a lessons-learned sharing process for the combination mode by which explicit knowledge is transferred to explicit knowledge between individuals.

2.4.	LESSONS-LEARNED, MANAGEMENT TOOLS, AND ORGANIZATIONAL LEARNING

I view the relationship between a lessons-learned sharing process and organizational learning using the management system model (MSM).

I review work on lessons-learned sharing processes by using the management tool literature because I define the lessons-learned sharing process through the eyes of the MSM and the data-to-information chain which is embodied in management tools. I view the lessons-learned sharing process as a "what is used to manage" component of the MSM. The lessons-learned sharing process converts data-to-information to support decision making through organizational learning. Therefore, when I use the term management tool for organizational learning to mean the "what is used to manage" component I'm referring to a lessons-learned sharing process.

Given a need in organizational learning is knowledge sharing which is an information processing activity, I study the previous work on these subjects. I define a "generic" knowledge sharing process based on the review of different management tools which support organizational learning. My interest is not designing a new tool, but to study how a lessons-learned sharing process impacts the problem-solving process between individuals. Management tools are used to support and are themselves lessons-learned sharing processes.

The information oriented questions for the relationship between organizational learning and a lessons-learned sharing process include: what is the information needed for organizational learning? and what data elements are needed to produce this information?

The current literature doesn't provide explicit and empirically tested models of the data-to-information chain or management tools to support organizational learning. On the information processing side of organizational learning there is need for work. Since management tools are data-to-information converters, that is, information processors, I

can address the information processing issue through the data-to-information chain. I define a data-to-information chain for organizational learning. I use the information processing model of learning as defined by Anderson (1993) to define the data-to-information chain. By using this model, I gain an understanding of the relationship between the use and performance of an AOR in one context, the refining of organizational memory, and subsequent selection of an AOR. Organizations need a data-to-information chain for sharing knowledge gained through experience to enhance organizational learning.

In this section I answer the question: why do organization's need management tools to support organizational learning? Management tools which provide information to support organizational learning can help overcome the "stickiness" of information as defined by von Hippel (1994) by providing descriptive solutions to past unstructured problems and reduce the cost of transferring this information. Information is sticky if it is costly to acquire, transfer, and use. This research addresses a management tool or lessons-learned sharing process to support organizational learning and is an operationalization of some the concepts described by Williams and Kotnour (1993a). Organizational learning requires both the creation of knowledge and capture of the knowledge in organizational memory, that is, if a member of the organization learns but doesn't incorporate the new knowledge in the organization's memory, then organizational learning has not occurred (Argyris & Schon, 1978). In essence, a corporate knowledge base is being created through the organizational learning process. Organizational members can use this knowledge base to further aid the organization in solving similar problems as those contained in the knowledge base. This corporate knowledge base or as Senge calls the " 'living library'...can be continually expanded, refined, and if need be, thrown out altogether to fit a changing world" (Meen & Keough, 1992, p. 72).

The major challenge in organizational learning "is to discover new management tools and methods to accelerate organizational learning, build consensus for change, and facilitate the change process" (Stata, 1989, p. 64). Current information technology does not facilitate organizational learning because the current information systems, as compared to knowledge-based systems, simply supply the manager with a piece of data which the manager uses to detect a deviation from the expected outcome (Jonsson, 1987). The information system does not provide assistance to the manager on how to solve the problem of fixing the deviation from expectation, that is, the information system does not supply any causal knowledge to assist the manager in the problem-solving activity. The information system does not facilitate learning because in does not provide a facility or capability for the capturing or "the development of insights, knowledge, and associations between past actions, the effectiveness of those actions, and future actions" (Fiol & Lyles, 1985, p. 811).

Shrivastava (1983) in studying organizational learning systems in the context of strategic decision making found four features of learning systems. First, the organizational learning systems acquire, communicate, and interpret organizationally relevant knowledge for use in decision making. Second, the systems are broad in scope. They are used by a diverse set of departments or functions and are not necessarily task specific. Third, the information contained in the system represents actual organizational practices. Forth, members of the organization knew about and used the systems.

From the previous discussion of organizational learning, we can describe the roles of management tools for organizational learning. Management tools can help in various stages of organizational learning. For example, quality tools can be used to increase learning in the problem-solving function. Charting, expectations, and the use of logs as defined by Kurstedt's management process can be used to close process loops for an individual department (Kurstedt, 1993). In this research, I view the role of a management

tool as a sharing mechanism for acquiring, storing, and making available for retrieval AORs from one problem-solving or individual learning experience to another.

2.4.1.	Types of Management Tools

I define a lessons-learned sharing process as a method, data-to-information (Kurstedt, 1993), and knowledge-sharing (Niwa, 1990) type management tool.

Kurstedt (1993) defines five groups of management tools:

1. **relationships and structures** help link the elements of work, e.g., a work breakdown structure;
2. **methods** suggest solutions for the decision maker to consider, e.g., an expert system;
3. **guides and rules** guide or direct you in doing your work and management process, e.g., policies and procedures;
4. **precedents** tools help us set up the stability and consistency, e.g., legends and stories, mission statements;
5. **data-to-information chain** converts data to information, e.g., management information system.

Two groups of management tools related to this research are the methods and data-to-information chain. Methods suggest solutions to the decision maker to consider. The very nature of a lessons-learned management tool is to provide a set of relevant cases to a decision maker to use as a descriptive input to the current problem-solving task. A lessons-learned management tool doesn't initially contain guides or rules but the information contained in the memory of the tool can be analyzed to develop best practices or procedures. This analysis function of the tool could help overcome the lack of sufficient number of cases barrier discussed earlier. The tool of this research is also a data-to-information type tool because the tool operates on data to supply information in the form of relevant AORs to support a decision maker.

The method type management tool can be further delineated into expert systems and knowledge-sharing systems (Niwa, 1990). In expert systems, an expert supplies the

knowledge to the knowledge base and novices use the knowledge to solve problems. In knowledge-sharing systems, the users are also the suppliers of the knowledge. The users share the knowledge they learn from problem-solving activities through the use of the tool. The problems are less structured in knowledge sharing as compared to the expert systems. Figure 11 shows the difference between these two types of method management tools.

Expert System

Supplier → Knowledge Base → User, User, User

(Expert)   (Novices)

Knowledge Sharing

Knowledge Base ↔ User, User, User

(Suppliers = Users)
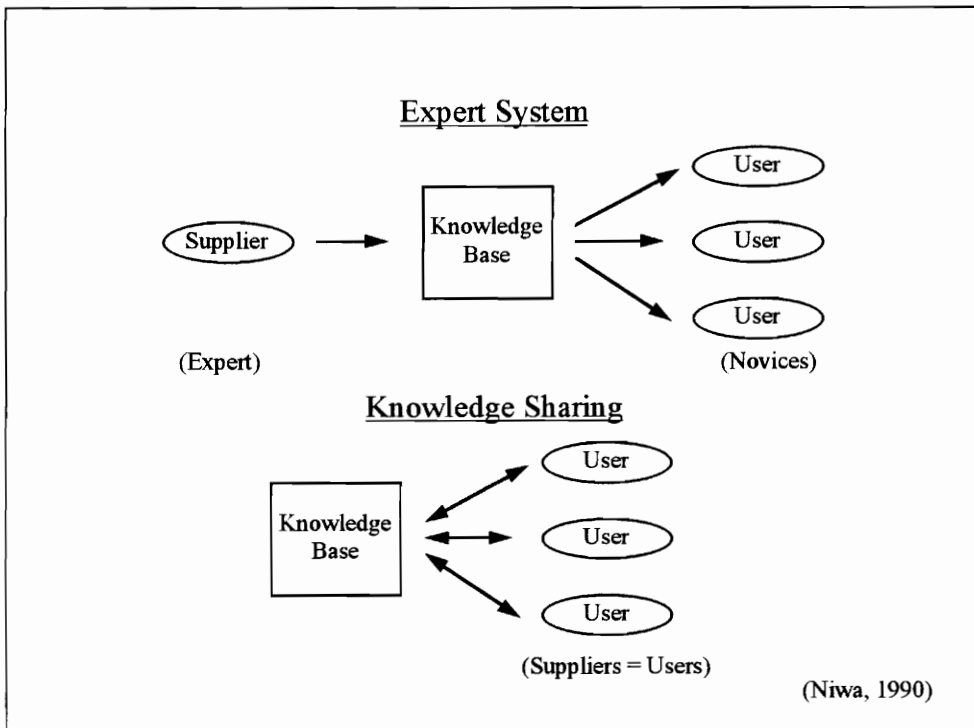
(Niwa, 1990)

Figure 11. Comparison of expert system and knowledge sharing method types of management tools. Taken from Niwa (1990).

2.4.2. Data-to-Information Chain

A data-to-information chain serves as the foundation for the lessons-learned sharing process.

I describe the data-to-information chain for organizational learning by first describing the data-to-information chain and then operationalizing the chain for organizational learning.

In building management tools we are constructing a data-to-information chain. A data-to-information chain "acquires, stores, retrieves, and manipulates data to compare to reference points (biases) to make and display information" (Kurstedt, 1993, p. 878). A data-to-information chain has five steps: (1) acquire data, (2) retrieve data, (3) manipulate data, (4) generate information, and (5) portray information. These five steps operate in conjunction with four components of the chain: (1) storage, (2) procedures, (3) reference points, and (4) information media. The chain acquires data from the "what is managed" or operation source through measurement. This data is stored and later retrieved. A datum is a fact plus meaning and information is a datum or reference compared to a reference. Data is retrieved, manipulated, and compared to the reference points to generate information. The generated information is portrayed to the "who manages" with management intelligence via the information media. The manager acts based on the decision made with the support of the information. Figure 12 is the data-to-information chain as defined by Kurstedt (1993). In the next sections, I focus on the data and information components with a brief discussion of the procedures. I don't address the specifics of storage, information media, or information portrayal.
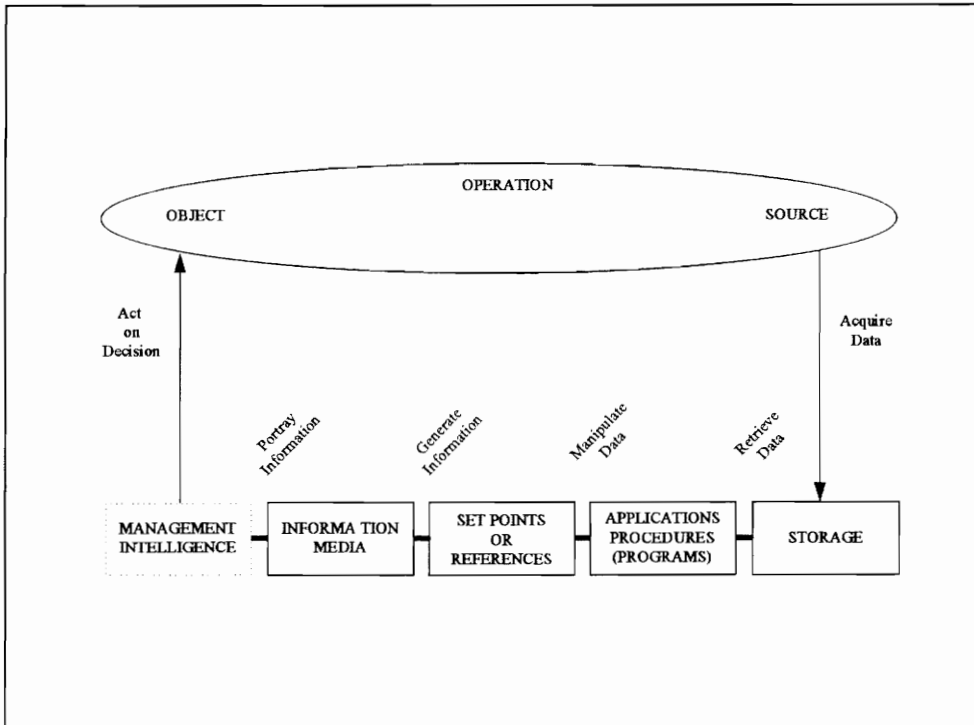
Figure 12. Data-to-information chain as defined by Kurstedt.

2.4.3. A Lessons-Learned-Sharing Data-to-Information Chain of Organizational Learning

I use management systems analysis to define the data-to-information chain for organizational learning.

The data-to-information chain developed by Kurstedt assumes a closed loop with a single "who manages" receiving feedback from decisions and actions. For organizational learning, the chain is not for a single individual but rather serves the set of organizational members, that is, is used to share knowledge.

From the discussions about organizational learning and the data-to-information chain, I define the requirements of an organizational learning data-to-information chain. The chain must support the sharing of knowledge or lessons learned from one individual to another in the organization (Niwa, 1990). The source is a problem-solving experience. The lessons learned about an AOR are stored in organizational memory. The chain must support the refinement, both confirming and disconfirming, of elements in organizational memory (Argyris & Schon, 1978). A manager or problem solver uses the data-to-information chain to retrieve and interpret lessons learned applicable to a new problem. Shown in Figure 13 is the data-to-information chain for organizational learning. In this figure, the functions of organizational learning are integrated with the data-to-information chain and the MSM.

The five steps and four components of the chain need to be operationalized for organizational learning. I define the data-to-information chain of a management tool for organizational learning using management systems analysis (Kurstedt, 1993) and the model provided by Anderson (1993). Management systems analysis involves five steps: delimiting the domain, determining the decisions to be made, determining the information to support the decision making, determining the data needed to make up the information, and determining the indicators to collect to produce the data. In defining the chain, I first

focus on the decisions, information, and data needed. From this, I discuss the procedures for manipulating and generating information.
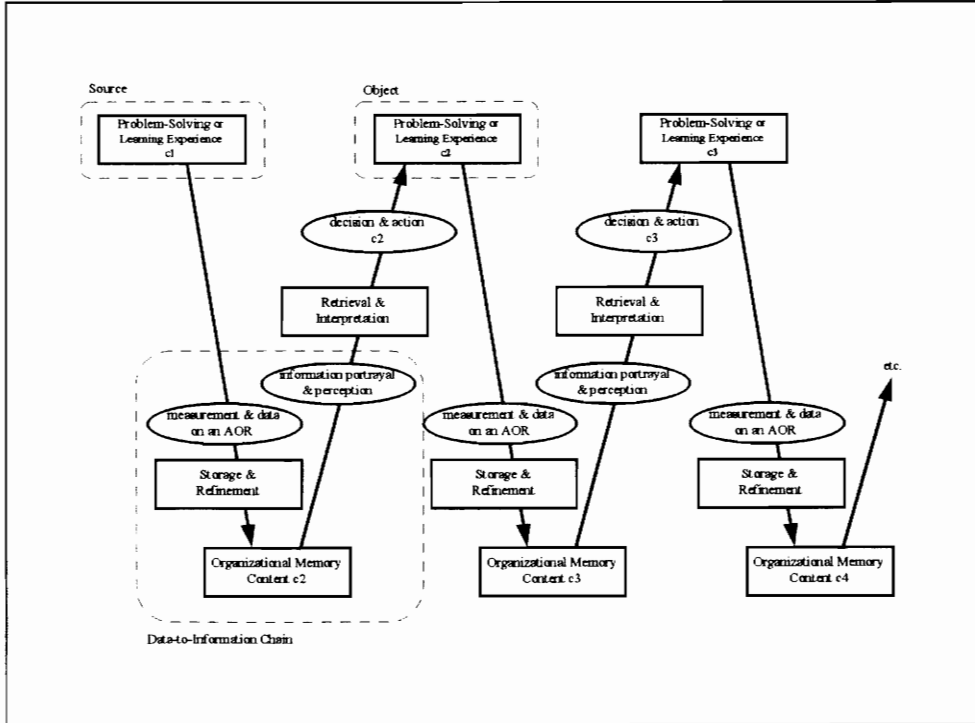
Figure 13. The data-to-information chain for organizational learning.

2.4.3.1. A Lessons-Learned Management Tool Supports Project Planning

I use the PDSA cycle and project management to describe the problem-solving function of organizational learning; i.e., the domain of responsibility.

Management tools support decision making. In this section, I define the task an organizational-learning management tool will support. Jacob and Pakath (1991) discuss the need to make explicit the decision-making process and stage a tool is supporting in the evaluation of a decision-support tool. As can be seen in the conceptual model and process view of organizational learning, problem solving is the activity to be supported by and provides the data and information for organizational learning.

I view the problem-solving function through the lens of the plan-do-study-act (PDSA) cycle. I use the PDSA because the aim of organizational learning is to improve organizational actions and performance through knowledge about AORs based on experience (Fiol & Lyles, 1985). The PDSA is a fundamental process of improving actions through experience (Deming, 1986). An individual PDSA cycle is the problem-solving function of organizational learning and organizational learning is the storage, retrieval, and interpretation from one problem-solving experience to another. Therefore, a management tool to support organizational learning will support a current PDSA with information gained from a previous and relevant PDSA.

I focus on the support of the planning function in the PDSA. Information and knowledge gained from one PDSA can be used to support the development of a plan to use in another PDSA. The "planning" step determines the nature of the problem and constructs a plan. The output of this step is a plan. The plan is a set of expectations about the set of steps to take and the results, i.e., a AOR. In the "do" step the plan is implemented. The result of implementation is a set of results, both outputs and outcomes. In the "study" step, the problem solver compares expected and actual results as well as the actual and intended steps. The result of this study step is information and knowledge about the actions to take

74

in similar context and what actions to take next. This information and knowledge is used in the "act" step to go through the cycle again. The decision is the choice to go through the cycle or to abandon.

The functions and associated outputs of the PDSA cycle are shown in Figure 14. Figure 14 shows two PDSA cycles connected by the sharing of lessons learned through a lessons-learned sharing process.
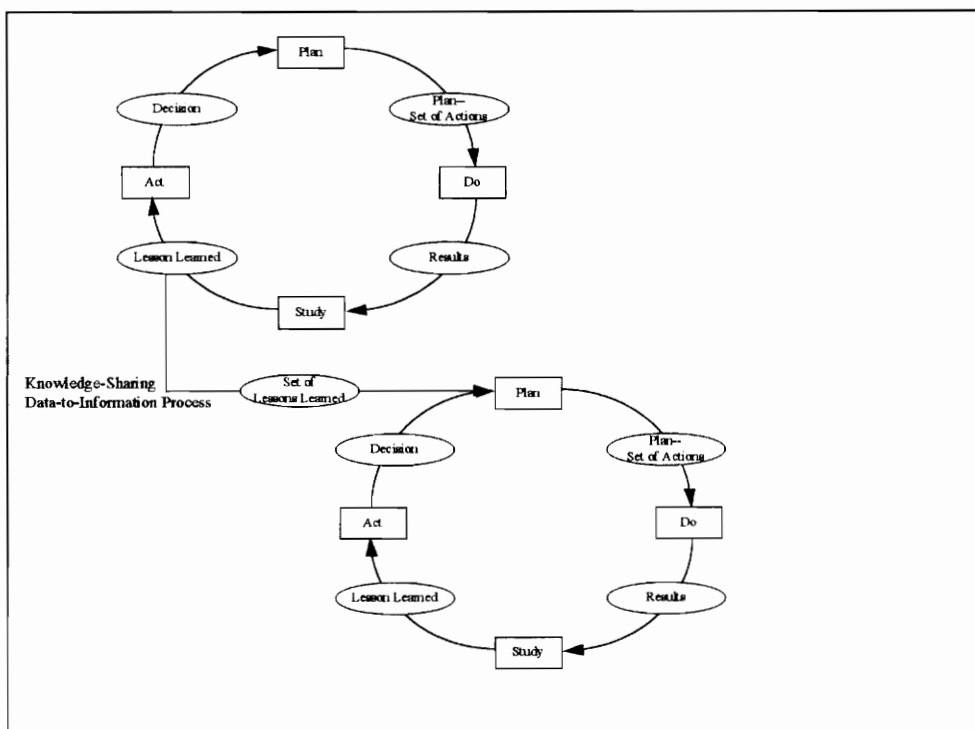
Figure 14. The functions and outputs of the plan-do-study-act cycle.

2.4.3.2. Decisions in Organizational Learning

I use the planning domain to define the decisions in organizational learning.

From organizational learning the domain is the problem-solving activity as defined by the PDSA cycle. More specifically, in organizational learning as the sharing of knowledge from one PDSA to another, we are supporting the planning step of the PDSA. Therefore, the decisions to be made are those related to planning. In planning, given an understanding of the goals and current conditions (i.e., problem context), the planner or decision maker must determine the set of steps to take to accomplish the set of goals. The decisions are (Hayes-Roth & Hayes-Roth, 1979; Kerzner, 1989):

- What are the goals to accomplish?
- What are the relevant conditions of the environment?
- What are the actions or set of steps to take?
- What are the alternative sets of steps?
- What are the expected results?
- What should I do that others have done and found to work?
- What should I not do that others have done and found not to work?
- How do I change the past plans to fit the current situation?
- What needs to be changed?

2.4.3.3. Manipulate and Generate Information to Support Organizational Learning

The information produced can be a variety of forms.

The continuum of forms is a function of the degree to which the tool acts as an "intelligent" entity. For example, the chain can produce (in increasing complexity): (1) a set of relevant plans or lessons learned, (2) a set of lessons with an evaluation for each lesson, or (3) a new plan from past plans by using artificial intelligence techniques (Mostow, 1990; Hammond, 1989). The problem solver uses the information as input to the planning process. For this research, the information to support the problem solver is a set of relevant lessons learned. Fiksel and Hayes-Roth (1989) suggest the design and development of systems which support the human planner by capturing and reapplying planners' knowledge as a viable and more pragmatic intelligent decision support system than automated plan development by a machine.

A lesson learned is "a catchall phrase describing what has been learned from experience" (Juran, 1988, p. 306) and contains three components:

- a plan that consists of the problem context (i.e., goals and conditions) and the set of steps taken to solve the problem;
- the performance of the plan (i.e., outcomes); and
- an explanation of what worked and didn't work and the reasons why.

2.4.3.4.	Procedures for Retrieving, Manipulating, and Generating Data and Information

I split the procedures into three groups: retrieval, manipulating, and generating.

The retrieval mechanisms can be defined using the Anderson (1993) model of human information processing. Retrieval and selection is based on relevancy or the level of match between the current set of conditions, the conditions associated with a lesson learned, and a cost-benefit analysis. Due to the scope of this research, I don't provide the details of the processes and associated formulas.

The information manipulation and generation procedures depend on the type of information provided to the problem solver as discussed in the previous section. If a set of relevant lessons learned is required, then the generation procedure simply produces the set in an ordered fashion. If the set of lessons is to be evaluated, then the procedures can use a cost-benefit evaluation function. The evaluation procedures could select a set of lessons to present to the problem solver. Finally, if the chain is to produce a new plan, then a generation procedure could use artificial intelligence techniques to produce the new plan.

Three sets of data are needed for organizational learning.

Users directly provide two sets of data. A past problem solver supplies the first set of data every time he or she reaches the study step of the PDSA. This first set is the description of the lesson learned from a PDSA cycle as defined earlier.

The second set is used in the retrieval and selection of a lesson learned from memory. A process Anderson (1993) calls pattern matching uses this second set to measure the use and performance of the lesson learned in a context similar to the current one. Pattern matching is the process of determining the match between conditions of rules (i.e., AORs or lessons learned) and the working memory propositions (i.e., conditions). In pattern matching, the rules in memory are matched to the current context or propositions defined in working memory based on the activation level of the rules. Activation level measures the match between the propositions in working memory and the conditions of the rules and is a function of the strength of the rule and the associative strength between the rule and the propositions in working memory. The data needed to determine the activation are:

- the number of times the rule was used in the past;
- the number of times the rule was used given the current context (goals and conditions present);
- the number of time units since the rule was last used; and
- the number of opportunities or rules matched since the rule was created.

The premise of activation is the more times the rule has been used given the presence of a condition the greater the strength of association between the rule and the current context. Pattern matching produces a set of rules that are further evaluated before selection.

The selection of a rule is based on a cost-benefit analysis. Conflict resolution is the process by which one from the set of matched rules is chosen to execute. The selection is based on the expected value of the rule to the current context. The expected value formulas are

used to determine which of the matched rules is the "best" rule to execute given the current context. The rule with the highest expected value is selected.

The expected value is the difference between the expected benefits and the costs. The data parameters needed for the evaluation are provided in the ( ). The expected benefits are computed by multiplying the value of achieving the goal (G) by a probability (P). The probability is a combination of the probability the rule will have its intended effect (q), the probability the goal can be achieved after the rule is fired (r), and the deterioration if the rule fails (f). The probability of rule success is based on the number of times the rule leads to success (mq) and the number of times the rule leads to a failure (nq). The probability of eventual success given the rule used is a function of the number of times the goal is eventually achieved given the rule was successful (mr) and the number of times the goal is not eventually achieved given the rule was successful (nr). The cost (C) is a combination of the cost of executing the rule (a) and the cost of efforts necessary to take after executing the rule to achieve the goal (b).

The current problem solver provides the third set of data. This third set of data acts as the reference points. The reference point defines the goals and conditions of the current problem. This set of data is used by the procedures to select or retrieve a set of "relevant" lessons learned from memory which are applicable to the current problem.

From the Anderson (1993) model, I group the data elements needed to support organizational learning into three categories:
1. the match between past plans and the current problem;
2. the performance of past plans; and
3. the current problem.

The first two data sets are used to refine and update organizational memory. The activation and selection procedures use the data, therefore, when the data is updated the

subsequent selection of a an action (i.e., decision) is based on past performance. Learning is the updating of the data elements for a rule in memory.

2.4.3.6. Conceptual Framework of Information Processing of Organizational Learning

I integrate the information processing model of Anderson (1993) with organizational learning work to develop a conceptual framework of information processing to support organizational learning.

For the information component of organizational learning, the question becomes how can we operationalize the model described by Anderson for an organization or total application system? In this section I begin to draw the parallels between the model of learning defined by Anderson and the literature on organizational learning. Prietula, Beauclair, and Lerch (1990) make the proposition that the mechanisms of individual problem solving are the same for a group of problem solvers or an organization. Since, problem solving and learning are related I can further say the mechanisms for learning are the same for the organization as for an individual.

The terms used by the literature for organizational learning and individual learning are similar in meaning. Organizational learning uses the term action-outcome relationship to represent action whereas individual learning uses a production rule. Both can be represented with an IF <condition> THEN <action> WITH <expected outcome> statement. The set of conditions represents the state of the environment and is called propositions in the individual learning model. Organizational members search for past solutions when designing solutions to new problems (Nutt, 1993). Anderson defines an explicit formula to represent this processing. Anderson calls this process pattern matching. Organizational members select an alternative using cost-benefit or economic analysis concepts. Anderson defines the cost-benefit evaluation of a rule using an expected value. One limitation of this map is that Anderson focuses on a single rule or decision. In organizational learning, we are focusing on both a single decision and a set of decisions called a plan.

2.4.4.	Previous Literature on the Effect of Management Tools on Organizational Learning, Problem Solving, and Project Planning

Past work on management tools and organizational learning has been primarily conceptual. I use two pieces of previous work to help understand the conceptual model.

Searching the management systems engineering (MSE) literature (see Appendix 2 for a list of the journals reviewed) for the last five years, I didn't find much work addressing the sharing of knowledge and information to support organizational learning. The work I did find provides a description of the concept of knowledge sharing or of a tool. However, an evaluation of a lessons-learned sharing management tool to support organizational learning has not been found.

Sidell (1993) describes a lessons-learned system built by Martin Marietta Energy Systems, Inc. This system structures the lessons using free form text and indexes the lessons according to pre-defined categories. The system is described but no evaluation is given. Sullivan and Yates (1988) describe a tool for planning by analogy. The tool is used to support strategic planning efforts for information technology selection and implementation. A profile of the current organization (based on background data and current priorities) is used to search and select cases which are relevant to the current organizational situation. Sullivan and Yates described results of six trials using the tool: one organization accepted the solution as is; three organizations investigated further; one combined features of different cases; and one couldn't find any cases suitable to its situation. This tool does show that a lessons-learned tool can support problem solving. Peters (1992) provides a case study of knowledge sharing at McKinsey. McKinsey uses a central "library" concept to manage knowledge gained through consulting projects. A two page summary of the approach to a project and lessons learned are developed for each project. Peters also describes a lessons-learned sharing process at Buckman Labs. Anecdotal evidence does support the benefits of using a formalized lessons-learned sharing

process. However, we need to evaluate in greater depth the effects of a lessons-learned sharing process on organizational learning.

Elofson and Konsynski (1993) describe a data architecture based on artificial intelligence techniques to support organizational learning of environmental scanning activities. The architecture provides a mechanism to store and retrieve attribute-value pairs describing an environmental phenomena. The authors do not evaluate the architecture for its effects on organizational learning. Fiksel and Hayes-Roth (1989) discuss issues relevant to the design of knowledge systems for supporting planning activities. The support includes a learning component of capturing, updating, and reapplying planners' rationales. The authors do not assess the framework for its effects on organizational learning.

2.4.4.1. Evaluation of Technology Information Exchange Workshops

I evaluated the effects of a formal process or set of workshops aimed at sharing lessons learned within the Department of Energy. I can use these results as a building block for other studies.

I review this work because the results increase my understanding of organizational learning outputs and outcomes.

The purpose of this evaluation was to determine the effects of the Technology Information Exchange (TIE) Workshops. The Department of Energy annually sponsors a workshop for its employees and contractors to discuss lessons learned from environmental restoration efforts. The TIE Workshops are designed to facilitate the sharing of technical information among DOE environmental restoration program workers at sites across the country. The expected result is that new and existing environmental cleanup technologies will be applied more efficiently, less expensively, with better results, and in compliance with regulatory requirements.

Figure 15 represents the conceptual model of the effects of TIE. I developed the model using content analysis of past participants' description of the benefits they received from attending TIE. The model shows a change in knowledge and relationships as the direct outputs of attending a TIE workshop. From this change in knowledge and relationships, participants take actions which impact program actions. Both the individual and subsequent program actions leads to program performance.

From this conceptual model, I developed a survey to assess the extent to which TIE participants received the benefits displayed in the model. The survey attempted to provide evidence to the following questions:

1) How well is TIE meeting its goal of improving communication among DOE environmental restoration program workers?
2) How well is TIE meeting its goal of improving efficiency, cost, and compliance of DOE's environmental restoration activities?
3) How have participants benefited from TIE?
4) How has DOE benefited from TIE?

The survey directly measures the change in knowledge and relationships. The program performance is measured based on a participants perceptions of the possible program performance benefits. Therefore, the survey objective was to determine 1) the extent to which the respondents receive the TIE outputs of knowledge and relationships and 2) the respondents perception of future program performance outcomes. The survey items asked the respondents to provide their judgments about the outputs they received and the subsequent program performance outcome.
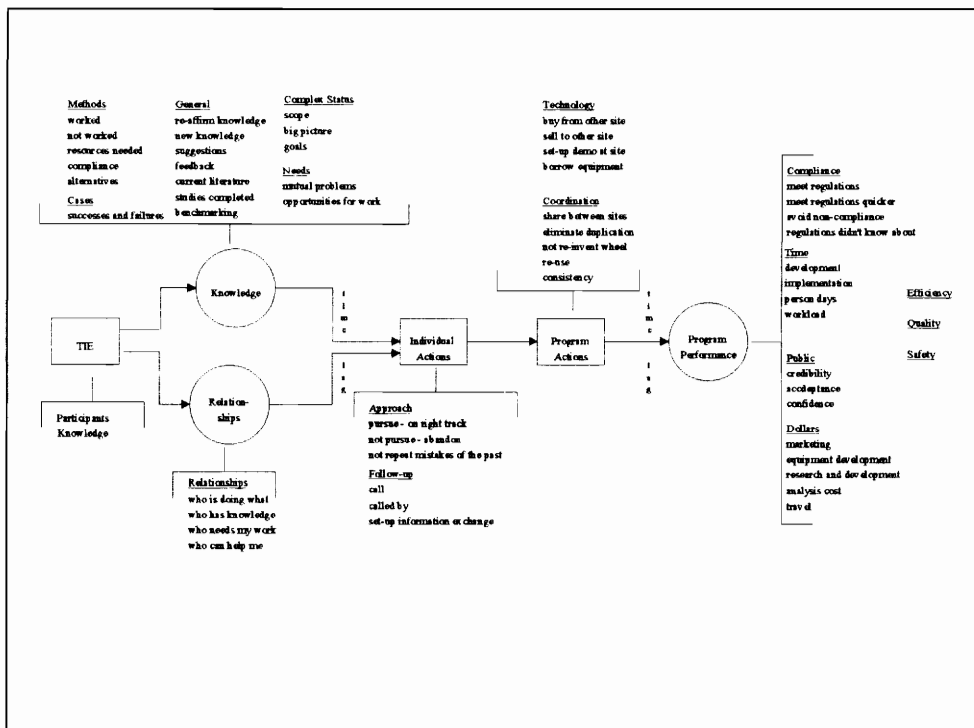
Figure 15. Conceptual model of the effects from TIE workshops.

2.4.4.2. Knowledge Sharing in New Product Development Teams

Purser, Pasmore, and Tenkasi's (1992) study provides survey items and associated factors I can use to assess the effects of a lessons-learned sharing process.

I reviewed this work because I can use the process and items of the survey the authors developed to measure the effects of a formal lessons-learned process.

Purser, Pasmore, and Tenkasi (1992) used an action research approach to study the effects team deliberations on learning in new product development efforts. Two teams were studied. Deliberations are the patterns of exchanges and communication between the research and development people. The author's focused on a non-routine task of new product development. The action research approach the authors used contained three steps: exploratory interviews, survey development, and survey implementation.

The authors conducted exploratory interviews using a structured protocol to identify critical issues of the deliberations. The interview results were then analyzed by the authors using content analysis to develop categories for a survey. The survey contained 17 items. Each item represented a knowledge development barrier. Eighty-one people responded to the survey. The survey results were analyzed using factor analysis. Four factors representing knowledge development barriers were identified: knowledge sharing and planning barriers, knowledge frame of reference barriers, knowledge retention and procedural barriers, and knowledge acquisition barrier. A score was computed for each factor by taking the average of the items making of the factor. The reliability of the scale was computed using a Cronbach alpha value (0.89).

2.4.5.   Functional Description of Lessons-Learned-Sharing Process

I define the functions of a lessons-learned sharing process based on an understanding of (1) the process view of organizational learning, (2) the individual model of learning, and (3) the management tool literature.

I identify three functions of a lessons-learned sharing process or management tool: acquire and store information and knowledge in organizational memory; refine organizational memory; and retrieve and distribute information to support a current decision making or problem-solving task.

The aim of the storage function is to acquire from an individual-learning experience a lesson learned and place the lesson learned in organizational memory for future use. Knowledge acquisition is the process by which the lesson learned is obtained. Knowledge-acquisition techniques such as cognitive task analysis could be used for this function (Williams & Kotnour, 1993b). Once an lesson learned is acquired, the organizational memory must be updated or refined. The aim of the second function is to refine organizational memory based on the new lesson. The retrieval function's purpose is to provide the decision maker with a set of relevant lessons learned to use as an aid to the current problem. This set would then serve as an input to the decision maker. For this research, the emphasis is not on how cases are matched and retrieved by the tool. However, these issues do provide an ample set of research topics. This research focuses on the effect of a lessons-learned sharing process. The flowchart of this proposed process is given in Figure 16.
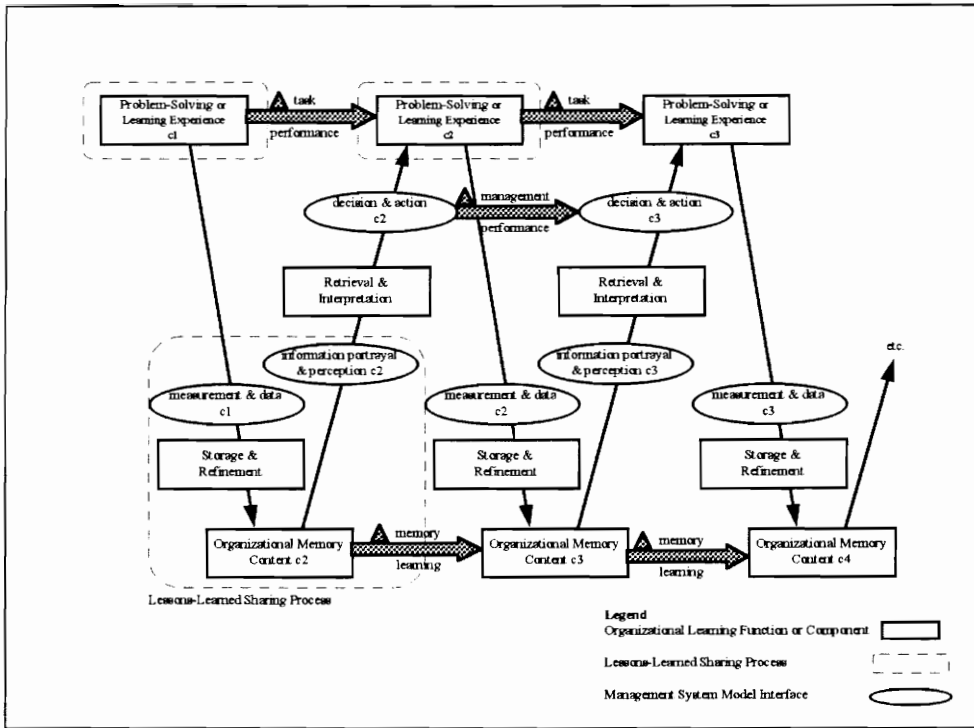
Figure 16. Functional process flow diagram for an organizational learning lessons-learned sharing process.

3.	METHODOLOGY

The methodology has three phases: a field task analysis to prepare for a laboratory experiment, laboratory experiment, and a field validation of the laboratory experiment.

The three phases are connected, with the primary focus of the methodology being the laboratory experiment. Phase one was conducted at Automotive Industries, Winchester manufacturing plant. This plant produces plastic molding pieces for use in automobiles. A piece is manufactured in an injection molding machine using a colored raw material or is painted after being molded. The pieces are then packaged and shipped to the customer. I completed a task analysis of the use of a marker board for communicating lessons learned in the shipping department.

Based on the task analysis, organizational learning literature, and management tool literature, I designed a laboratory experiment to investigate the effects of four different lessons-learned processes (formal and informal structure, and plan and plan+post content). I used my experience with this plant to develop the experiment by generalizing the manufacturing operations (molding, painting, packaging, and shipping) to a generic game for the experimental task. I describe the experimental task in section 3.2.2.

Based on the results of the laboratory experiment, I conducted a follow-up interview in the manufacturing site used in the task analysis. The purpose of the interview was to verify my findings in the field by having a supervisor at the field site (Automotive Industries, Winchester plant) review my findings and conclusions from the laboratory setting.

3.1. **PHASE 1--TASK ANALYSIS FOR EXPERIMENT PREPARATION (FIELD #1)**

I used a task analysis to define the important parameters of the laboratory experiment and lessons-learned process.

I conducted a task analysis of the use of a marker board to communicate lessons learned between supervisors between shifts for a manufacturing environment. Figure 17 is the first figure from my conceptual model, the representation of the lessons-learned process for a shift environment. Each PDSA cycle represents a work shift. The lessons learned from the previous shift (A) is shared with the next shift (B). I developed this shift representation from interacting with first-line supervisors at the Automotive Industries plant in Winchester, Virginia.
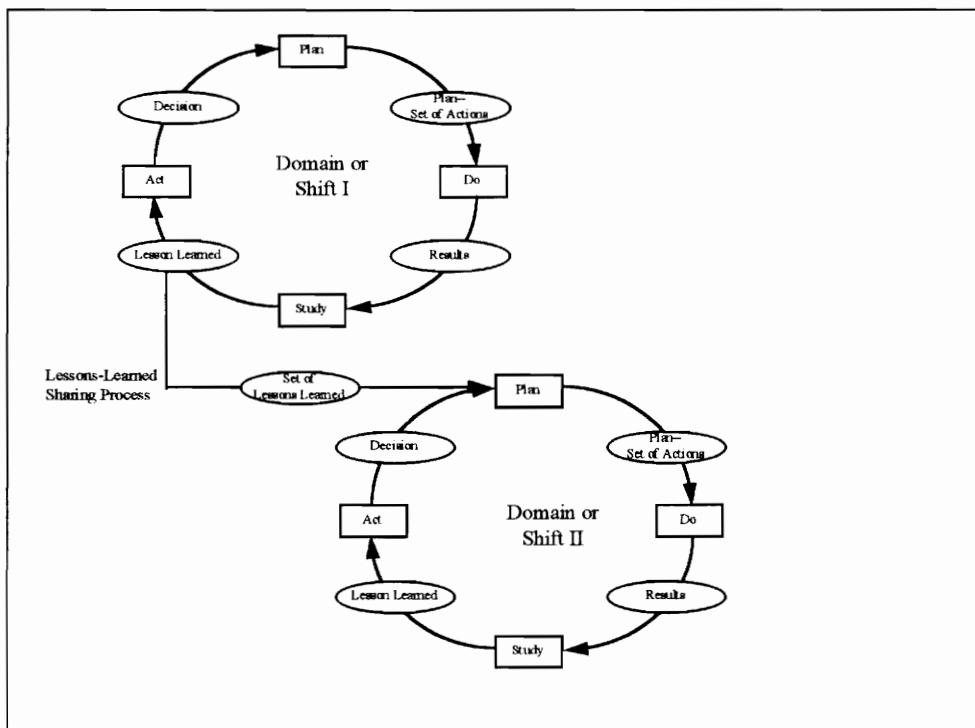
Figure 17. Conceptual model of lessons-learned process in a shift environment.

3.1.1. Important Findings from Task Analysis

In conducting the task analysis, I uncovered five findings useful to the design of an experiment studying the effects of different lessons-learned processes.

The useful findings are:

1. There is variance in the structure of the marker board--unstructured and structured. Different supervisors used different structures for defining the required data on a marker board. One supervisor used a board that had no structure while three other supervisors used boards with structure to define the data to be included on the boards.

2. There is an underlying process of the marker board which is consistent with my view of lessons learned and organizational learning. I can operationalize the model shown in Figure 8 of organizational learning and Figure 17 with shifts at a manufacturing site. From Figure 8, the problem-solving experience is a shift. The storage, refinement, and distribution of organizational memory occurs with the use of a marker board. A supervisor or subordinate interprets the information on the board to support the next shift or problem-solving experience. I discuss the underlying process in more detail when discussing the results of the task analysis.

3. The primary time for updating the marker board is at the end of shift but is updated as needed. I'll focus on the end of the shift.

4. The content of a lesson learned is centered on the status of the plant's operations and changes to standard operating procedures.

5. The content of the lesson learned is used to schedule tasks and resources (people, time, equipment, and shipments) based on changes in status of plant operations and standard operating procedures.

3.1.2.   Task Analysis Process

I used a structured interview process to guide the task analysis with a first-line supervisor of the shipping department on the use of a marker board to communicate lessons-learned.

The task analysis process I used had three major steps. In the first step, I explained to the supervisor the purpose, objective, and process of the task analysis. The purpose of the task analysis was to gain an understanding of how supervisors use the marker board to communicate between shifts. The objective of the task analysis was a detailed description of the process, data, and information associated with the marker board. The process I studied was the use of a marker board to support supervisors in a shipping department as they communicate with each other. In the second step, I reviewed the marker board with the supervisor, drew the marker board, and reviewed an initial process flow diagram of the marker board process with the supervisor. I'll discuss the flowchart in the next section, 3.1.3. In the third step, I interviewed the supervisor. The interview questions are given in Figure 18. Following this interview, the supervisor showed me three other marker boards used by different departments in the plant. The task analysis was completed only for the marker board used by the shipping department.

General Description
1. What is the goal or purpose of the marker board?
2. Where is the marker board located?
3. Why was the board placed there?
4. What are the elements on the board? (Use data-information sheet and draw the board.)
5. What are the major functions of using the board; e.g., update board contents and use information on the board, determine when to update? (Review process flow diagram.)
Inputs and Updating Functions
1. What data are placed on the marker board?
2. How frequently are the data updated?
3. When are the data updated?
4. Who places the data on the board?
5. How are the data collected?
6. How are the data updated?
7. Are all the contents updated at once or as the data change?
8. What problems occur when updating the board contents?
9. How long does it usually take to update the board?
Outputs
1. What information is used on the board?
2. How long does it take to get the information from the board?
3. What are the possible consequences if the information on the board is wrong?
4. Is the information on the board verified before using it?
5. How valid or reliable is the information?
6. How do you know this information is correct or usable?
Decision-Making Use of Board
1. What decisions are supported by the information on the board?
2. Is the information on the board used with other information?
3. What is the other information?
4. How is this other information gathered or communicated (e.g., talk on the phone or face-to-face communications)?

Figure 18. Questions I used for task analysis.

3.1.3. Results of Task Analysis

The manufacturing plant uses the marker board to communicate changes in the status of plant operations and standard operating procedures between and during shifts. The content of the marker board (i.e., lessons learned) is used to schedule tasks and resources (people, time, equipment, and shipments) based on changes in status of plant operations and standard operating procedures.

The purpose of the board is to better communicate information between shifts and during shifts among supervisors and subordinates. The board is used to communicate changes in the status of plant operations and standard operating procedures between and during shifts. The marker board is located outside of the shipping department's office. The board is placed there for convenience since all shipping employees start their shift there and pass by the board frequently during a shift. The functions for using the board are updating the data contents of the board and gathering information from the board to guide decision making. Figure 19 is a representation of the marker board used by the shipping department. The bold items in the figure are the headings or structure defining the data elements and are a permanent part of the marker board. The text in smaller font represents the contents of the board on the day I completed the task analysis. Table 5 provides a description of each of the data elements.

The board is primarily updated at a shift change. The supervisor leaving and the supervisor coming on a shift update the board. The supervisors also have an informal meeting between themselves. This meeting provides more detail than on the board and these data provide the context for the information on the board. Supervisors will also add data to the board during the shift as needed. The data may not change between shifts if the data are still relevant and each datum is updated as needed. The data on the board come from all departments in the plant as well as concerns from customers. Updating the board usually takes less than 10 minutes.

Subordinates and supervisors both use the board. Supervisors use the board with the informal meeting at the beginning of the shift. During the informal meeting, supervisors describe why information is on the board. Supervisors and subordinates take about 5-10 minutes to look at the board and get the information they need. The information on the board supports decision making by both supervisors and subordinates. Subordinates schedule work tasks and determine what procedures to follow. Supervisors use the board to schedule work, set priorities, and schedule trucks for shipment. Supervisors use information on the board with other information: informal shift meetings, production or shipping schedule, and requests made by managers.

The shipping department receives benefits from using the marker board. As a result of using the marker board, supervisors feel they are making better decisions. The supervisor I interviewed felt if she didn't have the markerboards then supervisors would have to tell subordinates everything orally, subordinates would have to find a supervisor during the shift for clarification, or the subordinates and supervisors would find out the information only after the fact or the hard way. Supervisors do find they get called less often on the weekends when they are not at the plant because the board contains the information they need. Also, subordinates have a better idea of what to do if they have free time.

Other departments also use the shipping marker board to check on the working assumptions the shipping department is operating under. For example, if quality sees a quality alert still on the board after the alert has been canceled, then the quality department tells shipping to no longer worry about the quality problem. One problem with the use of the marker board is the accuracy and timeliness of the information on the board. Sometimes, changes in expectations from a manager or the quality department make the information on the board irrelevant or wrong. If information on the board is wrong, then the plant may have to pay for expedition of a shipment or pay a charge if there is an error in a shipment. At times, subordinates double check with the supervisors to see if the

information is accurate. Otherwise, the information is assumed to be trustworthy and reliable.

The process flow diagram for the shipping marker board is given in Figure 20. The process begins with a supervisor making a set of decisions at the beginning of the shift (shift A of Figure 17 and cycle 1 of Figures 2 and 3 shown as SI/C1 in Figure 20). The supervisor makes these decisions by integrating information from many sources (i.e., manager, other supervisors, marker board, production schedule, other departments, and customers). The supervisors and subordinates carry out these decisions. During the shift, the supervisor gets feedback about the plant's operations and customer needs. Finally, at the end of the shift, the supervisor communicates to the next supervisor (shift II of Figure 16 and cycle 2 of Figures 2 and 3 shown as SII/C2 in Figure 19) using the marker board and an informal meeting.

Other departments started to use marker boards to communicate between and during shifts based on the results in the shipping department. The supervisor showed me four other marker boards used by other departments. I did not complete a formal task analysis on these marker boards. The data structure for the marker board ranged from a blank marker board to a marker board with defined categories. The blank marker board, or the board with the most informal structure, was a marker board a supervisor wrote any important messages on for a manufacturing department. The marker board didn't have defined fields. The next marker board was more formal. This marker board used by a manufacturing department had nine columns to add any issues about a specific area (i.e., production, quality, material, process, maintenance, mold shop, rework, paint line, and housekeeping). The receiving department uses the third marker board I reviewed. This board was structured around issues about a specific area as was the manufacturing board (i.e., requirements for raw materials, rework, concerns, paintline, off-line, miscellaneous). The final marker board was used at each manufacturing station. This station board

described the part being made, the mold, the automobile the part was being made for, working leader, and team members at the station. This last station board described what was being worked on and by whom.

I reviewed five boards: shipping, receiving, manufacturing formal, manufacturing informal, and manufacturing station. The first four boards contained more process issues than the station board; i.e., what and how tasks should be carried out for the shift. In the experiment, I'll focus on the marker boards for communicating lessons learned (i.e., how and what to do) between shifts.

Table 5
Description of the Data Elements for the Shipping Marker Board

Date Element	Description or Why Have on Board
Off today	who is not at work today; affects the partnering of subordinates
Locating	used by the manager to determine who is doing what function--docks, corner, shuttles
Loads	what trucks are going out, on what dock, and when; used by all to determine where to put loads
News	informal complaints or quality problems to be aware of
Holding on	what part a truck is waiting for; used by all to determine what to put on the truck next
LTLS (Less Than truckLoad Shipments)	shipments less than a full truck load to be made during the shift
Procedures	changes in standard operating procedures for a specific part
Alert	describes parts that must have an alert label before they can be shipped
Rework	complaint from a department; tells the parts that can not be shipped
Maintenance	status of broken equipment and when it may be available
Special projects	special projects defined by manager to be completed during the shift
Radio frequency	information on on-the-floor shipping scanners
Warehousing	housekeeping tasks for the warehouse

Off Today:
Locating:
     Corner:
     Shuttles:
         In Dock:		

Loads **Plant DK Due Out** 1 2 3	**News** when shipping F718, F385, or F386 air, you must strap cartons and lids together. Do not cut lid on F718	**Holding On**
4 5 6 7 8 9 10 11 12	**LTLS**	**Procedures** starting on 1-23, we will be locating off the floor in Harris 1 & assembly. We are to locate in process as well as finished-same in process goes to GS. Receiving will remove finished product from Harris 2 and paintline (temporary) and put in a holding area in 4Q section to be located. They will handle in process from Harris 2 paintline.

Alerts In process that goes to Gulfstream main F725, Fl27, F533, F328, F619, F185, F329, F294801 Dept. 80 only F293801-Dept. 80 only	**Rework** F955 all F935 all

Maintenance
     Docks:
     Forklifts:
	Special Projects:
	ship F381161-F381162 from 4-D-418 first, do not locate any more F381's in D-48 or D-46 until all old inventory is shipped. Also, ship all O'Sullivan cartons.

Radio Frequency	**Warehousing**
	     Plant:
	     Repack:
	     Consolidate:

Figure 19. Representation of marker board used for communicating between shipping department supervisors.
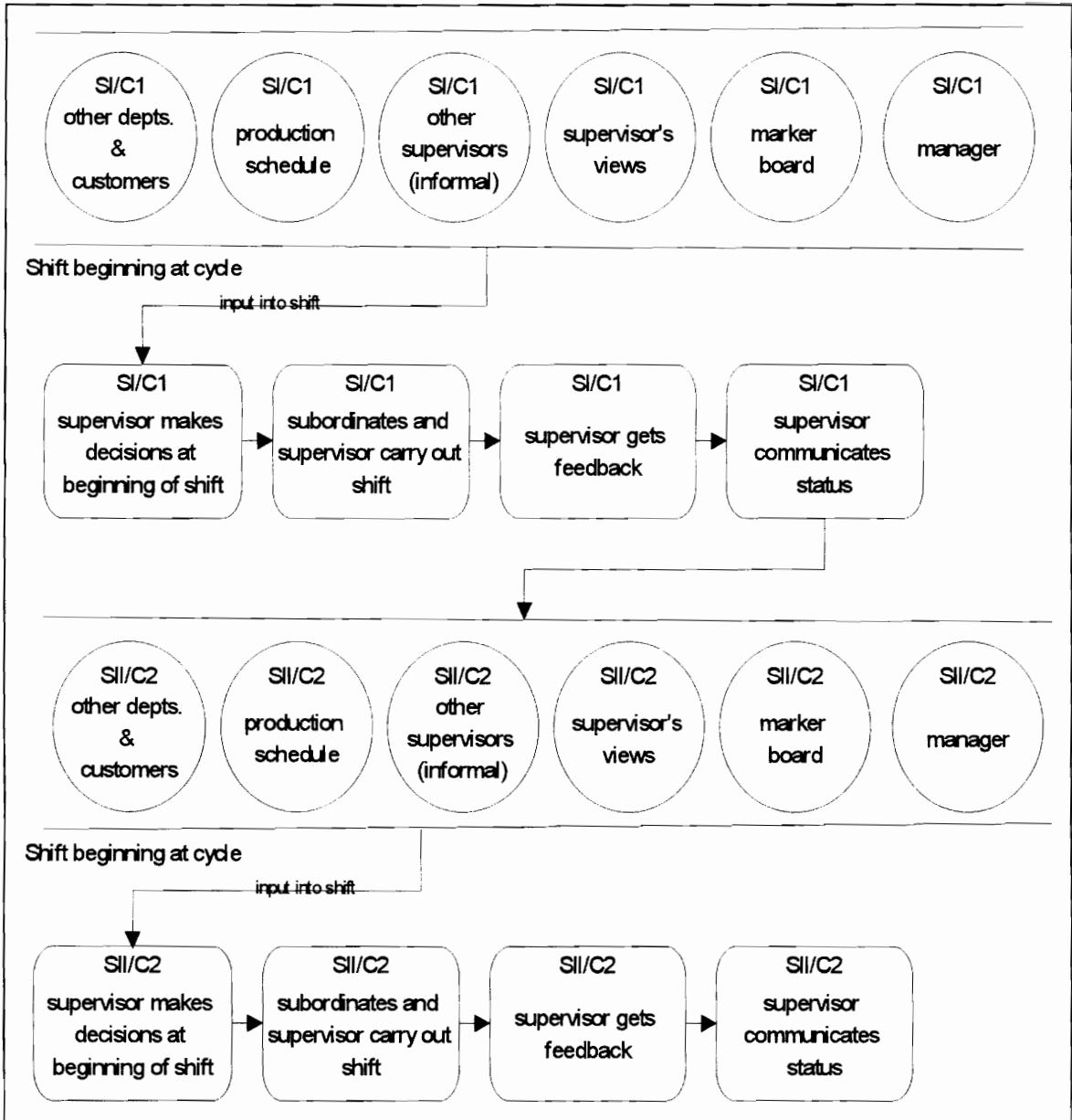
Figure 20. Flowchart of the use of a marker board for communicate lessons learned between shifts.

3.2.	**PHASE 2--LABORATORY EXPERIMENT**

> **I conduct a lab experiment to investigate the effects of four lessons-learned processes. I define an experimental unit to be the subject producing a lesson learned, the lesson learned, and the subject using the lesson learned.**

By conducting this experiment, I answer the research question and provide evidence for the research objective:

> **Research Question**: What is the effect of a lesson-learned sharing process on decision-making performance?
> **Research Objective**: The objective of this research is to provide tangible evidence of the effects of a lesson-learned process to support organizational learning.

I provide tangible evidence and answer the research question by addressing the following specific questions:

1) Is there is a difference in decision quality using no lesson learned and using a lesson learned? Does lesson-learned content affect decision quality?
2) Does structure of the lesson learned affect the quality of a decision?
3) Does an interaction of content and structure affect decision quality?
4) Do the different structures affect the quality of the lesson learned?
5) Is there is a difference in decision-making time using no lesson learned and using a lesson learned? Does lesson-learned content affect the time a subject takes to complete a solution?
6) Does the structure of a lesson learned affect decision-making time?
7) Does an interaction of content and structure affect decision-making time?
8) What affect does structure have on the time to complete a lesson learned?

I attempt to make the experimental situation match the organizational setting as much as possible. I want to have the controls of the experimental setting and the realism of the organizational setting in which a lessons-learned sharing process would be used (Cohen & Bacdayan, 1994). I designed the experiment to allow control but also to be realistic. The experiment was designed with an understanding of the real-world application of a shift-to-shift crew change. This methodology is consistent with management tool or decision support system type research (DeSanctis & Gallupe, 1987).

I define an experimental unit as the unit of analysis for the experiment. The experimental unit for the experimental setting is the sharing process: two subjects and a lesson-learned process structure. The dependent variables for this experiment include the decision quality for the subject producing a lesson learned (subj-P) and the subject using the lesson learned (subj-U). I also need to measure the effects of the process on the lesson-learned content and quality. Figure 21 is a graphical representation of the experimental unit.
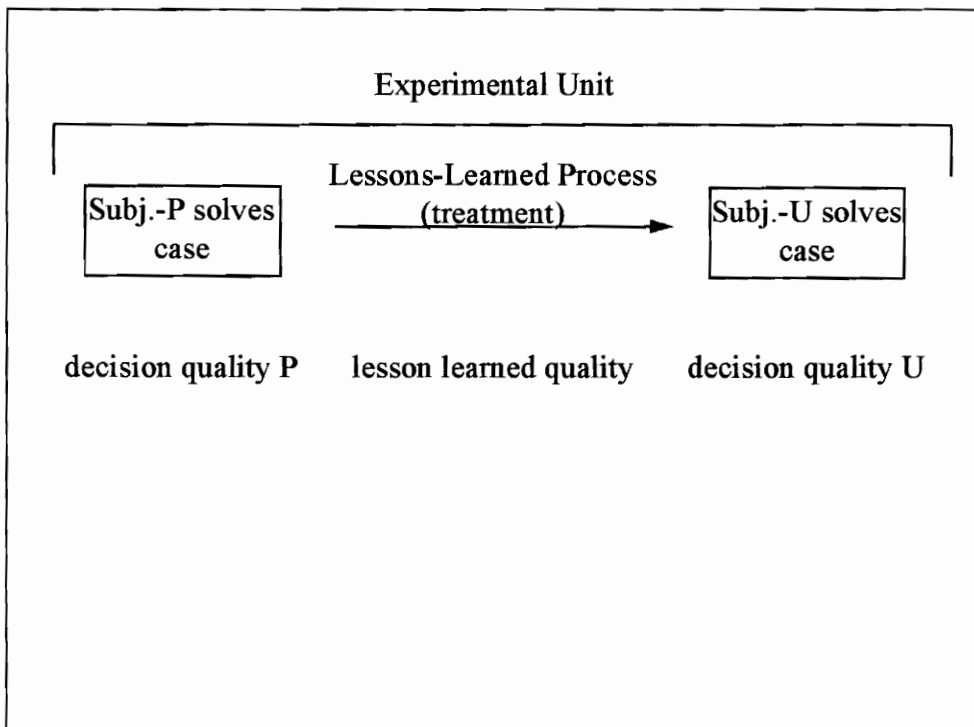
Figure 21. Graphical representation of experimental unit.

In the experiment, I provide a subject with a task or problem to solve. The subject generates a plan or set of decisions. From this set of decisions, I compute and provide feedback to the subject. The subject studies the feedback and produces a lesson learned. The next subject uses the lesson learned to solve the same problem. I assume an experimental task in which a subject is presented with a case description. The case involves selecting a value for each of a set of variables. The different combinations of the

variable values represent different solutions. As part of the experiment, the subject receives feedback that provides insight into the most favorable combination of variable values. For example, if the case has three variables (A,B,C) each with two possible values (1,2), then the different solution combinations are:

1. $A_1B_1C_1$
2. $A_1B_1C_2$
3. $A_1B_2C_1$
4. $A_1B_2C_2$
5. $A_2B_1C_1$
6. $A_2B_1C_2$
7. $A_2B_2C_1$
8. $A_2B_2C_2$.

After the subject produces a solution set, I provide written feedback. The feedback to the subject depends on the set of variable values designated by the subject. I assume one variable set (e.g., $A_2B_2C_2$) to be the best answer or combination of variable values based on a total cost of the decisions.

In designing this methodology, I was influenced by the methodologies used by Marchant et al. (1991) and Antonietti (1991). Their work on studying the analogy process provided insight into how to measure decision quality for a solution derived from an analogy. The work of Sharda, Barr, and McDonnell (1988) also influenced the methodology. They used a decision support tool with a manufacturing "game" played by students. In their experiment, subjects made a set of decisions and then received feedback based on their inputs.

3.2.1.	Assumptions

I make three important assumptions in conducting the laboratory experiment.

The three assumptions are:

1. The amount of initial information for subject-P will be less than or equal to the initial information for subject-U because I use the Plan-Do-Study-Act (PDSA) cycle as a way to view the production and use of a lesson learned. By the very nature of the PDSA cycle, subject-P will uncover information during the first cycle and this information can be used in the next cycle. I am focusing on the process to determine if the information can be transferred and aid the decision making of the second subject; i.e., can subject-P produce a good lesson learned and will subject-U use the lesson learned?

2. The individual decision variables within the task are equally important.

3. There is only one correct value for a variable.

3.2.2. Laboratory Task

I use a task that represents issues relevant to an organizational setting.
The experimental task in the laboratory should have the following characteristics:
represent organizational relevant issues, allow a systematic assessment of a subject's
performance on the task, require limited expertise so as not to limit the subject pool, and
be able to develop feedback for subjects to develop a lesson learned.

I developed a manufacturing "game" in which subjects must determine the correct value
for 10 decision variables. The subject acts as a manager in a manufacturing plant
responsible for distributing resources and tasks for the shift. A shift is evaluated on total
cost of operations for the day, customer satisfaction, and supervisor's satisfaction. The
plant makes three different pieces (A, B, C) on three different machines (X, Y, Z) using
either colored or uncolored raw material. If a piece is made with uncolored raw material,
then the piece must be painted. Each machine has a different processing time. Once the
pieces have completed manufacturing they are packaged for shipment. Two packaging
options are available: standard and binding. The plant also has two forklift trucks to use.
A complete task description is given in Appendix 2.

I make two assumptions in using this game for the experimental task:

1. Subject-P does not have the following information available to him or her but does
   receive the information in the feedback:
   - the correct material option for a piece,
   - notification that part A can't run on machine Y because the manufacturing
     time for machine Y has increased,
   - correct packaging for a product,
   - which forklift to use,
   - overtime costs $15.00 per minute, and
   - overtime is not allowed.
   If the subject had this information, then he or she could develop the correct
   solution.

2. Subject-P does receive feedback that gives the correct answer for each variable. Table 6 shows the feedback given for each decision variable. The total feedback is the combination of all of the individual feedbacks.

A subject has to make the following decisions:

1. Use colored raw material or paint piece A (Colored or Uncolored raw material)
2. Machine to produce part A (Machine X, Machine Y, or Machine Z)
3. Packaging option for part A (Standard or Binding)
4. Use colored raw material or paint piece B (Colored or Uncolored raw material)
5. Machine to produce part B (Machine X, Machine Y, or Machine Z)
6. Packaging option for part B (Standard or Binding)
7. Use colored raw material or paint piece C (Colored or Uncolored raw material)
8. Machine to produce part C (Machine X, Machine Y, or Machine Z)
9. Packaging option for part C (Standard or Binding)
10. What forklift truck to use. (Truck 1 or 2)

Table 6
Information Used for Qualitative Feedback to a Subject

Variable	Feedback if Correct Value Is Chosen[4]	Feedback if Incorrect Value is Chosen
Piece A raw or paint	C: The colored material for piece A was worth the extra cost because we did not have overtime to make the piece.	U: The uncolored material took too long to paint for piece A. Next time use colored material and do not have overtime.
Piece A machine	X: no specific feedback given.	Y: The manufacturing dept. miscalculated the time for machine Y. The manufacturing time for both colored and uncolored materials on machine Y has increased by 0.05 minutes per unit. Try using machine X for piece A. Z: Try using machine X for piece A.
Piece A packaging	B: The customer sent a note to the boss commending you for the excellent shipping service by binding piece A.	S: The customer sent a note to the boss expressing his concern that units of piece A were destroyed in the shipping process. The organization was charged $650 for the pieces. Next time bind the shipping boxes for piece A.
Piece B raw or paint	C: The colored material for piece B was worth the extra cost because we did not have overtime to make the piece.	U: The uncolored material took too long to paint for piece B. Next time use colored material and not have overtime.
Piece B machine	Z: no specific feedback given.	X, Y: Try using machine Z, which has the lowest cycle time. The manufacturing dept. miscalculated the time for machine Y. The manufacturing time for both colored and uncolored materials on machine Y has increased by 0.05 minutes per unit.
Piece B packaging	S: no specific feedback given.	B: The customer was upset because they had to waste their time to unpack the pieces due to the binding of the boxes for piece B. We were charged $150 by the customer and wasted $500 in packaging.
Piece C raw or paint	U: no specific feedback given.	C: Do not waste money on colored material for piece C.
Piece C machine	Y: The manufacturing dept. miscalculated the time for machine Y. The manufacturing time for both colored and uncolored materials on machine Y has increased by 0.05 minutes per unit.	X, Z: Try using machine Y next time.

[4] C represents colored material, U represents uncolored material, X represents machine X, Y represents machine Y, Z represents machine Z, S represents standard packaging, B represents binding packaging.

Table 6 (continued)
Information Used for Qualitative Feedback to a Subject

Variable	Feedback if Correct Value is Chosen	Feedback if Incorrect Value is Chosen
Piece C packaging	**B:** The customer sent a note to the boss commending you for the excellent shipping service by binding piece C.	S: The customer sent a note to the boss expressing his concern that units of piece C were destroyed in the shipping process. The organization was charged $650 for the pieces. Next time bind the shipping boxes for piece C.
Forklift	**Truck 2:** no specific feedback given.	**Truck 1:** Truck 1 broke in the middle of the shift and is in maintenance. The truck will not be available for a week. You were charged overtime because the truck breaking caused a delay in getting the pieces loaded on the truck.
Overall	**If get all the decision variables right:** You completed the best shift the organization has ever had. We made a profit for the shift. Great job, you are up for promotion.	**Overtime:** Your decisions for the day are unacceptable. We had too much overtime to produce the goods. We will not have overtime again.

3.2.3.	Sources of Variance

I define the important sources of variance using a research model.
The important sources of variance are given in Figure 22. The goal of the methodology is to allow me to measure and understand the effects of lessons-learned processes. Two important questions of a lesson-learned process are:

1. what data do we collect? and
2. what structure do we place on the data?

I study two factors in the experiment: content of the lesson learned (none, post, plan + post) and structure placed on the data (informal and formal). The different variables are defined in more detail in the next subsections.

Independent Variables → **Dependent Variables**

Structure of LL*
- Informal
- Formal

Content of LL
- None
- Post
- Plan + Post

Mediating Variable
- quality of lesson learned

Decision Making Performance
- decision quality
- time to make decisions
- time to develop LL

Exploratory Measures
- how subject solved problem and used LL
  - retrospective, open-ended questions
  - worksheets
- what subj.-P gleaned from feedback
- what subj.-U gleaned from LL

*LL = Lesson Learned

Figure 22. Research model.

109

3.2.3.1. Treatments: Independent Variables

I define the independent variable to be the lesson-learned process with two characteristics: content and structure of a lesson learned. I operationalize the concept of a lesson learned using an action-outcome relationship framework.

Content of the Lesson Learned

I use content of the lesson learned to define what component of an action-outcome relationship (AOR) (See section 2.1.2.) is included in the lesson learned. From the AOR framework, a generic lessons-learned structure contains the following components: goals, conditions, and steps or actions (plan); performance (results); and what worked and why, and what didn't work and why (lesson). The content can be "none" (no lesson learned is provided); "post" (contains just the lesson); and "plan + post" (contains the plan, results, and lesson). As shown in Figure 23, I operationalize these generic components for a process-oriented environment like a manufacturing organization.

Structure

I use structure to define the level of detail or prompts provided to the subject to define a lesson learned. The structure can be informal, which is represented by a general question, or formal, in which specified parameters are given for the subject to use.

Figure 23 describes the different components of a lesson learned for both the content and structure factors. As seen in Figure 23, the formal lesson-learned components prompt the subject for specific information, whereas the informal lesson-learned components ask a basic question for each component. I developed the formal prompts based on the task analysis completed in phase 1 and the "game" I use for the experimental task.

Structure Component	Formal Prompts	Informal Prompts

Plan	• What was your plan or set of decisions for the shift?
	   • piece run on Machine X
	   • piece run on Machine Y
	   • piece run on Machine Z
	   • pieces using colored raw material
	   • pieces using uncolored raw material
	   • pieces using standard packaging
	   • pieces using binding packaging
	   • truck used
		• What was your plan or set of decisions for the shift?

Results	• What were the results?
	   • manufacturing, painting, and total time for each piece
	   • costs for material and penalty or overtime (OT) costs
	   • shipping costs and penalty or OT costs
	   • supervisors feedback
		• What were the results?

Lesson	• What did you learn from your shift?
	   • piece run on Machine X
	   • piece run on Machine Y
	   • piece run on Machine Z
	   • pieces using colored raw material
	   • pieces using uncolored raw material
	   • pieces using standard packaging
	   • pieces using binding packaging
	   • truck used
		• What did you learn from your shift?

Figure 23. Components of a lesson learned for both content and structure.

3.2.3.2.   Measures: Dependent Variables

I use decision quality as the primary dependent variable for this methodology. I investigate the time to produce solutions and the time to produce a lesson learned.

Related to the aim of organizational learning and the MSM view of organizations, the primary dependent variable for this methodology is decision-making performance. More specifically, I'm concerned with the decision quality for each subject in an experimental unit as a result of a lessons-learned process. Decision quality can be assessed by 1) comparing a generated solution to an optimal solution, 2) having a set of expert raters judge the solution, or 3) calculating a task-specific measure such as profit (Sharda, Barr, & McDonnell, 1988). I use comparison to an optimal solution for two reasons:

1. I can define the optimal solution and provide feedback to the subject based on the difference between the generated solution and the optimal solution.
2. I need to assess the solution and provide feedback immediately to the subject; therefore, the use of a rater isn't feasible.

Decision Quality (DQ) for a Subject

I define decision quality for a subject as the number of decision variables with the correct value. Each decision variable has a decision variable score (DVS) to denote if the decision variable has the correct answer.

$$DQ_j = \sum_{i=1}^{n}(DVS_i); \text{ where DVS}_i = \quad \text{0 if the decision variable value is not correct;}$$

1 if the decision variable value is correct.

Decision quality is computed for both the producer (DQP) and user (DQU) of a lesson learned. I assume all variables are equally important and there is only one correct value for a variable.

<u>Time</u>

I define three measures of time:

1. DTP - time for producer of lesson learned to develop a solution;

2. LLP - time for producer of lesson learned to develop a lesson learned; and

3. DTU - time for user of lesson learned to develop a solution.

3.2.3.3. Experimental Design

I use a mixed experimental design, with the structure being the between factor and the content being the repeated factor.

Figure 24 is a graphical representation of the experimental design. I use this design to test if:

- there are significant differences in the dependent variables based on content (none, plan +post, post)?
- there are significant differences in dependent variables based on structure (formal, informal)?
- there are significant differences in dependent variables based on the interaction of content and structure?

By using this experimental design, I can also control for the different producers of a lesson learned on the content factor. I have subject-P produce a lesson learned containing both the plan and post components. I then use this lesson learned for two different subjects. One subject uses the post component and the other subject uses the plan+post components. In the Figure 24, EU denotes an experimental unit. Each experimental unit has three subjects, with each subject denoted as $S_{EU,n}$, where EU is the experimental unit and n is the subject number within the experimental unit. For the dependent measures, each subject within an EU is the unit of analysis; that is, each dependent variable is computed for each subject. The EU is used to account for the variance in producing the lesson learned.
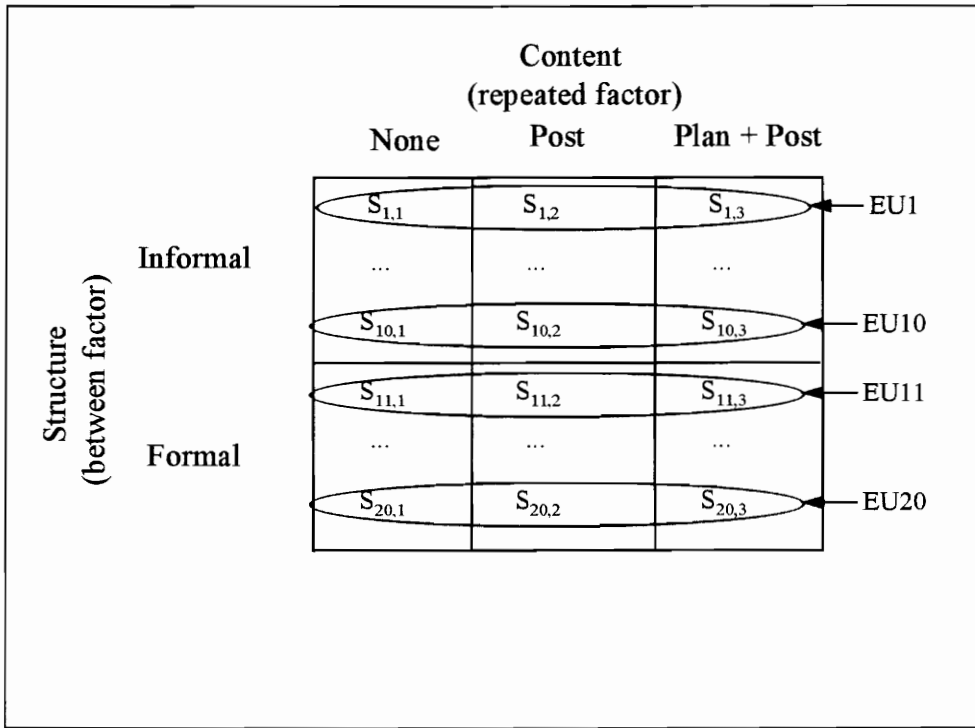
Figure 24. Experimental design.

3.2.3.4.   Measure for Mediating Effect

I define a mediating effect to be the quality of the lesson learned.

A mediating variable is "the generative mechanism through which the focal independent variable is able to influence the dependent variable of interest" (Baron & Kenny, 1986). For this experiment, the quality of the lesson learned is the mechanism through which the lesson-learned process influences the change in decision quality.

Quality of Lesson Learned (QLL)

I define the quality of a lesson learned as the sum of ratings for each variable in a lesson learned.

The quality of a lesson learned = $QLL = \sum_{i=1}^{n}(DVR_i)$.

A decision variable in a lesson learned has a decision-variable rating (DVR) to denote the correctness of the value:

1	if the correct value for a decision variable is specifically described in a lesson learned; e.g., "use colored material for piece A" (where colored material should be used for piece A);
0.5	if the correct value for a decision variable is generally described in a lesson learned; e.g., "use colored material" (where colored material should be used for piece A);
0	if the variable is not described in a lesson learned;
-0.5	if the incorrect value for a decision variable is generally described in a lesson learned; e.g., "use colored material" (where uncolored material should be used for C);
-1	if the incorrect variable value is specifically described in a lesson learned; e.g., "use colored material for piece C" (where uncolored material should be used for C).

The quality of a lesson learned is only measured for the lesson component as described in section 3.2.2.1.

3.2.3.5. Exploratory, Qualitative Data

For this methodology, I collect exploratory, qualitative data. I do not make any hypotheses about these data. These data consist of responses to retrospective, open-ended questions and the worksheets subjects use while solving the task.

I collect these data to look at the general characteristics of the subject's thought process (Ericsson & Simon, 1980) and to provide anecdotal evidence to clarify the quantitative results (Sanderson, James, & Seidler, 1989).

Retrospective, Open-Ended Questions

I collected responses to retrospective, open-ended questions after the subject receives the feedback and produces a lesson learned. I ask these questions to determine if, how, and to what extent the subject used the lesson learned. Questions I ask subjects are given in Figure 25.

Worksheets Used by Subject

I give subjects a set of blank work sheets they could use to record any calculations. I collect the worksheets.

Retrospective, Open-Ended Questions for Subject P

Solution Generation Questions for Subject-P

- What was your decision-making process? How did you arrive at your solution?
- How did you decide what machine to run a piece on and the raw material to use?
- How did you select the packaging options?
- How did you select the forklift truck for the shift?
- What information did you use?
  __Process data   __Problem description
- If you solved this problem again, what information would be helpful?

Lesson Learned Generation-Subject-P

- When you developed the lesson learned:
      How did you determine what data to include in the lesson learned?

Retrospective, Open-Ended Questions for Subject U

Solution Generation Questions for Subject-U

- What was your decision-making process? How did you arrive at your solution?
- How did you decide what machine to run a piece on and the raw material to use?
- How did you select the packaging options?
- How did you select the forklift truck for the shift?
- What information did you use?
            __LL   __Process data   __Problem description

Please explain why your value for a decision variable is the same or different as the value in the lesson learned:

Variable	Lesson Learned Value	Your Value	Why the Same or Different
Material for A			
Machine for A			
Material for B			
Machine for B			
Material for C			
Machine for C			
Packaging for A			
Packaging for B			
Packaging for C			
Truck			

- In summary, how did you use the lesson learned?
- __plan   __post   __plan + post
- __ID wrong __ID right   __Not at all
- Why didn't you use the lesson learned?
- Why did you use the lesson learned?
- What were the advantages of the lessons-learned process?
- What were the disadvantages of the lessons-learned process?

If you solved this problem again, what information would be helpful?

Figure 25. Questions for qualitative verbal reports.

118

3.2.3.6. Exploratory, Quantitative Data

I collect exploratory, quantitative data using this methodology. I do not make any hypotheses about these data. I use these data for further information about the lessons-learned process.

The interaction of the producer and user subjects' actions in the lessons-learned process can be measured at two different points:

1. the information gleaned by subject-P from the feedback; and
2. the information gleaned by subject-U from the lesson learned.

Information Subject-P Gleaned from the Feedback

I give the subject another answer sheet and ask the subject to choose what they believe to be the correct response for each decision variable based on the feedback they received.

Information Subject-U Gleaned from the Lesson Learned

I give the subject another answer sheet and ask the subject to choose what they believe to be the correct response for each decision variable based on the lesson learned.

3.2.4. Research or Methodology Protocol

I follow a process as shown in Figure 26 to conduct the experiment.
In the experiment, I provide a subject with a task or problem to solve. I describe the task I have subjects solve in section 3.2.2. The subject generates a plan or set of decisions. From this set of decisions, I compute and provide feedback to the subject. The subject studies the feedback and produces a lesson learned. After the subject produces the lesson learned, I ask the subject to describe his or her decision-making process. I then present the next subject with the same problem to solve. This subject also receives the lesson learned from the previous subject. The next subject uses the lesson learned to solve the same problem. After the subject completes the task, I ask the subject to explain his or her decision-making process and use of the lesson learned. The detailed process for handling subjects is given in Figure 26. The protocol task sheets used in the experiment are given in Appendix 3.

Dependable Variable Output | **Process** | **Process Output** | **Dependable Variable Output**

1 — Describe experiment to Subj-P

2 — Give task to Subj-P

time 1

Decision-making time for Subj.-P

3 — Subj.-P solve task and develop a solution → Subj.-P Worksheet

time 2

4 — Experimenter "implement" solution → Subj-P solution → Subj-P Decision Quality

5 — Subj-P given written feedback

time 3

Time to make LL

6 — Subj-P develop lesson learned → LL* → Quality of LL Produced

time 4

7 — Subj.-P assessed for what gleaned from feedback → What Subj-P gleaned

8 — Experimenter conduct verbal protocol → Subj.-P Verbal Protocol

9 — Describe experiment to Subj-U

10 — Give task to Subj-U

11 — LL given to Subj.-U → Subj-U solution → Subj-U Decision Quality

time

Decision-making time for Subj.-U

12 — Subj-U solve task and develop a solution → Subj.-U Worksheet

time

13 — Subj-U assessed for what gleaned from lesson learned → What Subj-U gleaned

14 — Experimenter "implement" solution

15 — Subj-U given written feedback

16 — Experimenter conduct verbal protocol → Subj.-U Verbal Protocol

*LL = Lesson Learned

Figure 26. Research protocol for measuring and controlling effects of a lessons-learned sharing process.

121

3.2.5. Testable Hypotheses

I formulate four hypotheses. These hypotheses relate to the analysis to be described later.

Decision Quality

Ha1: The use of a lessons-learned process will affect the decision quality on average for each subject in an experimental unit.

Time to Make Decision

Ha2: The use of a lessons-learned process will affect the time a subject takes to produce a solution.

Quality of Lesson Learned

Ha3: The use of a lessons-learned process will affect the quality of a lesson-learned.

Time to Produce a Lesson Learned

Ha4: The use of a lessons-learned process will affect the time a subject takes to produce a lesson learned.

3.2.6.   Data Collection, Reduction, and Analysis

I follow a process to collect, reduce, and analyze the experimental data.

Collection of Data

I collect a subject's decision set with an answer sheet. I collect the responses to the retrospective, open-ended questions with a tape recorder and by taking notes.

Data Reduction

I use the following table to record the quantitative data for a subject.

Subject #	Experi-mental Unit	Content	Structure	Decision Quality	Time to Make Decision	Time to Make Lesson Learned	Lesson Learned Quality
1	1	N	I				
2	1	PP	I			na	na
3	1	P	I			na	na
4	2	N	F				
5	2	PP	F			na	na
6	2	P	F			na	na

Note: For content: N=none, P=post, PP=post + plan; and for structure I = informal, F = Formal.

For the qualitative data, I classify the decision-making processes and uses of lessons learned by using content analysis. An initial classification is given in 3.2.8.1.

Analysis of Decision-Quality Data

I analyze the data with a mixed-factors ANOVA design. The repeated or within factor is the content of the lesson learned. An experimental unit has the repeated measures for decision quality as (1) the producing subject not having a lesson learned (i.e., the "none" level of the lesson-learned content factor), (2) the subject using the "post+plan" component for the content of a lesson learned, and (3) the subject using just the "post"

component for the content of a lesson learned. The between factor is the structure of the lesson-learned. This ANOVA answers:

1) Is there a difference in decision quality using no lesson learned and using a lesson learned? Does lesson-learned content affect decision quality?
2) Does structure of the lesson learned affect the quality of a decision?
3) Does an interaction of content and structure affect decision quality?

The Statistical Analysis System (SAS) program statements for this analysis are:

```
proc anova;
    class content structure eu;
    model dq = structure eu(structure) content content*structure content*eu(structure);
    test H=structure E=eu(structure);
    test H=content content*structure E=content*eu(structure);
```

Analysis of Time-to-Make-a-Decision Data

I analyze the data with a mixed-measures ANOVA design. The repeated or within factor is the content of the lesson learned. An experimental unit has the repeated measures for decision quality as (1) the producing subject not having a lesson learned (i.e., the "none" level of the lesson-learned content factor), (2) the subject using the "post+plan" component for the content of a lesson learned, and (3) the subject using just the "post" component for the content of a lesson learned. The between factor is the structure of the lesson-learned.

This ANOVA answers:

1) Is there is a difference in decision-making time using no lesson learned and using a lesson learned? Does lesson-learned content affect the time a subject takes to complete a solution?
2) Does the structure of a lesson learned affect decision-making time?
3) Does an interaction of content and structure affect decision-making time?

124

Analysis for Lesson-Learned-Quality Data

I analyzed the quality of the lesson learned using a one factor between-subjects analysis of variance. This ANOVA allows me to answer the question: Do the different structures affect the quality of the lesson learned?

Analysis for Time-to-Produce-a-Lesson-Learned Data

I analyzed the quality of the lesson learned using a one factor between-subjects analysis of variance. This ANOVA allows me to answer the question: What effect does structure have on the time to complete a lesson learned?

3.2.7. Subjects and Sample Size

I use 60 students primarily from the Industrial and Systems Engineering Department.

Based on the results of the pilot study, I use a total of 60 subjects. The subjects receive a $5.00 compensation for participating in the experiment. Fifty seven (87%) of the subjects are engineering majors; 52 are Industrial and Systems Engineering Department students. Three of the sixty subjects (5%) are business majors. Twenty (33%) of the subjects are graduate students, 35 (58%) are seniors, four (7%) are juniors, and one (2%) is a sophomore.

I focus on engineering and industrial engineering students as subjects because I wanted the students to have exposure to the issues relevant to the experimental task. Students need the ability to allocate resources in a cost effective manner, to compute basic mathematics, and to construct and compare different options for a decision. Subjects need these skills because 1) the decision-making process involves developing alternatives and evaluating alternatives against a criterion and 2) the experimental task involves decisions about how to make a piece based on different alternatives. I do not restrict subjects to an industrial engineering background. I have each prospective subject complete a pre-experimental task. The task is described in Appendix 3. If the prospective subject can't complete the task, they are not used as a subject for the experiment. Two prospective subjects are not used in the final analysis. After reading the experimental task, one subject felt she couldn't complete the experiment. One subject worked on the experimental task for 40 minutes and decided she couldn't complete the experiment. Both of these subjects are not used in the final analysis.

I used the pilot study results discussed in section 3.2.8. to determine the effect size and sample size (Keppel, 1991). I conducted an one-factor ANOVA with the factor being the content. The content factor levels for the pilot study are 1) not havinh a lesson learned

and 2) having a lesson learned. As I discuss in the pilot study results, I used the pilot
study to refine the methodology. The results of the ANOVA are:

Source	DF	SS	MS	F-value	Pr>F
Content	1	12.00	12.00	4.00	0.1161
S/Content	4	12.00	3.00		
Total	5	24.00			

I followed a process to determine the sample size:

1. Determine the relative amount of variance explained by the treatment manipulation
    (have no lesson learned or have a lesson learned) =
    $$\omega^2_A = \frac{SS_A - (a-1)(MS_{S/A})}{SS_T + MS_{S/A}} = \frac{12 - (1)(3)}{24 + 3} = .333.$$

2. Determine $\phi^2_A = n' \frac{\omega^2_A}{1 - \omega^2_A} = n' \frac{.333}{.666} = .5n'; \; \phi_A = .707\sqrt{n'}.$

3. Determine the trial size based on the degrees of freedom for the content factor
    (df= c-1=1), the degrees of freedom for the denominator used in the F-value
    computation (df$_{EU/C}$ = c(EU-1) =2(n'-1)), and the power function charts. The
    approximate powers for different sample sizes are:

n'	df$_{EU/C}$	ϕ_A	Approximate Power @ alpha .05	Approximate Power @ alpha .01
5	8	1.58	0.55	
6	10	1.73	0.57	
7	12	1.87	0.68	
8	14	1.99	0.76	0.46
9	16	2.12	0.78	0.52
10	18	2.23	0.85	0.65
11	20	2.34	0.89	0.67
12	22	2.45	0.91	0.72
13	24	2.55	0.93	0.76
14	26	2.65	0.95	0.80
15	28	2.74	0.97	0.84

Balancing the constraints (such as time to run and analyze a subject's quantitative and
qualitative data and availability of subjects) and the above calculations, the trial size is 10
experimental units. I suggest the calculated power (i.e., the ability of the experiment to

detect differences in treatments) is sufficient for the experiment. However, there is a limitation of these calculations in that I do not consider the interaction effects of content and format. Based on my earlier definition of an experimental unit and experimental design, I needed a total of 60 subjects which is 10 experimental units multiplied by 3 subjects per unit (for the content factor) multiplied by 2 subjects per unit (for the structure factor).

3.2.8.	**Lab Pilot Study**

> **I pilot studied the different components of the research protocol by using six subjects to complete four experimental units (i.e., I used each producing subject twice.) From the pilot study I found 1) where I had to clean up the protocol, 2) how to adjust feedback given to a subject, 3) I needed to clarify the type of qualitative data to collect, and 4) I needed to clarify what to look for in terms of use of the lesson learned.**

I grouped my observations from the pilot study on the experiment into nine categories.

1) Time for Subject to Complete Task
- Clarify the time given to the subject (time to read the case and time to solve the case).
- Is the problem too complicated from a time perspective?
- Can I give subjects a time limit of 35 minutes? A 35-minute limit would be comparable to the beginning of a shift because a supervisor must complete the decisions before the start of a shift.
- Do I need to measure a trade-off between cost and quality of decision (maybe standardize and then multiply)?
- Do I want to and how can I limit processing time to 35 minutes (pros: real-life preparation for a shift; cons: influence process, make subject complete too soon) or make 15 minutes to highlight the need to make speedy decisions?

2) Understanding of Lesson-Learned Process
- What is important for the lesson learned, the process (I scheduled the most pieces on the fastest machine, then...) versus the results. This issue may be related to the type of lesson learned: process versus results.
- I found that subjects used the lesson learned differently:
    - Pilot #6 used the lesson learned for information that was absent from the task description; otherwise he used his calculations.
    - didn't use at all
    - used to verify decisions after they made their initial decisions
    - used to try to improve on decisions
    - used to identify things to look for
    - used as an answer

3) Qualitative Data Collection
- I need to determine the best way to get the qualitative information I want.
- I want to get information to allow the description and classification of a subject's use of the lesson learned.

- I need to get the pros and cons from Ericsson and Simon's articles for during and after verbal protocol.
- Collect general observations while the subject is solving the case; for example, his or her process, the use of the lesson learned, or where the lesson learned is (out in the open or hidden away).
- Group the qualitative questions according to decisions such as machines, materials, packaging, and truck. Don't group by individual piece.
- Clarify the following question in the protocol: "If you solved again, what information would you like?"
- Tape record and/or video record solving process and/or qualitative questions. (benefit maybe 2 or 3 papers)
  - Consider possible video measures: # of times and length of look at lesson learned.
- Ask subjects how they used the lesson learned for answer to machine X, etc.
- Compare subject's results to the lesson learned and ask why there is a difference.
- Review the subject's qualitative and process sheets for added information.
- Make observation sheets for process problem-solving observations.
- Ask subjects: Did you see any advantage to the lesson learned and how?
- Ask subjects: What was the first goal you tried to accomplish? How did you determine the machine utilization? How did you determine the raw material to use? How did you determine what packaging to use? How did you determine what truck to use? Did you use the lesson learned in any way when determining.....?

4) Directions Given to a Subject
- Make sure subject understands each part of the information they are given.
- Explain feedback (raw numbers and explanation).
- How do I establish credibility of lesson learned?
  - "The lesson learned represents a previous plant manager's insight into the running of the shift including processing times, status of the plant, and customer desires."
  - "The lesson learned was developed by another subject who performed the same task. You can assume the lesson learned is valid. The lesson learned isn't an attempt to trick you. You can use the lesson learned as an aid to your problem-solving process.
  - Explain or draw picture how the lesson learned was produced.
  - How do I balance the realness versus "forcing" a subject to use the lesson learned?

5) Task Information
- Maybe add a fourth machine to make more difficult, so task isn't as simple as if the subject knows two machines and the third can be determined.
- Add constraint of only piece per machine to the task description.

- Put the number of pieces to produce on the detailed description sheet.
- Change "edition" to "addition" in task description.
- Do I need to include the penalty cost for overtime in the task description?
- Clarify the $600 and $650 penalty cost. The figure is different in the task and detailed descriptions.
- Fix minutes/piece in detailed description.
- Should I reorder the questions into material and machine, packaging, and truck, instead of by piece?
- Fix wording for painting time "A Piece" to "for Pieces A, B, or C".
- Check wording on SOP and standard packaging. There may be some confusion.
- Can I increase possible decision-quality change by increasing the number of pieces requiring binding? Check and see what most of the subjects did.
- Should I include information about binding requirements for customers as part of the task description or feedback? The information would be "once a customer defines a certain packaging option; must forever do." Consider making the packaging options alternating (e.g., one shift want and the next shift not want) but stays the same in feedback?
- Should I do basic calculations for the subjects (e.g., total time to manufacturing for colored and uncolored materials)?
- Where do I include overtime costs: description and/or feedback?
- Emphasize total time per machine is 420 minutes.
- Reorder answer sheet to read machines, materials, packaging, and truck.

6) Lesson Learned Forms
- Make size of unstructured box larger.
- Put in a line in structured lesson learned for the change in machine status.
- Fix the top part of the structured lesson learned for Machine Z.
- Title the different parts of the lesson learned: plan, results, what learned.

7) Feedback Information
- Add to the feedback the 0.1 penalty for piece A on machine Y.
- Put a title on the feedback sections.
- Explain the feedback when I give the feedback to the subject.
- Should the overtime cost be explicitly placed in the feedback?
- Should I talk about the last scheduled maintenance for truck 1?
- Clarify the feedback given to the first subject about machine Y:
  - Give all "hidden" information or just the information pertaining to the decisions made by the subject?
  - For example, do I need to add feedback about machine Y and part A: "Good choice you avoided a 0.1 penalty"?
  - Do I highlight machine Y and piece A interaction no matter the decision.

- How do I balance influencing the experiment in one direction versus developing the same level field for all subjects. Not all of the "hidden" information will necessarily be found in just one cycle; probably two if I only give the subject feedback specific to his or her decisions.

8) Protocol Issues
- Give the subject only one answer sheet.
- Give subjects a complete description of the experiment for them to read.
- Don't allow subject to change the lesson learned once they complete it.
- Schedule subjects in 1.5 hour intervals.
- Give the subject each section of the experiment and task description to read and then ask them if they understand what they read.
- Use pencils.
- Develop a standardized response to subject's questions: "The only data available are contained in the problem description, detailed data, and lesson learned."
- Use a plug-in calculator for the subjects.

9) Discussion
- Explain why I have subject-P produce the lesson learned versus the experimenter. To make more realistic; maybe explain as an experimental alternative.

3.2.8.1. Pilot Study Data and Results

In this section, I describe the data and results from the pilot study. Contained in section 3.2.8. is a description of what I learned from the pilot study in terms of how to improve the experiment. In this section I discuss a subject's quantitative and qualitative results.

Quantitative Data and Results

Subject #	Experi-mental Unit	Content	Structure	Decision Quality	Time to Make Decision	Time to Make Lesson Learned	Lesson Learned Quality
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	1	N	I	4	29:20	4:39	6
3	1	P	I	7	48:00		
4	1	P	I	10	9:04		
5	2	N	F	6	7:27	4:45	10
6	2	P	F	9	12:23		
7	2	PP	F	6	34:56		

Note: For content: N=none, P=post, PP=post + plan; and for structure I = informal, F = Formal.

Qualitative Data and Results
From the qualitative data, I found that subjects use the lesson learned in the following ways:
- Pilot #6 only used the lesson learned when other information that wasn't available; otherwise used his numbers
- not at all
- verify decisions after made
- try to improve on decisions
- use as a check
- identify things to look for
- use as an answer.

Pilot #1- One Person Review Task Description, Worst Case Feedback, and General Process.
I used the first pilot subject to check the protocol, task description, and task feedback. The subject didn't complete the task. Therefore, I don't have any data for this subject.

Pilot #2 - Subject Produced an Unstructured Lesson Learned

The subject solved the problem by:

- manufacturing: developed machine assignments by minimizing processing time and costs; assigned most pieces on fastest machines and manufacturing time for colored or uncolored raw materials; looked at either all uncolored or all colored (mixing them was too difficult).
- packaging: not sure since costs the same either way, did SOP hoping customer didn't complain.
- truck: used A because was serviced most recently.

Other information wanted by subject:

- past history on what machine runs what part the best;
- for packaging, tell ahead of time the customer needs; and
- more history on the truck.

Pilot #3 - Subject Used an Unstructured Lesson Learned

The subject solved the problem by:

- mapping out all of the options,
- not using lesson learned right away, and
- saying he would use the lesson learned to check his work.
- manufacturing: scheduled all pieces on one machine, but when told to revise then did and used lesson learned to determine the correct answer; used the lesson learned for the raw materials.
- truck: used the lesson learned for the truck; he reversed his decision based on the lesson learned.

Pilot #4 - Subject Used an Unstructured Lesson Learned

The subject solved the problem by:

- studying lesson learned first,
- working primarily from lesson learned,
- computing very few calculations,
- using a process of elimination, and
- saying "I'm going to trust this. If I didn't, then I would do more double checking."

Pilot #5 - Subject Produced Structured Lesson Learned (Plan + Post)

The subject solved the problem by:

- manufacturing: looked at the processing times and demands and scheduled the most pieces on the fastest machines (miscalculated times because of seconds per piece versus minutes per piece in task description)
- packaging: use SOP and risk customer complaints because is probably cheaper
- truck: used new truck.

134

Other information wanted by subject:
- customer expectations for packaging,
- why truck broke down, and
- he did say he overlooked some things.

Pilot #6 - Subject Used Structured Lesson Learned (Post)
The subject solved the problem by:
- manufacturing: most pieces on the quickest machine and if time >420, then used colored raw material.
- packaging: not do any binding.
- truck: two-week maintenance was OK.
- using lesson learned for only the packaging-changed decision and said "maybe I'll learn something."
- using lesson learned in face of zero information; didn't override any of his original decisions, but did use to validate some of his decisions.

Other information wanted by subject:
- what item was penalized in packaging.

Pilot #7 - Subject Used Structured Lesson Learned (Plan + Post)
The subject solved the problem by:
- using information in lesson learned and calculated total time, from this tried to see if could switch machines to lower time and
- charting out total time for each machine.
- packaging: tried to lower costs and had no specs on customer expectations.
- truck: used lesson-learned recommendation.
- using lesson learned by calculating his own and then looking at lesson learned.
- still needing to think for yourself but allow to not reinvent the wheel.

Other information wanted by subject:
- customers shipping preferences.

3.3. PHASE 3--POST-HOC FIELD VALIDATION OF LABORATORY EXPERIMENT (FIELD #2)

I used the field to add support or add further detail of the results I found in the laboratory study.

The ideal field verification would be to conduct a field experiment. I did not perform this ideal field verification because that would entail another study and is beyond the scope of this study. However, I did attempt to verify my findings in the field by having a supervisor at the field site (Automotive Industries, Winchester plant) review my findings and conclusions from the laboratory setting. I interviewed the original supervisor from the task analysis.

4.0	**DATA ANALYSIS AND INTERPRETATION**

The experimental data support two of the four hypotheses defined in Chapter 3.

H1:   The use of a lessons-learned process did significantly affect the decision quality on average for each subject in an experimental unit.

H2:   The use of a lessons-learned process did not significantly affect the time a subject takes to produce a solution.

H3:   The use of a lessons-learned process did significantly affect the quality of a lesson-learned.

H4:   The use of a lessons-learned process did not significantly affect the time a subject takes to produce a lesson learned.

I conducted a pre-analysis check on the data. The dependent variables were checked for normality. All dependent variables were found to be from a normal distribution. Also, significant correlations among the dependent variables didn't exist. I used the ANOVA procedure for a mixed (between and repeated factors) experimental design as described by Williges (1992) and Keppel (1991).

4.1.	DECISION QUALITY

The presence and type of a lesson learned had a significant effect on decision quality.

As shown in Table 7, the ANOVA summary table, the original hypothesis about the use of a lesson learned and the decision quality was supported:

H1:   The use of a lessons-learned process did significantly affect the decision quality for each subject in an experimental unit.

The ANOVA shows both main effects of structure (STR) and content (CON) to significantly affect the decision quality for a subject. The formal structure had a significantly higher effect than the informal structure. The higher effect of the structured lesson learned can be explained by the quality of the lesson learned. I discuss lesson learned quality in section 4.3. As shown by the content factor with levels of none, post, and plan+post, having a lesson learned did affect decision quality. Using Duncan's Multiple Range test for the content factor (MS error was CONxEU/STR = 2.400; alpha =.05), there is a significant difference between not having a lesson learned and having a lesson learned (post or plan+post). There is not a significant difference between the post and plan+post type of lesson learned on the effect on decision quality. I discuss the qualitative information about how a subject used a lesson learned in section 4.1.1. The qualitative information offers insight into why there was a significant effect of having a lesson learned (i.e., content factor) and the structure of the lesson learned. The effect of the structured lesson learned on decision quality is also explained by the results of lesson-learned quality.

Table 7
ANOVA Summary Table for Decision Quality

Source	DF	SS	MS	F-value	Pr>F
Between					
STR	1	30.817	30.817	8.27	0.0101
EU/STR	18	67.100	3.728		
Within					
CON	2	56.233	28.117	11.72	0.0001
CON x STR	2	8.033	4.107	1.67	0.2018
CON x EU/STR	36	86.400	2.400		
Total	59	248.583			
Post-Hoc Analysis	None	Post Plan+Post	alpha=0.05		

Note: STR=Structure, EU=Experimental Unit, CON=Content

In Figure 27 the mean decision quality score is given for the content factor. The figure also shows the groupings from the post-hoc analysis. The means and standard deviations for each combination are given in Table 8.
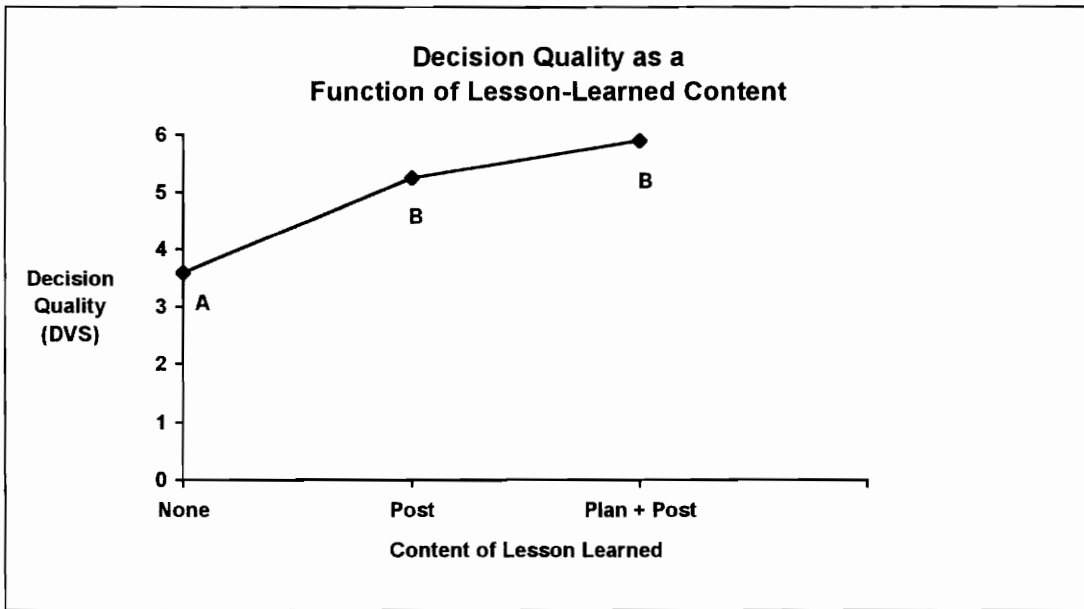
Figure 27. Decision quality as a function of content.

Table 8
Decision Quality Means and Standard Deviations

Factor	Mean	Standard Deviation
Informal STR/ None CON	3.4	1.075
Informal STR/ Post CON	4.3	1.947
Informal STR/ Plan+Post CON	4.9	1.287
Formal STR/ None CON	3.8	0.427
Formal STR/ Post CON	6.2	2.348
Formal STR/ Plan+Post CON	6.9	2.183

4.1.1. Exploratory Qualitative Data: Uses of Lesson Learned

Subjects' responses to retrospective, open-ended questions offer insight into how to, why to, and why not to use a lesson learned. The responses also describe the advantages and disadvantages of using a lesson learned. These results provide insight into the variance of the effects and are hypotheses to be tested in further studies.

I conducted content analysis on subjects' responses to the following questions:

- How did you use the lesson learned?
- Why didn't you use the lesson learned?
- Why did you use the lesson learned?
- What were the advantages of the lesson-learned process?
- What were the disadvantages of the lesson-learned process?

First, I grouped the responses according to factor and level (i.e., informal plan+post, informal post, formal plan+post, and formal post). Second, I read all comments within a group highlighting the important concepts. Third, I reread the highlighted comments and wrote the essence of the comment or concept on a separate sheet according to each question. From the three steps, I had four sets of concepts. I then integrated the four groups of concepts for each question. A summary of this content analysis is given below.

How Subjects Used Lesson Learned

From the subject responses to the retrospective, open-ended questions, I abstracted six processes on how a subject used a lesson learned. The use of the lesson learned ranged from not using the lesson learned at all to using the lesson learned completely as the answer without regard to the validity of the information in the lesson learned. In using the lesson learned as the answer, some subjects used the lesson learned without verifying the recommendations. Other subjects first verified the recommendations; and then, based on their verification, they used the lesson learned. Other subjects used the lesson learned as an input. In this case, subjects used the recommendation as the starting point to narrow the problem space. Subjects also used the lesson learned as a comparison. As a comparison, the lesson learned served as a verification for a subject's calculations. If a

difference existed between a lesson-learned recommendation and a subject's work, then subjects were confused and had to choose between their work and the lesson learned. If the recommendation matched their work, then subjects felt more comfortable with their decision. In summary the lesson learned was used in six ways:

- didn't use at all;
- used as a comparison by completing calculations and then comparing their work to the recommendations in the lesson learned; if there was a difference, then subjects choose either the lesson learned or their own work;
- used the lesson learned as input into the decision-making process as alternatives to explore in developing their own solutions;
- verified the recommendations in the lesson learned and compared to their own work;
- validated the recommendations in the lesson learned and then used as an answer; and
- used the lesson learned as answer without verification.

Why Subjects Used Lesson Learned and Advantages to Using a Lesson Learned

Subjects used the lesson learned because:

- they trusted the information;
- they lacked other information; and
- they wanted to make the problem-solving process more efficient.

Subjects used the lesson learned because they trusted the information as being valid and assumed a competent person developed the lesson learned. Subjects did address the reliability or credibility of the information contained in the lesson learned. One subject said he would be more likely to use the lesson learned if the person who produced the lesson learned was from Harvard University. Subjects felt the credibility of the lesson learned depended on the previous manager who produced the lesson learned and the previous situation under which the lesson learned was developed.

Subjects reported they used the lesson learned because additional information developed from previous experience and results were valuable to solve the current problem. The lesson learned was available and provided an additional source of information; e.g., one

subject said the lesson learned was "the next best thing to being there." They used the lesson learned when they didn't have complete information and felt they had to guess (e.g., packaging options). When a subject was indecisive then he or she used the lesson learned as the answer. Subjects wanted to avoid the previous mistakes of other people. In the case of the formal and plan+post lesson learned, the recommendations or the post part of the lesson learned was used because the plan and associated results provided supporting data for the recommendations. Subjects felt the explanations and reasons for the recommendations were valuable. Subjects used the lesson learned as an additional source of information to support decision making and provide information they lacked and were in need of (e.g., packaging options). Subjects used the lesson learned as an information source:

- to serve as a reference point to start from and narrow down choices,
- to serve as a source of information they didn't have,
- to determine what mistakes to avoid and not repeat,
- to validate or justify a decision or act as a comparison to their own work,
- to serve as the basis for their decisions, and
- to serve as a source of explanations for possible results.

Subjects used the lesson learned to make the problem-solving process more efficient by using the recommendations as the answer or narrowing the set of decisions to consider. In using the lesson learned as the answer, one subject said he didn't have to complete any other work besides taking the recommendations from the lesson learned. Using the lesson learned saved him time and effort.

From an experimental basis, one subject said he had no experience with the task and was therefore more comfortable using the lesson learned than relying on his work. Another subject used the lesson learned because he didn't feel he would be punished if a wrong solution was produced.

Once subjects used the lesson learned and saw the results from their decisions, subjects saw the advantages to using the lesson learned. Subjects identified advantages to having a lesson learned. These advantages include:

- a good source of information provided the information is valid;
- provide another viewpoint and insight into the problem (help identify the right things to do, thoughts on what needs to be changed, eliminate mistakes, not repeat calculations, helped in unknown situations like the truck and packaging decisions);
- provides a comparison or verification of own work; and
- convenience (save time, easier).

Why Subjects Didn't Use Lesson Learned and Disadvantages to Using a Lesson Learned

Subjects didn't use the lesson learned because:

- the information or recommendations were vague or not given,
- there wasn't support for the recommendations,
- they didn't trust the lesson learned,
- their answers seemed better than the recommendations in the lesson learned, and
- they overlooked or ignored the lesson learned by reading too quickly.

Some subjects felt the lesson learned was too vague or general and didn't contain enough specific information to be used. The vagueness of lessons learned are explained in section 4.3. Without having support for the recommendations, subjects were confused by the recommendations and the numerical data initially given. In explaining why he didn't use the lesson learned, one subject said "figures don't lie, but liars figure." Subjects wanted support for the recommendations with "cold, hard facts." Subjects wanted supporting data. Supporting data include both objective numbers and the reasons for the recommendations. To avoid treating a subjective opinion as fact, subjects wanted to see if the lesson learned was based on facts or opinions. Subjects were unsure of the accuracy of the information.

Subjects didn't trust the lesson learned because they didn't know the person who produced the lesson learned and didn't know if the person who produced the lesson learned gleaned or learned the right things or not. One subject questioned the competence or abilities of the producer of the lesson learned. Questioning the competence is a trust issue.

Individual subjects reported other reasons for not using the lesson learned. One subject said he would rather deal with numbers than general suggestions. One subject was unsure if the past situation that the lesson learned was based on was the same as the present situation. A subject was unsure if the past event was just a "freak thing that happened only once" because the past doesn't necessarily foretell the future.

Subjects identified disadvantages to using a lesson learned:
- restricts thinking;
- provides a false sense of security;
- affects decision performance if the lesson learned is not right and use, then results may not be as good as their own work; and
- increases confusion.

The lesson learned can restrict thinking by biasing a subject towards an answer; i.e., as one subject said "jump to a conclusion." A person may use the recommendations without paying attention to other detailed information or his or her own solution. One subject said a person using the lesson learned shouldn't take the lesson learned as a rule book but rather as an additional source of information. The lesson learned can give a false sense of security by providing answers that are not appropriate to the current situation. If the answers of the lesson learned were wrong and taken in a prescriptive manner, then the current answers will be wrong. Subjects said when using a lesson learned a person needs to verify both his or her work and the lesson learned. The subjects also suggest not using the lesson learned as a "crutch." Furthermore, as a one subject said, a person doesn't have to use the lesson learned.

Subjects became confused when their answers didn't match the recommendations and when the recommendations were not supported by reasons or explanations. One subject felt this confusion may have increased his problem-solving time.

4.2.	DECISION-MAKING TIME

The presence and type of a lesson learned did not have a significant effect on decision-making time.

As shown in Table 9, the ANOVA summary table, the original hypothesis about the use of a lesson learned and the decision making-time wasn't supported:

H2:   The use of a lessons-learned process did not significantly affect the time a subject takes to produce a solution.

The means and standard deviations for each combination are given in Table 10.

Table 9
ANOVA Summary Table for Decision-Making Time

Source	DF	SS	MS	F-value	Pr>F
Between					
STR	1	24.461	24.461	0.300	0.5924
EU/STR	18	1482.081	82.338		
Within					
CON	2	266.025	133.013	2.08	0.1402
CON x STR	2	142.957	71.479	1.12	0.3388
CON x EU/STR	36	2306.557	64.071		
Total	59	4222.082			

Note: STR=Structure, EU=Experimental Unit, CON=Content

Table 10
Decision-Making Time Means and Standard Deviations

Factor	Mean (minutes)	Standard Deviation
Informal STR/ None CON	19.092	8.341
Informal STR/ Post CON	16.677	7.148
Informal STR/ Plan+Post CON	17.625	8.559
Formal STR/ None CON	17.615	7.942
Formal STR/ Post CON	11.723	6.088
Formal STR/ Plan+Post CON	20.225	11.265

4.3.	**LESSON LEARNED QUALITY**

Subjects produced a higher-quality lesson learned with a formal structure than with an informal structure.

As shown in Table 11, the ANOVA summary table, the original hypothesis about the lesson-learned structure and the lesson-learned quality was supported:

H3:   The use of a lessons-learned process did significantly affect the quality of a lesson-learned.

In Figure 28 the mean lesson-learned quality score is given for each effect. The means and standard deviations for each combination are given in Table 12. The low quality of an informal lesson learned can be attributed to three factors: subjects not having training in what makes a high-quality lesson learned, the prompts for eliciting the information weren't good enough, or subjects didn't glean the information from the feedback.

The first two reasons, training and lesson-learned prompts, are related. Subjects were not trained or exposed to a lesson learned as part of the experiment. The structured prompts helped subjects define the information. The structured lesson learned was partially a fill-in-the-blank form. The prompts for the informal lesson learned weren't sufficient to elicit the information needed by the next subject.

The third reason, gleaning of information from the experimental task feedback, was checked. I checked for the amount of information a producing subject gleaned from the feedback. A subject after completing his or her lesson learned and answering the open-ended questions, completed a "post" set of decisions. I asked the subject to re-answer the problem using nothing else but the feedback. By having subjects re-answer the problem, I was trying to determine what information they gleaned versus the information they put in the lesson learned. There is no significant difference in this "post decision quality" between subjects completing informal and formal lessons learned (informal mean = 8.5,

formal mean = 9.2, p-value = 0.2564). Post-decision quality is calculated in the same manner as the decision quality for a solution as defined in Chapter 3. The structured lesson learned content may appear to be the best route; however, there are still dangers. The structure helps ensure consistency but not accuracy in defining the data included in the lesson learned. For example, one experimental unit of the structured lesson learned had a lesson-learned quality of -2.

Table 11

ANOVA Summary Table for Lesson-Learned Quality

Source	DF	SS	MS	F-value	Pr>F
STR	1	245.00	245.00	30.25	0.0001
EU/STR	18	145.80	8.10		
Total	19	390.80			

Note: STR=Structure, EU=Experimental Unit, CON=Content
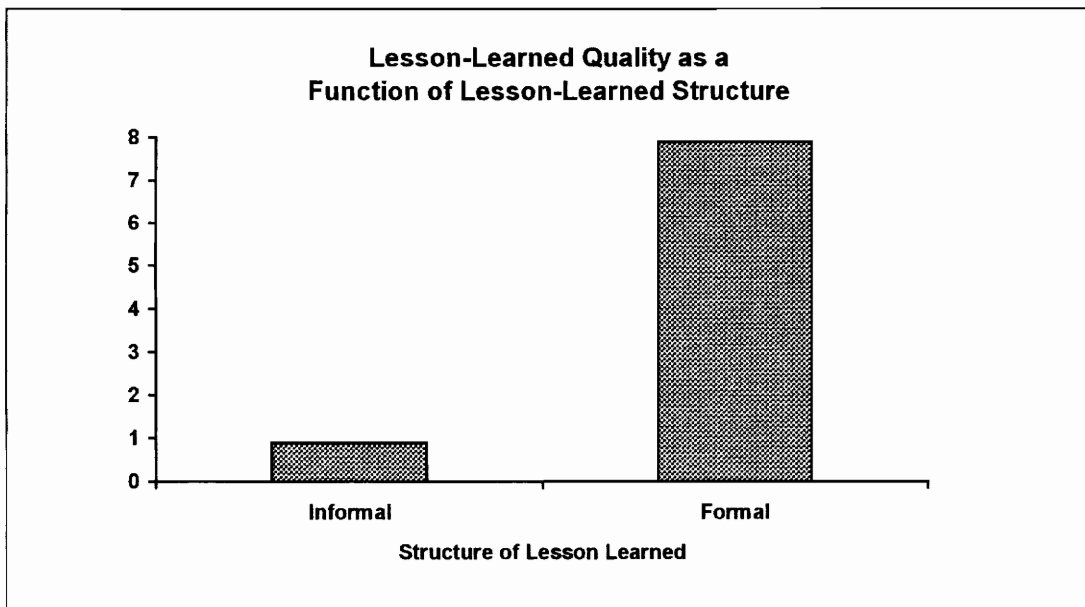
Figure 28. Lesson-learned quality as a function of structure.

Table 12

Lesson-Learned Quality Means and Standard Deviations

Factor	Mean	Standard Deviation
Informal	0.900	1.663
Formal	7.900	3.665

4.3.1.	Exploratory Qualitative Data: Content of Lesson Learned

I classify the content of a lesson learned into six categories. I performed content analysis on both informal and formal lessons learned.

A qualitative analysis of the content of the lesson learned revealed that subjects' responses in a lesson learned can be classified into six categories:

- **specific answer:** subject explicitly stated a decision variable and the value (e.g., use colored material for piece A or use binding for packaging piece C);
- **specific answer with a reason:** subject explicitly stated a decision variable, the value, and the explanation for the value for the decision variable (e.g., use colored material for piece A because colored material has a faster processing time or use binding for packaging piece C because the pieces broke);
- **general answer:** subject provided a description of a set of decision variables values without reference to a specific decision variable (e.g., use colored material or use standard packaging);
- **general answer with a reason:** subject provided a description of a set of decision variables values without reference to a specific decision variable with an explanation for the value (e.g., use colored material because faster processing times or use binding for packaging because customer requested);
- **process:** subject defined a process to arrive at a solution or value for a decision variable (e.g., assign highest demand pieces to machines with fastest processing times); and
- **overall goals:** subject defined the overall goals to achieve by their set of decisions (e.g., reduce the number of processing steps, meet customer requirements, or avoid overtime).

I used a content analysis process to develop the above six categories (Weber, 1985). I first read all the lessons learned. Second, from the initial reading, I developed the classification scheme of the responses. Third, I reread the lesson learned and classified each comment or sentence in the lesson learned. Fourth, I made a grid of the responses and associated classification scheme. Fifth, I reread the lessons learned and refined the classification of the comments.

The more-structured lesson learned elicits specific information. In addition to the specific information, the reasons for making an initial decision and the resulting recommendation need to be captured. The full lesson learned (i.e., plan + post) provided the most insight. Specific fields for a structured lesson learned need to be developed and balanced with the ability to elicit the more-general issues such as overall goals and explanations.

4.4.	**TIME TO PRODUCE A LESSON LEARNED**

The time to produce a lesson learned wasn't significantly affected by the structure of the lesson learned.

As shown in Table 13, the ANOVA summary table, the original hypothesis about the use of a lesson learned and the time to produce a lesson learned wasn't supported:

H4: The use of a lessons-learned process did not significantly affect the time a subject takes to produce a lesson learned.

The means and standard deviations for each combination are given in Table 14.

Table 13
ANOVA Summary Table for Time to Produce a Lesson Learned

Source	DF	SS	MS	F-value	Pr>F
STR	1	54.186	54.186	2.19	0.1566
EU/STR	18	446.358	24.798		
Total	19	500.544			

Note: STR=Structure, EU=Experimental Unit, CON=Content

Table 14
Time to Produce a Lesson Learned Means and Standard Deviations

Structure	Mean (minutes)	Standard Deviation
Informal	9.721	3.799
Formal	13.013	5.929

4.5.	**PHASE 3-FIELD STUDY RESULTS**

The results from the experiment are consistent with experience in the field. Based on the findings of the experiment, I interviewed the supervisor from Phase 1 of this research for further insight into the findings.

The purpose of this third phase, or second field study, was to gain an insight into how the experimental findings related to a field setting. I asked the supervisor the following open-ended questions in relation to her experience in using the marker board to communicate between shifts:

- Why do people use the marker board?
- Why don't people use the marker board?
- What are the advantages to using the marker board?
- What are the disadvantages to using the marker board?

The supervisor said people do use the marker board as a source of information. They use the board because they trust the person placing the information on the board. The supervisor completes the information on the board, conducts a short meeting with her subordinates explaining the information on the board, and the subordinates use the board during the shift. Subordinates don't use the marker board because the information on the board is lengthy or subordinates don't take enough time to read the board. The supervisor reported the primary advantage to using the marker board was not having to repeat the same information to different subordinates. Also, the structure of the board helps her remember what to place on the board. Disadvantages to using the marker board include not having the correct information on the board. The environment may change and the information may not get updated on the board in a timely manner.

The employees in the shipping department changed the structure of the original marker board. They removed some items and expanded space for other items. They increased the space to provide more detailed information and the reasons or explanations for the recommendations on the board.

I also had the supervisor complete a structured survey. I developed the survey using the findings from the qualitative data from the experiment. The survey items and response for each item are given in Table 15. As can be seen in the table, the supervisor agreed with most of the items. Two of the items she disagreed with. These items (too vague and no support for recommendations) focus on why subordinates don't use the marker board. She disagreed with these now; however, two months ago she would have agreed with them. Two months ago they switched the marker board by providing more space for very specific information and explanations for the recommendations. They also started to have a formal meeting every day to discuss the content of the board. The supervisor did agree that the marker board provides a false sense of security. Some subordinates don't go back and check to see if the information has changed since the last shift and they rely on the supervisor to ensure the accuracy of the information.

Table 15
Field Use of Marker Board

Item	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Why do people use the marker board?					
People use the marker board because they trust the information.		X			
People use the marker board because they lack other information.			X		
People use the marker board because they want to make the decision-making process more efficient.		X			
Why do subordinates use the marker board as a source of information?					
Subordinates use the marker board to serve as a reference point to start from and narrow down choices.		X			
Subordinates use the marker board to serve as a source of information they don't have.		X			
Subordinates use the marker board to determine what mistakes to avoid and not repeat		X			
Subordinates use the marker board to validate or justify a decision or act as a comparison to their own work.				X	
Subordinates use the marker board to serve as the basis for their decisions.		X			
Subordinates use the marker board to serve as a source of explanations for possible results.		X			
What are the advantages to using the marker board?					
The marker board is a good source of information, provided the information is valid.		X			
The marker board provides another viewpoint and insight into the problem.		X			
The marker board provides a comparison or verification of own work.		X			
The marker board is a convenience by saving time and making decision making easier.		X			

Table 15 (continued)
Field Use of Marker Board

Item	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Why don't subordinates use the marker board?					
Subordinates don't use the marker board because the information or recommendations on the board are vague or not given.				X	
Subordinates don't use the marker board because there isn't support for the information on the board.				X	
Subordinates don't use the marker board because they don't trust the information on the marker board.			X		
Subordinates don't use the marker board because their answers seem better than the recommendations on the marker board.			X		
Subordinates don't use the marker board because they overlook or ignore the information on the marker board.			X		
What are the disadvantages to using the marker board?					
The marker board restricts thinking.				X	
The marker board provides a false sense of security.		X			
The marker board affects decision performance. If the information on the board is not right and a subordinate uses the information, then results may not be as good as the subordinate's own work.			X		
The marker board increases confusion.				X	

| 5.0 | **CONCLUSIONS** |

This research has increased the information and knowledge and raised more questions about lessons learned.

The aim of this research was to operationalize and validate a lessons-learned sharing process for supporting organizational learning. Within the context of the conditions of the methodology, I validated the process by measuring and evaluating the effects of the process on decision-making (i.e., management) performance. A process is valid if the process is "able to effect or accomplish what is designed or intended" (Webster, 1981), that is, is able to achieve the outcomes. The outcome of organizational learning I studied was management or decision-making performance. The research results provide tangible evidence (i.e., the research objective) about the effects of a lessons-learned sharing process to support organizational learning. A lesson-learned process does improve decision-making performance as measured by decision quality. The research hypothesis was supported; that is, a lessons-learned sharing process will support the aim of organizational learning or improving management performance through knowledge based on experience. Juran's (1988) assumption of lessons learned being beneficial is supported. A lesson-learned process did help improve decisions through better knowledge and understanding (Fiol & Lyles, 1985).

I draw three conclusions from the quantitative data and associated hypotheses:

- having a lesson learned was better than not having a lesson learned;
- a formal or structured lesson learned had a greater effect on decision quality than an informal or unstructured lesson learned; and
- the formal or structured lesson learned produced a higher-quality lesson learned.

I draw these conclusions under the following conditions of the experimental setting:
- the experimental task as described in section 3.2.2,
- the lesson-learned structure and prompts described in section 3.2.3.1., and
- the voluntary subject pool described in section 3.2.7.

I draw three hypotheses to be tested from the qualitative results:

- subjects want explanations for the recommendations in the lesson learned;
- the accuracy and consistency of a lesson-learned content needs to be ensured because people may use the lesson learned as a solution without further work; and
- prompts for eliciting the information in a lesson learned need to be developed.

The quantitative results didn't show a significant difference in the use of a "plan+post" versus a "post" lesson learned on decision quality. However, subjects did say they wanted explanations for a recommendation in the post part of a lesson learned. Further study needs to be completed to clarify the whether or not explanations are needed.

Implications for Research

Based on the results of this research, we can begin to address the role of formal processes and tools for building organizational memory (Huber, 1991) as a formal mechanism needed to transfer individual learning (Kim, 1993). A formal mechanism in the form of a management tool can help ensure process loops are closed for improvement efforts (Kurstedt, 1993). Daft and Huber (1987) called for the definition of the data and information for organizational learning. The results of this research give initial support for the information to collect and distribute. The information should be structured. This structured information should contain all parts of an action-outcome relationship (Duncan & Weiss, 1979): plan, results, lessons. The plan and results provide the hard evidence and reasons for the recommendations. The recommendations at some level provide the theory for the recommendations needed for understanding (Deming, 1986). Other data and information to be part of a lesson learned include the explanations for a recommendation and a contact person to follow-up with and to lend credibility to the lesson learned. The quantitative data showed no difference between the post and plan+post lesson learned on decision quality. However, subjects indicated they wanted to know the "hard evidence" and reasons or explanations for the recommendations. Further research needs to be

conducted on the structure and prompts needed to make a "good" lesson learned. The structured lesson learned supports the detailed coding of knowledge.

A structured lesson learned can improve the transfer of knowledge because a structured lesson learned leads to an explicit coding of knowledge. Zander and Kogut (1995) discuss the transfer of knowledge based on five dimensions, with one dimension being codability. They define codability "as the degree to which knowledge can be encoded" (p. 88) in such ways as a manual or software program. In studying the process of technology transfer, a more-macro process than studied in this research, they found a transfer has a high likelihood of being transferred if the knowledge is codified. This experiment shows that a formal lesson learned leads to a greater-quality lesson learned (i.e., encoding of knowledge) and increases the decision quality.

Implications of this Research for Users of Lessons Learned

The use of lessons learned can be both beneficial and harmful. A balance between the prescriptive and descriptive use of a lesson learned needs to be made. As described in section 4.1.3., there are advantages and disadvantages to using a lesson learned. If a person uses a lesson learned in a prescriptive manner (i.e., uses the lesson learned as the answer without further work) and the lesson learned no longer applies because the knowledge in the lesson learned is outdated, then performance could dramatically decrease. A lesson learned can provide valuable insight and information to help solve a problem. However, an extra source of information containing specific recommendations may also bias or constrain the thinking of the decision maker.

The more-structured lesson learned elicits the specific information. In addition to the specific information, the reasons for making an initial decision and the resulting recommendation need to be captured. The full lesson learned (i.e., plan + post) provided the most insight. Specific fields for a structured lesson learned need to be developed and

balanced with the ability to elicit the more-general issues, such as overall goals and explanations. The structured-lesson-learned content may appear to be the best route; however, there are still dangers. The structure helps ensures consistency but not accuracy in defining the data included in the lesson learned. For example, one experimental unit of the structured lesson learned had a lesson-learned quality of -2.

To effectively use lessons learned, an organization must plan for the lesson learned process. The process should ensure credibility and lead to trustworthy lessons learned. One subject explained that he didn't use the lesson learned because he didn't have confidence in the recommendations. A verification of incoming information is needed (Sidell, 1993). When distributing or using the lesson learned, the similarities and differences between the context of the lesson learned and the current context needs to be addressed (Neustadt & May, 1986).

The use of a lessons learned process needs to be part of an organization's total improvement efforts (Tobin, 1993). The structure, prompts, and training for effective lessons learned need to be developed. The data and information will be different for different domains; for example, a manufacturing plant, a service operation such as continuing education, or a hospital. A formal learning process needs to integrated with a formal management process such as the one described by Kurstedt (1993).

5.1. INTERNAL VALIDITY AND TRANSFERABILITY ISSUES

In this section, I address the validity issues.

In considering validity, we are focusing on the results of our measurement: "Are we really measuring what we think we are measuring?" (Leedy, 1989, p. 27). Pedhazur and Schmelkin (1991) define internal validity as: "the validity of assertions regarding the effects of the independent variable(s) on the dependent variable" (p. 224). Transferability refers to the applicability of the results from one domain to another (Lincoln & Guba, 1985). I discuss transferability within the context of the conditions of the experimental setting as described in section 5.0.

Internal Validity

Internal validity deals with trying to establish the level to which the manipulation or independent variable caused or influenced the observed or measured performance (dependent variable). Pedhazur and Schmelkin (1991) describe nine threats to internal validity. Table 16 summarizes these nine threats and how I addressed them in the research methodology. I used a standard research protocol to help ensure internal validity.

Table 16
Addressing Internal Validity of this Research

Threat to Internal Validity	Description of Threat	How Research Process Addressed Threat
history	events external to the study happen during the study	A subject was used only once and wasn't used between sessions.
maturation	subjects mature during the study	A subject was used only once and wasn't used between sessions. A screening task was used to determine if the subject could perform the basic calculation process. Subjects from engineering and business were used.
testing	a lot of testing leads to practice, memory, or conjecture of research purpose	A single experimental test was used.
selection	process used to assign subjects to treatments	Subjects were randomly assigned to treatment. However, subjects were primarily from a single class.
mortality	attrition of subjects during the study	A subject was used only once and wasn't used between sessions.
instrumentation	the instrument doesn't measure what it is supposed to measure or influences responses	I used a direct measure of decision quality.
regression towards the mean	correlation of items or measures influences the results	I used a direct measure of decision quality. Also, no other relevant measures significantly correlated with each other.
diffusion of treatments	subjects learn about different treatment levels not meant for them	I asked subjects not to discuss the experiments with other people.
compensatory rivalry	subject perceives a difference in compensation for treatments and acts differently	Each subject received the same compensation.

Transferability

Transferability refers to the applicability of the results from one domain to another (Lincoln & Guba, 1985). Transferability is related to external validity. External validity is concerned with generalizability of the conclusions or "can the conclusions drawn from a sample be generalized to other cases?" (Leedy, 1989, p. 27). Internal validity must first be met before external validity can be met. If internal validity isn't met, then there is no need to determine how far we can generalize the results. Transferability or generalizing has to do with the conditions under which the study was conducted:

- **subjects:** population, age, education, experience;
- **setting:** laboratory, field, organizations; and
- **experimental task:** realism between the experimental task and real-world task.

As discussed in Chapter 3, I used primarily students from the Industrial and Systems Engineering Department. These students represent people with a technical background. I generalize to other decision makers with a technical problem working on a task relevant to their domain. The task represented both a process-type activity as found in a manufacturing plant and also a generic problem-solving task. The task and associated lesson learned was used to investigate how well information for running a shift could be communicated. I also generalize to other problem-solving tasks through a general problem-solving model because the lesson learned passed on pertinent information to help in problem solving.

I addressed the setting and experimental task generalizability conditions by using a field study to develop the experiment and the conditions necessary for organizational learning. By using the first phase, or task analysis, I established the use of a lesson-learned process and designed the experiment based on the field study. Therefore, the experiment relates to a use of a lesson-learned process in a field setting. Also, the third phase, or second field study, provided further evidence of a lesson-learned process.

I can generalize to other organizational-learning processes because this experiment met the conditions necessary for organizational learning. I look at validity of the experiment process to ensure that I studied an organizational-learning process. I also address validity by looking at the conditions for organizational learning as defined in section 2.2.8.:

1. an individual must have learned (i.e., confirmed or disconfirmed) an aspect of an AOR (condition, goal, actions, or performance) through experience;
2. an individual must place the lesson learned into organizational memory;
3. organizational members must accept the lesson learned; and
4. organizational members must distribute and retrieve the lesson learned (i.e., use the lesson).

This experiment studied organizational learning. In the experiment, one subject (the producing subject) completed a task. Based on the results and feedback of the task, the producing subject learned something. I confirmed this learning with the post decision-quality measure (condition #1). Next, the producing subject produced a lesson learned that was captured by the experimenter (condition #2). Another subject (the using subject) read the lesson learned that was provided by the experimenter (condition #3 and #4). The degree to which the lesson learned was accepted and used is highlighted in the qualitative and quantitative results. This experiment ensured the four conditions necessary for organizational learning took place.

5.2. OTHER RESEARCH

This research has raised more questions about lessons learned.
From the experiment, we have a better understanding of lesson-learned processes, which can lead to more in-depth studies. I define four groups of other research projects related to lessons learned. Authors such as Tobin (1993) discuss the need for disseminating information to support organizational learning. However, we need to continue to study the process of organizational learning. Other research projects include:

- experimental conditions,
- content of lessons learned,
- field studies, and
- formal models of organizational learning.

Experimental Conditions

This research has shown that lessons learned do help in decision making, but we need to understand the conditions around the use of a lesson learned. These conditions include the types of problems or decisions (e.g., structured versus unstructured), the type of domain (e.g., project management or strategic planning), the reward for getting a correct answer, the level of a person's expertise, and the amount of time to complete a solution (e.g., 5 minutes, 10 minutes, and unlimited time). I would also study in greater depth how a subject uses the different parts of a lesson learned. How does the content of a lesson learned relate to the different stages of the problem-solving process (Jacob & Pakath, 1991)? How does the use of lesson-learned content (plan, results, post) relate to the problem-solving stages?

From the qualitative results, I can develop a structured interview to gain further insight into how a subject developed and used the lesson learned. Some subjects used the lesson learned as an answer without further work while another subject said he relied on his work and data over suggestions. Are there differences in individuals such as problem-solving

styles that affect the use of lessons learned? Why do people prefer to rework versus using past experience? What is this preference a function of?

Content of Lesson Learned

The lesson-learned quality results lead to the research needs of:

- what characteristics make up a good lesson learned?;
- what prompts ensure the most appropriate information is elicited from a person developing a lesson learned?; and
- how does the completion of a lesson learned help a person solve the problem again in the future?

The qualitative data on the content of a lesson learned leads to other research to study the characteristics of a "good" lesson learned. We can study conversations between people and have them rate the usefulness of the conversations. Conversations or implicit transfers are one of Nonaka's (1994) four modes of knowledge transfer. Under what conditions does one mode out-perform another? How do the modes complement each other? We can then compare the classification of the content to see what people think are best lesson-learned conversations. For example, we can study the conversations between nurses during shift changes.

The results for the experiment show that a lesson learned containing a plan, results, and lesson had the greatest effect on decision quality. However, we still need to determine what is the specific type of data and information to include and how to elicit from individuals the "right" information. What other prompts such as the following should we use:

- What was your goal?
- How did you attempt to reach your goal?
- What was your process?
- What were the results?
- What did you learn?
- What would you do again?
- What wouldn't you do again?

- What information do we need to capture and how do we capture it?
- What problems did you have?
- How did you overcome these problems?
- What worked well?
- If you solved this problem again in one year, what would you want to remember?

How do the prompts change for different pursuits and the nature of communication (e.g., during or at the end of a process or project)? Kurstedt (1993) uses pursuits to classify the amount of uncertainty contained in a domain of responsibility. Pursuits range from a perplexity, where we don't have enough information to specify the start nor the end, to a process, where we have enough information to repeatedly achieve the same known end. What data or feedback need to be collected to best support people who construct a lesson learned? Related to the prompts is the question of what is the right training for building a lesson learned?

Another study would determine if by completing a lesson learned, the producing subject increased his or her learning versus a person who didn't create a lesson learned or used different types of lesson learned. How does producing a lesson learned affect later problem-solving performance? Does the lesson learned help the person learn more from the feedback than if he or she didn't complete a lesson learned? What structure helps people learn more? Does a formal structure serve as a checklist of things to look for?

Field Investigations

Field investigations can be undertaken to develop knowledge on implementation issues associated with lesson-learned processes such as the effects of, limitations of, and barriers to using a lesson-learned process in an organization.

Field investigations can be completed on different lesson-learned or organizational-learning processes. We can use a benchmarking process to identify the best practices and

the effects of the different lesson-learned processes. The objective of this research would be to determine the process characteristics needed to ensure a successful lesson-learned process. The conceptual model developed for the dissertation research and the results from the experimental data can be used as a foundation to developing a structured interview. The conceptual model identifies the primary functions and outputs of a process. A series of questions can be developed to describe how an organization implements each function and output. The experimental results, especially the qualitative data, describe the human issues associated with a lesson learned. Again, a structured interview or survey can be developed from the qualitative data to elicit why and how lessons learned are used in the field. The work completed by Purser, Pasmore, and Tenkasi (1992) can be integrated with this research to develop a more detailed survey.

Different domains and organizations may use lesson-learned processes differently. We could study the type of learning processes in different organizations. For example, the industrial site used in the field study uses marker boards and a production control book to track production parameters. What are the various forms of a lesson learned? Why do lesson-learned processes fail? What are the costs and benefits to justify a lesson learned process?

Research needs to be completed on the structure used to define and store lessons learned. As shown in the quantitative results, the structure and content we place on a lesson learned affects the quality and usefulness of the lesson learned. The theoretical definition of the action-outcome relationship shows the importance of defining the context or conditions to describe a problem. The attribute-value pairs need to be defined for a given domain if an organization is to collect, store, and retrieve a lesson learned (i.e., index the lessons learned). Smith (1994) has started developing a classification scheme for quality improvement efforts. Different classification schemes need to be developed for different

domains. For example, what is the classification scheme for management or decision-making tasks? What is the classification scheme for improvement efforts?

In developing a lesson-learned process, a primary question is what to place in organizational memory, what to exclude, and what are the criteria by which we separate the items to keep and discard. Other research focuses on the nature of the problem-solving experiences in organizations. Specific research questions include:

- How many problem-solving experiences are available in an organization to learn from?
- How many opportunities to are there to learn from and transfer?
- What experiences should be captured?
- What are the characteristics of these experiences that tell us to capture them?

Formal Models of Organizational Learning

More work needs to completed on formal models of the data, information, and knowledge needed for organizational learning. We can use the information-processing model of Anderson (1993) as a basis for further work. We can extend the model for one individual to many individuals in an organization. How can we extend Anderson's model to help us understand organizational learning? What are the limitations of using the Anderson model to understand organizational learning?

We can also use the results of the dissertation research as parameters for a simulation model of different organization-learning processes. We can study the effect on an organization over time of methods to transfer lessons learned across the organization. We can include issues such as availability of lessons learned and the similarity of problems.

| 5.3. | **WHAT I LEARNED** |

> **From the experiment, the knowledge about lessons learned did increase; however, I would attempt to make changes to improve on this research.**

In the spirit of the dissertation, in this section I describe my lessons learned. I define these lessons learned by answering the question: If I completed the research project again, what would I do I differently? I did learn that experiments are hard to do because of the need for control. I'm not sure if a person can ever define the "perfect" experiment.

My Research Process

I would do a better job of estimating the time and resources needed to complete a project. I would better understand the trade-offs of doing different methodologies to get the information I wanted. I would spend more time investigating the different approaches in terms of the benefits of the information I could get and the costs of resources and loss of information. I would have thought more about the generalization issues before I developed the methodology as opposed to afterwards.

I would focus more on designing in the controls for the methodology as compared to the measurement of possible nuisance variables. In regard to trust and use of the lesson learned, I focused more on the measurement and not on the process to ensure trust in the lesson learned. I would implement a TQM approach of designing rather than "measuring in."

I learned an experiment is hard to do because of the need to understand and control for interacting variables that affect the dependent variable, with the human being the hardest to control. I found that I enjoy field work much more. However, I do see the need to have a good grasp of theory developed in a laboratory experiment to clarify the issues relevant to a field study. Also, I need to broaden my perspective on how I can use a field

experience as a source of data. For example, I initially didn't see a connection to the dissertation and the field site. However, after talking with a committee member, the possibilities for using the field site were realized.

Research Protocol

The first thing I would do is to better explain the relationship between the subject producing the lesson learned and the subject using the lesson learned. Subjects identified trust as an issue in using or not using a lesson learned. I was aware of the problem when I designed the experiment. My emphasis was more on measurement of the problem than on designing a process to ensure the "trustworthiness" of the lesson learned. I attempted to measure-in trust as compared to design-in trust (a fundamental of quality). The instructions provided a brief set of instructions. I would augment these instructions with a picture of the lesson-learned process in terms on the PDSA cycles. I would also add these instructions:

- Please read the lesson learned carefully, because it may be helpful to you in solving the problem.
- This is not an attempt to trick you.
- Another subject produced this based on his or her experience. The subject completed the task, received feedback, and developed the lesson learned from the feedback. I typed the lesson learned to ensure readability.
- Please speak clearly and loudly during your responses to the open-ended questions.

I'm not sure if I would have other subjects produce the lesson learned. I lost control of the quality of the lesson learned. By having other subjects produce the lesson learned, I increased the realism but lost the control. Some of the lesson-learned subjects had a lesson learned that didn't provide any guidance. These subjects had the same information as the subject producing the lesson learned. I would use a single person as the experimental group as compared to three individuals. I would vary the type of lesson learned or amount of information in the lesson learned. I may have been better able to control for factors affecting decision-making time and the lesson-learned quality or

content. I believe part of the decision-making-time variable is a function of different abilities. I could control for the difference in abilities by using the same subject for each level of the lesson-learned content. By using different subjects in an experimental unit, I increased the amount of error variance.

I would change the manner in which the using subject produced the post-decision quality. I would collect the post-decision quality after the subject completed his or her work and before he or she was given feedback on his or her original answers. I would also tell the subject to leave an answer blank if the lesson learned didn't give him or her an answer. I used this measure to determine how much information the subjects could glean from the lesson learned. By having the subject complete this measure at the end of the experiment, the subject was influenced by feedback from his or her decisions.

I would have used a task already developed and used in other decision-making experiments. A generic task would have increased my subject pool. By using a task I developed, I entered a possible source of variance which hasn't been extensively used and tested.

In asking a subject about how they used the lesson learned, I would use a questionnaire developed from the qualitative data collected in this experiment. The questionnaire could ask the subject to rank order the information and parts of the lesson learned they used. A subject could also define how they used each component of the lesson learned.

The pilot study played an important role on developing the final protocol used in the experiment. In conducting the pilot study, the experimenter needs to keep the same validity issues in mind as when completing the full experiment. I used people I knew in the pilot study. I'm not sure of the effect of the relationship, but the relationship may have affected the use of the lesson learned because the pilot subjects knew me. Therefore, they

may have been more likely to use the lesson learned. When using lessons learned in an organization, the user will probably know the producer. Therefore, the relationship issue may be more realistic.

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| A1. | **JOURNALS USED FOR DISSERTATION** |

I use the management system model to map the body of knowledge related to management systems engineering and my research. I divide the body of knowledge into decision making, management tools, and contextual journals.

Decision-Making Journals
- Decision Sciences
- Journal of Applied Psychology
- Journal of Behavioral Decision Making
- Organization Behavior & Human Decision Processes

Contextual and Management Journals
- Academy of Management Journal
- Academy of Management Review
- Adminstrative Science Quarterly
- Harvard Business Review
- Journal of Management Studies
- Organization Science
- Sloan Management Review

MSE-Management Tool Journals
- ACM Transactions on (Office) Information Systems
- Behavior & Information Technology
- Computers and IE
- Decision Support Systems
- Human Computer Interaction
- Human Factors
- IEEE Transactions of Knowledge and Data Engineering
- IEEE Transactions on Engineering Management
- IEEE Transactions on Man-Machine Systems
- IEEE Transactions on Systems, Man, and Cybernetics
- Industrial Management
- Interfaces
- International Journal of Human-Computer Studies
- International Journal of Intelligent Systems
- International Journal of Man-Machine Studies
- Journal of Engineering and Technology
- Journal of Man-Machine Systems
- Journal of Management Information Systems
- Management Science
- MIS Quarterly
- Machine Learning
- ACM Human Computer Interaction
- Proceedings of the Annual Hawaii International Conference on Systems

EXPERIMENTAL TASK DESCRIPTION

<u>Description of Task</u>
You are a manager at a manufacturing plant. Part of your responsibilities are to distribute resources and tasks for the shift. Your goal is to meet the production schedule in a cost effective manner. Your shift is a standard 8-hour shift with 1 hour of breaks (i.e., a total 420 minutes is available).

<u>Evaluation</u>
You will be evaluated on three dimensions:
- total cost of operations for the day (materials, overtime, shipping, and penalties),
- customer satisfaction, and
- your supervisor's satisfaction.

<u>Product Information</u>
Your organization produces three different pieces: trim piece A, trim piece B, and trim piece C. The customer demands 900 units of piece A, 1000 units of piece B, and 800 units of piece C. The different manufacturing operations include molding and painting. Molding is a process of injecting raw materials into a hot press. Painting is a process of applying paint to a molded piece. Two options exist for producing a piece. The piece can be either molded with a colored material that matches the customer's requirements or the piece can be molded and then painted. However, there are differences in molding time and raw material costs for colored and uncolored pieces. Only one piece can be scheduled on a machine during a shift.

Once the pieces have completed manufacturing they are packaged for shipment. Two packaging options are available: standard and binding. This standard packaging consists of placing the pieces in a box and putting a top on the box. The standard packaging is used unless a customer requests the shipping container be binded. The more extensive binding packaging is the same as the standard with the addition of plastic wrapping and binding of the shipping container. The binding costs $500 more per container than the standard. However, if the customer requests but doesn't receive the special binding then your department is penalized $650. If you send the binding package and the customer didn't request the binding, then you must pay the additional $500 plus a penalty of $150 to the customer to cover the customer's cost of removing the additional packaging material.

<u>Equipment Information</u>
Your department has three machines which can produce the trim pieces and two forklift trucks to transport the materials and finished products. Some pieces work better on some molding machines than others. However, the processing department has not determined the best assignment yet. Both forklift trucks are available, but only one is needed. The trucks do receive periodic maintenance but do fail from time to time. If a truck fails, you may incur overtime cost to fix the truck for the shift.

182

Data About Manufacturing and Shipping Times and Costs

Demand for Piece

Piece	Demand (# of units)
A	900
B	1000
C	800

Molding Time for a Machine per Unit

Machine	Molding Time for Uncolored Raw Material (min/unit)	Molding Time for Colored Raw Material (min/unit)
X	0.40	0.45
Y	0.36	0.43
Z	0.35	0.41

Painting Time per Unit

Type of Raw Material	Painting Time (min/unit)
Colored Raw Material	0.0
Uncolored Raw Material	0.1

Costs for Raw Material

Type of Raw Material	Cost ($/unit)
Colored Raw Material	1.00
Uncolored Raw Material	0.75
Paint	0.20

Costs for Packaging Option

Packaging Option	Cost ($)
Standard Packaging	0.00
Binding Packaging	500.00
Penalty for Not using Binding When Should Have	650.00
Penalty for Using Binding When Shouldn't Have	150.00

Maintenance History for Forklift truck

	Truck 1	Truck 2
Purchase Year	1993	1989
Scheduled Maintenance	Every 6 months	Every 6 months
Last Maintenance	2 weeks ago	4 months ago

A3.   TASK SHEETS FOR EXPERIMENTAL PROCEDURE

This appendix contains the complete set of sheets used to conduct an experimental session with a subject.

Subject-P Process Checklist
Subject #: _____
Group #: _____
Structure: _____
Content: _____
Date & Time: _____

____ Explain experiment
____ Give subject experiment description
____ Ask "Do you have any questions or concerns?"
____ Give IRB consent form
____ Ask "Do you have any questions or concerns?"

____ Get demographic information

____ Give subject the pre-experimental task
____ Check subject's answers
____ Keep or dismiss subject

____ Give subject the task description
____ Ask if have any questions
____ Give subject the detailed information
____ Ask if have any questions
____ Mark the starting time: _____
____ Subject solves the case
____ Subject completes
____ Mark the ending time: _____
____ Get answer sheet
____ Provide and explain feedback to subject
____ Ask if have any questions

____ Give subject the form to produce a lesson learned and give directions
____ Mark the starting time: _____
____ Subject complete the lesson learned
____ Mark the ending time: _____

____ Ask qualitative questions
____ Have them re-answer the question
     If you used nothing but the feedback what would your answers be.
____ Thank them for their help and leave

I will give you a pre-experimental task to perform. If you answer the question right on the pre-experimental task then I will use you as a subject. If you don't answer the problem correctly then I will dismiss you and you will be paid $1 for your time.

For the experimental task, you will be asked to solve a manufacturing resource problem. I'll give you a case to solve. In this case, you will be playing the role of a plant manager. You will provide me with a set of decisions on the case.

The information and tools you have available to you to help in making the decisions are the description, paper, pencil, and calculator.

In developing your answer, the goal is to be as accurate and complete as possible. So take an appropriate amount of time to complete the task. The task should take no more than 40 minutes to complete. I'll inform you when you have worked the problem for 40 minutes. You can take as long as you want.

Based on your decisions, I will give you feedback on the results of your decisions.

From your decisions and feedback, you will produce a lesson learned. A lesson learned is used to capture what we have gained from experience. This lesson learned can then be used by another plant manager (subject) to help him or her run the plant.

After you complete the lesson learned, I'll ask you some questions.

Subject-U Process Checklist

Subject #: _____

Group #: _____

Structure: _____

Content: _____

Date & Time: _____

____ Explain experiment
____ Give subject experiment description
____ Ask "Do you have any questions or concerns?"
____ Give IRB consent form
____ Ask "Do you have any questions or concerns?"

____ Get demographic information

____ Give subject the pre-experimental task
____ Check subject's answers
____ Keep or dismiss subject

____ Give subject the task description
____ Ask if have any questions
____ Give subject the detailed information
____ Ask if have any questions

____ Give subject description of lesson learned
____ Give subject the lesson learned
____ Ask if have any questions
____ Mark the starting time: _____
____ Subject solves the case
____ Subject completes
____ Mark the ending time: _____
____ Get answer sheet

____ Provide and explain feedback to subject
____ Ask if have any questions
____ Ask qualitative questions
____ Have them re-answer the question
       If you used nothing but the lesson learned what would your answers be.
____ Thank them for their help and leave

Experiment Description

I will give you a pre-experimental task to perform. If you answer the question right on the pre-experimental task then I will use you as a subject. If you don't answer the problem correctly then I will dismiss you and you will be paid $1 for your time.

For the experimental task, you will be asked to solve a manufacturing resource problem. I'll give you a case to solve. In this case, you will be playing the role of a plant manager. You will provide me with a set of decisions on the case.

The information and tools you have available to you to help in making the decisions are the description, paper, pencil, calculator, and a lesson learned.

A lesson learned is used to capture what we have gained from experience. The lesson learned was developed by another subject who earlier was part of the experiment. He or she developed the lesson learned based on his or her set of decisions and feedback I gave them.

In developing your answer, the goal is to be as accurate and complete as possible. So take an appropriate amount of time to complete the task. The task should take no more than 40 minutes to complete. I'll inform you when you have worked the problem for 40 minutes. You can take as long as you want.

After you complete the experiment, I'll ask you some questions.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Title of Project: The Effects of Lessons Learned
Principle Investigator: Tim Kotnour and Dr. Harold A. Kurstedt

I.   THE PURPOSE OF THIS RESEARCH
You are invited to participate in a study about information sharing for organizational learning. Information sharing will take place using a lesson learned. A lesson learned represents anything gained from experience. This study involves experimentation for the purpose of determining the effects of different lesson-learned processes for sharing information between people to support organizational learning.

II.   PROCEDURES
In this experiment you will be asked to solve a problem by making a set of decisions about a manufacturing operation. The experiment will require about one (1) hour of your time. You will solve a case, answer questions to be used by another subject, and answer questions the experimenter will ask you.

III.   BENEFITS OF THIS PROJECT
Your participation in the research will provide insight into the usefulness of lessons-learned for sharing information. This research will investigate different forms of a lesson-learned process. You may receive a summary of this research when completed. If you would like this summary please let the experimenter know.

IV.   EXTENT OF ANONYMITY AND CONFIDENTIALITY
The results of this study will be kept strictly confidential. At no time will the researchers release the results of the study to anyone other than individuals working on the project without your written consent. The information you provide will have your name removed and only a subject number will identify you during analyses and any written reports of the research. Part of experiment will be audio taped. These tapes will be reviewed by Tim Kotnour.

V.   COMPENSATION
For participation in the research you will receive $5.00. You will first perform a screening task. If you successfully complete this task then you will complete the full experiment and receive $5.00. If you fail to complete the screening exercise then you will be dismissed and receive $1.00.

VI.   FREEDOM TO WITHDRAW
You are free to withdraw from this study at any time without penalty. If you chose to withdraw, you will be compensated for the portion of time of the study.

VII.   APPROVAL OF RESEARCH
This research project has been approved, as required, by the Institutional Review Board for projects involving human subjects at Virginia Polytechnic Institute and State University and by the Department of Industrial and Systems Engineering.

VIII.   SUBJECT'S RESPONSIBILITIES
I know of no reason I cannot participate in this study.

_____

Signature

IX.   SUBJECT'S PERMISSION

I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

Should I have any questions about this research or its conduct, I will contact

Tim Kotnour	231-7822
Investigator	Phone
Dr. Harold A. Kurstedt, Jr.	231-5885
Faculty Advisor	Phone
Ernest R. Stout	231-9359
Chair, IRB	Phone
Research Division	

Demographic Information

Major
__ Engineering

_____ (Department)

__ Business

_____ (Department)

__ Other

_____ (Department)

Level in school
__ Freshman
__ Sophomore
__ Junior
__ Senior
__ Graduate Student

Pre-Experimental Task

You are to travel from City D to City E. The distance between the cities is 500 miles. You can travel by three methods: fly, drive, or walk. Your goal is to spend the least amount of money in the trip. Your total costs are: 1) cost of transportation and 2) cost of your time.

You personal time costs $10.00/hour.
The costs and time for each travel method is given below:

Method	Transportation Miles/Hour	Cost/Mile
Fly	500	$1
Drive	50	$0.50
Walk	5	$0.05

How long does it take to complete the trip by each method?
- fly
- drive
- walk

How much is the transportation cost for each method?
- fly
- drive
- walk

How much is your personal cost for each method?
- fly
- drive
- walk

What is the total cost for each method?
- fly
- drive
- walk

What is the cheapest alternative?
- fly
- drive
- walk

Experimenter's Observations

Description of Task

You are a manager at a manufacturing plant. Part of your responsibilities are to distribute resources and tasks for the shift. Your goal is to meet the production schedule in a cost effective manner. Your shift is a standard 8-hour shift with 1 hour of breaks (i.e., a total 420 minutes is available).

Evaluation

You will be evaluated on three dimensions:
- total cost of operations for the day (materials, overtime, shipping, and penalties),
- customer satisfaction, and
- your supervisor's satisfaction.

Product Information

Your organization produces three different pieces: trim piece A, trim piece B, and trim piece C. The customer demands 900 units of piece A, 1000 units of piece B, and 800 units of piece C. The different manufacturing operations include molding and painting. Molding is a process of injecting raw materials into a hot press. Painting is a process of applying paint to a molded piece. Two options exist for producing a piece. The piece can be either molded with a colored material that matches the customer's requirements or the piece can be molded and then painted. However, there are differences in molding time and raw material costs for colored and uncolored pieces. Only one piece can be scheduled on a machine during a shift.

Once the pieces have completed manufacturing they are packaged for shipment. Two packaging options are available: standard and binding. This standard packaging consists of placing the pieces in a box and putting a top on the box. The standard packaging is used unless a customer requests the shipping container be binded. The more extensive binding packaging is the same as the standard with the addition of plastic wrapping and binding of the shipping container. The binding costs $500 more per container than the standard. However, if the customer requests but doesn't receive the special binding then your department is penalized $650. If you send the binding package and the customer didn't request the binding, then you must pay the additional $500 plus a penalty of $150 to the customer to cover the customer's cost of removing the additional packaging material.

Equipment Information

Your department has three machines which can produce the trim pieces and two forklift trucks to transport the materials and finished products. Some pieces work better on some molding machines than others. However, the processing department has not determined the best assignment yet. Both forklift trucks are available, but only one is needed. The trucks do receive periodic maintenance but do fail from time to time. If a truck fails, you may incur overtime cost to fix the truck for the shift.

Data About Manufacturing and Shipping Times and Costs

Demand for Piece

Piece	Demand (# of units)
A	900
B	1000
C	800

Molding Time for a Machine per Unit

Machine	Molding Time for Uncolored Raw Material (min/unit)	Molding Time for Colored Raw Material (min/unit)
X	0.40	0.45
Y	0.36	0.43
Z	0.35	0.41

Painting Time per Unit

Type of Raw Material	Painting Time (min/unit)
Colored Raw Material	0.0
Uncolored Raw Material	0.1

Costs for Raw Material

Type of Raw Material	Cost ($/unit)
Colored Raw Material	1.00
Uncolored Raw Material	0.75
Paint	0.20

Costs for Packaging Option

Packaging Option	Cost ($)
Standard Packaging	0.00
Binding Packaging	500.00
Penalty for Not using Binding When Should Have	650.00
Penalty for Using Binding When Shouldn't Have	150.00

Maintenance History for Forklift truck

	Truck 1	Truck 2
Purchase Year	1993	1989
Scheduled Maintenance	Every 6 months	Every 6 months
Last Maintenance	2 weeks ago	4 months ago

Lesson-Learned Instructions for Using Subject

This lesson learned represents a previous supervisor's insight into the running of the shift including actual processing times, status of the plant, and customer desires.

Original Answer Sheet

Please give your assignments to the workers using the following scoring sheet:

1. Use colored raw material or uncolored raw material and paint piece A
   1. Colored raw material
   2. Uncolored raw material

2. Machine to produce piece A
   1. Machine X
   2. Machine Y
   3. Machine Z

3. Use colored raw material or uncolored raw material and paint piece B
   1. Colored raw material
   2. Uncolored raw material

4. Machine to produce piece B
   1. Machine X
   2. Machine Y
   3. Machine Z

5. Use colored raw material or uncolored raw material and paint piece C
   1. Colored raw material
   2. Uncolored raw material

6. Machine to produce piece C
   1. Machine X
   2. Machine Y
   3. Machine Z

7. Packaging option for piece A
   1. Standard packaging
   2. Binding

8. Packaging option for piece B
   1. Standard packaging
   2. Binding

9. Packaging option for piece C
   1. Standard packaging
   2. Binding

10. Which forklift truck to use
    1. Truck 1
    2. Truck 2

Lesson-Learned Instructions for Producing Subject

Use the following form to capture what you have learned from this shift or problem. This lesson learned can then be used by the next shift manager to help him or her in making a set of decisions. In developing your lesson learned, the goal is to be as accurate and complete as possible. So, take an appropriate amount of time to complete the lesson learned.

Verbal Report Form for Subject P

What was your decision-making process? How did you arrive at your solution?

How did you decide what machine to run a piece on and the raw material to use?

How did you select the packaging options?

How did you select the forklift truck for the shift?

What information did you use?
__Process data   __Problem Description

If you solved this problem again, what information would be helpful?

Lesson Learned Generation-Subject-P
When you developed the lesson learned:
        How did you determine what data to include in the lesson learned?

Verbal Report Form for Subject U

<u>Solution Generation Questions for Subject-U</u>

What was your decision-making process? How did you arrive at your solution?

How did you decide what machine to run a piece on and the raw material to use?

How did you select the packaging options?

How did you select the forklift truck for the shift?

What information did you use?
__LL   __Process data   __Problem Description

Variable	Lesson Learned Value	Your Value	Why the Same or Different
Material for A			
Machine for A			
Material for B			
Machine for B			
Material for C			
Machine for C			
Packaging for A			
Packaging for B			
Packaging for C			
Truck			

In summary, how did you use the lesson learned?
__plan   __post   __plan + post
__ID wrong   __ID right   __Not at all

Why didn't you use the lesson learned?

Why did you use the lesson learned?

What were the advantages of the lessons-learned process?

What were the disadvantages of the lessons-learned process?

If you solved this problem again, what information would be helpful?

Follow-Up Answer Sheet
Please give your assignments to the workers using the following scoring sheet:
1. Use colored raw material or uncolored raw material and paint piece A
    1. Colored raw material
    2. Uncolored raw material

2. Machine to produce piece A
    1. Machine X
    2. Machine Y
    3. Machine Z

3. Use colored raw material or uncolored raw material and paint piece B
    1. Colored raw material
    2. Uncolored raw material

4. Machine to produce piece B
    1. Machine X
    2. Machine Y
    3. Machine Z

5. Use colored raw material or uncolored raw material and paint piece C
    1. Colored raw material
    2. Uncolored raw material

6. Machine to produce piece C
    1. Machine X
    2. Machine Y
    3. Machine Z

7. Packaging option for piece A
    1. Standard packaging
    2. Binding

8. Packaging option for piece B
    1. Standard packaging
    2. Binding

9. Packaging option for piece C
    1. Standard packaging
    2. Binding

10. Which forklift truck to use
    1. Truck 1
    2. Truck 2

Closing Instructions

Thank you for participating in the experiment. Please do not communicate with other people about this experiment because they may be a subject.

Informal Lesson Learned Form

What was your plan or set of decision for your shift?

What was the result?

What did you learn from your shift that could be useful to the next manager?

Formal Lesson Learned

What was your plan or set of decisions for your shift?		
Piece Made on Machine X:	Piece Made on Machine Y:	Piece to Made on Machine Z:
Packaging Option Used for Each Piece: Standard_____. Binding_____.	Raw Material Used for Each Piece: Colored:_____. Uncolored:_____.	Forklift Truck Used Truck 1:_____. Truck 2:_____.

What were the results?

Piece	Manufacturing Time	Paint Time	Total Time
A			
B			
C			

Manufacturing Costs
        Colored Materials
        Uncolored Materials
        Paint
Penalty Costs
        Manufacturing Overtime

Total Manufacturing Costs

Explanation of Manufacturing

Packaging and Shipping Costs
        Binding
Penalty Costs
        Shipping Overtime
        Customer Complaints
Total Packaging and Shipping Costs

Explanation of Packaging and Shipping Results

Supervisor's Feedback

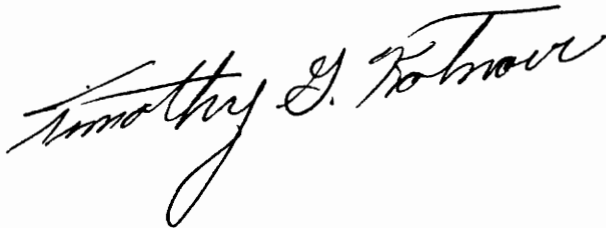| What did you learn from your shift that could be useful to the next manager?		
Piece to Make on Machine X:	Piece to Make on Machine Y:	Piece to Make on Machine Z:
Packaging Options to Use for Each Piece: Standard_____. Binding_____.	Raw Material to Use for Each Piece: Colored:_____. Uncolored:_____.	Forklift Truck to Use Truck 1:_____. Truck 2:_____.
Changes to Processing Times		

EU	CON	STR	DQ	TC	DT	LLQ	LLT	PDQ
01	1	1	3	6400	27.05	2.5	12.92	8
01	2	1	4	5680	12.08	.	.	.
01	3	1	3	6400	20.05	.	.	.
11	1	2	4	5680	20.67	10	9.63	9
11	2	2	6	5700	31.93	.	.	.
11	3	2	7	3990	11.02	.	.	.
02	1	1	4	6000	05.63	4	6.47	10
02	2	1	4	5680	17.42	.	.	.
02	3	1	9	5160	16.32	.	.	.
12	1	2	4	6000	29.90	10	21.67	10
12	2	2	4	5680	37.72	.	.	.
12	3	2	2	6440	12.17	.	.	.
03	1	1	2	6715	26.32	3	17.98	9
03	2	1	7	3880	12.62	.	.	.
03	3	1	5	4180	13.00	.	.	.
13	1	2	4	6250	8.75	10	13.20	10
13	2	2	10	3660	10.68	.	.	.
13	3	2	9	5160	3.28	.	.	.
04	1	1	5	6030	10.73	0	11.80	9
04	2	1	5	6030	7.78	.	.	.
04	3	1	3	6400	10.38	.	.	.
14	1	2	4	5680	11.76	8	18.33	9
14	2	2	5	4180	7.18	.	.	.
14	3	2	5	5530	12.12	.	.	.
05	1	1	4	6000	23.82	0.5	5.06	8
05	2	1	5	6030	14.98	.	.	.
05	3	1	4	6750	15.65	.	.	.
15	1	2	3	6650	30.08	8	9.42	7
15	2	2	9	5160	27.82	.	.	.
15	3	2	6	5380	05.85	.	.	.
06	1	1	4	5680	13.45	0	9.72	10
06	2	1	5	5640	33.38	.	.	.
06	3	1	5	4180	30.15	.	.	.
16	1	2	4	5680	17.27	10	7.27	10
16	2	2	10	3660	10.90	.	.	.
16	3	2	9	4310	8.25	.	.	.

07	1	1	4	6000	17.35	.5	7.65	10
07	2	1	5	6350	30.12	.	.	.
07	3	1	5	5250	18.63	.	.	.
17	1	2	3	6400	13.15	-2	22.77	10
17	2	2	8	3960	28.68	.	.	.
17	3	2	6	5865	6.02	.	.	.
08	1	1	4	6000	12.17	-1	6.50	9
08	2	1	4	6000	15.70	.	.	.
08	3	1	2	6440	15.77	.	.	.
18	1	2	4	5680	6.93	7	12.82	8
18	2	2	6	4350	20.03	.	.	.
18	3	2	8	3850	19.32	.	.	.
09	1	1	2	6715	30.58	0	9.28	7
09	2	1	7	5850	9.50	.	.	.
09	3	1	3	6400	23.07	.	.	.
19	1	2	4	6000	19.82	8	7.37	9
19	2	2	5	6265	5.43	.	.	.
19	3	2	7	5850	19.10	.	.	.
10	1	1	2	7050	23.82	-.5	9.83	5
10	2	1	3	6080	22.67	.	.	.
10	3	1	4	5680	3.75	.	.	.
20	1	2	4	5680	17.82	10	7.65	10
20	2	2	6	4600	21.88	.	.	.
20	3	2	3	6040	20.10	.	.	.

Timothy G. Kotnour was born May 5, 1968 in Chicago, Illinois. He received his bachelor's degree in industrial engineering with minors in computer science and business administration from Bradley University in 1990. He completed an engineering intern program at Eli Lilly and Company. He earned his master's degree in industrial and systems engineering with an emphasis in management systems engineering from Virginia Polytechnic Institute and State University in 1992. As a graduate student, he was employed by Management Systems Laboratories of Virginia Tech were he conducted applied research, completed consulting assignments, and conducted workshops for the university, government sponsors, and private industry. He received his Ph.D. in 1995 and was appointed to the industrial engineering faculty at the University of Central Florida in Orlando, Florida.