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The effect concept acquisition techniques have on the identification and structuring of ill-structured problems

Wenig, Robert Gregory, Ph.D.
The Ohio State University, 1987

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THE EFFECT CONCEPT ACQUISITION TECHNIQUES HAVE ON
THE IDENTIFICATION AND STRUCTURING OF
ILL-STRUCTURED PROBLEMS

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Presented in Partial Fulfillment of the Requirements for
the degree of Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Robert Gregory Wenig, B.S., M. Ed.

**********

The Ohio State University
1987

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ACKNOWLEDGMENTS

I express sincere appreciation to Drs. James Altschuld and Keith Hall for their guidance and insight throughout the research. Thanks go to the other member of my advisory committee, Dr. James Buffer. Gratitude is expressed to my parents, Dr. and Mrs. Robert E. Wenig and my wife's parents, Mr. and Mrs. Robert Paul Johnson for their support and encouragement. The technical assistance of Ms. Janis Summers is gratefully acknowledged. To my wife, Judith, I offer sincere thanks for your unshakable faith in me and your willingness to endure with me the vicissitudes of my endeavors.
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FIELDS OF STUDY

Educational Research and Measurement
Organizational Behavior
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CHAPTER I
INTRODUCTION

The utilization of computers in education and business to assist in higher level cognitive processing has become more prevalent in the last two or three years. Part of this expansion is attributable to the increased role of the computer in assisting the user in the cognitive processing (thinking) that is required to learn concepts, solve problems, and make decisions. For example in education, there is an interest in the computer aiding the user with the higher level cognitive processing associated with concept learning and problem solving. In business, there is an increased interest in computer systems that support executive decision making and problem solving. The term "mind support" has been used in relation to this work in business. Hence, in both business and education the computer is used to amplify the cognitive processing skills of the user.

The computerized support systems used to aid/support the learner/decision maker are called different names in education and business. In education, they are called computer aided instruction (CAI) systems because they are used to help instruction (learning). In business, they
are called decision support systems (DSS) because they assist in executive decision making (problem solving).

1.1 Statement of Problem

The computerized support systems (CAI and DSS) aid/support the learner/decision maker in the same adaptive process. Kolb in his research on decision making styles and learning stated "Decision making and learning are the same adaptive process viewed from different perspectives." (p.105) This relationship between decision making/problem solving and learning has been noted numerous times in the literature (Kolb, 1974; Einhorn, 1980; Sage, 1981).

Even though CAI and DSS support the same adaptive process, they operate differently. The difference lies in how the systems aid the user in acquiring the knowledge needed to accomplish tasks. In CAI the knowledge can be prespecified because learning is directed or planned to meet objectives set prior to instruction. This is not the case in DSS where objectives can change often and/or it is not known what knowledge is necessary to obtain the objectives. As a result, DSS aids the user in determining the objective(s) desired and in specifying the knowledge needed to obtain the objective(s).

Advocates of each system (CAI or DSS) believe the other is inappropriate for their use. Gagne and Briggs
(1974), both authorities on instructional design, believed that undirected support (as is often characteristic of DSS) led to incompetent individuals. By contrast, authorities on DSS believed CAI systems cannot be used as models for DSS due to the prespecified nature of the knowledge that is dealt with by the system (Fisk & Sprague, 1981).

The problem central to this study was what effect does a selected CAI technique (from education) have on identification and structuring of problems that are typically of the type DSS (from business). The selected CAI technique was a method for learning concepts which were described by Hall (1982). The types of problems to which the techniques were applied were those that were ill-structured. (See Operational Definitions section in this chapter.) Therefore, what was not known was the effect of a selected CAI technique from education (a method for learning concepts) had on identifying and structuring problems where: (a) the set of characteristics of the problem is obscure, ambiguous, and complex; (b) the procedures for solving the problem are indeterminate, and/or (c) the consequences are unknown.

1.2 Purpose

The purpose of this research was to add new knowledge in the area of computer supported cognitive processing
needed for learning and problem solving/decision making. The new knowledge was the result of an integration of selected work from both education and business. The new knowledge concerned the interchangeability of CAI and DSS systems in general and specifically the use of concept acquisition techniques (a CAI technique) to help structure problems normally dealt with by DSS.

1.3 Objectives of the Study

The following were the objectives of this study.

1. Determine the degree of interchangeability of two types of computerized support systems, CAI and DSS.

2. Determine the role concepts have in decision making/problem solving as found in selected literature by: (1) defining a method of using concept acquisition techniques to aid in the identification and structuring of ill-structured problems, and (2) specifying the levels of cognitive skills necessary to use the proposed method to identify and structure ill-structured problems.

3. Develop two decision support systems. One system named PSICAT will utilize the proposed CAI concept learning technique to identify and structure ill-structured problems. The other DSS named DTT will utilize a decision tree technique to identify and structure the same ill-structured problems.
4. Test the proposed CAI concept learning technique on selected subjects using PSICAT in relation to the following hypotheses: (1) Given an ill-structured problem in a familiar knowledge area (travel) that is an example of those described in both PSICAT and DTT, subjects will not be able to identify the problem equally well using PSICAT than DTT. The subjects have varying levels of analytical ability. (2) Given an ill-structured problem in a familiar knowledge area (travel) that is not an example of those described in both DTT and PSICAT, subjects will be able to identify the problem equally well using DTT than PSICAT. The subjects have varying levels of analytical ability.

5. Identify what new knowledge, if any, resulted from the study that can be added to computer supported cognitive processing needed to improve learning and problem solving/decision making.

1.4 Justification of the Study

When advocating just one system (CAI or DSS) and disregarding the other, opportunities may be missed to improve the use of computers to aid the user in the adaptive process. As noted previously, the CAI method typically uses prespecified knowledge (Gagne & Briggs, 1974). However, in real world situations many tasks cannot be clearly defined with all the corresponding
knowledge prespecified. Effectiveness in dealing with real world situations requires that the task be defined and the knowledge specified. The DSS can help the user better define the task and specify the corresponding knowledge.

As is true with new learning/decision making, the effectiveness of DSS is contingent upon the prerequisite knowledge the user brings to the situation. To insure the effectiveness of a DSS, it is necessary for the system to aid the user in bringing sufficient prerequisite knowledge to the situation. The CAI system is one that aids in the transfer of this type of knowledge to the user.

One method used in CAI systems to aid in the transfer of knowledge to the user is concept acquisition techniques. These techniques are appropriate for the acquisition of conceptual knowledge, which accounts for most of learning (Hall, et al 1982). The method aids the user in classifying situations as examples of one type of task or another.

The possibility exists that if these concept acquisition techniques can aid the learning process, then they could aid the decision making/problem solving process. As will be shown, CAI and DSS are computer support systems of the same adaptive process, namely learning/decision making/problem solving. Concept acquisition techniques used in CAI aid in achieving higher levels of efficiency.
in transferring knowledge. The question was what are the effects of these techniques on decision making/problem solving.

1.5 Assumptions

1. Adequate information can be gleaned from the literature that will enable the comparison of computer aided instructional systems and decision support systems.

2. Adequate information can be gleaned from the literature that will enable the examination of the role concepts had in the problem solving/decision making process.

3. The proposed method of problem identification and structuring for use in decision support system can be adequately tested by experiment.

4. The decision support system which uses the proposed method of problem identification and structuring can be adequately constructed for the experiment using a computer aided instructional language.

5. Decision makers and problem solvers of ill-structured problems/decisions are in vital need of techniques which will aid them in solving those problems/decisions.

1.6 Delimitations of the Study

The study was limited to comparing CAI and DSS, determining the role of concepts in problem
solving/decision making, developing and testing a proposed method to identify and structure problems through experimentation, and determining the relationship between an individual's analytical ability and his/her ability to identify and structure ill-structured problems.

1.7 Limitations

1. The literature reviewed served as the major basis for comparing CAI and DSS and for determining the role of concepts in problem solving/decision making.

2. The correctness of a problem was based only upon the judgment of the problem raters.

3. The DSS developed for this study was designed to test the proposed method. It was not considered a fully operational DSS.

1.8 Research Methodology

A flow diagram (see Figure 1.) was developed to aid in the explanation of the research methodology. Note that there is a direct relationship among levels, chapters, study objectives, and the specific research methodology applied. Levels one through four are explained in the following:

Level 1 relates to Chapter II (Review of Literature) and achieves objectives 1 and 2.
Figure 1. Flow Diagram for the study.
Level 2 relates to Chapter III (Design of the Study) and covers objective three. This level includes the following four items. First is the **Experimental Treatments**. The subjects were provided with one of two decision support systems, Structuring and Concept Acquisition Technique (PSICAT) and Decision Tree Technique (DTT). Both systems represented alternative techniques to assist the user in problem structuring and identification. Second is the **Instrumentation**. The two measures used in the study were the Group Embedded Figures Test (GEFT) and a set of ten travel problems. The GEFT is a group administered test to measure the global-analytic dimension of cognitive functioning. The set of problems consists of two subsets of five problems each, one to measure the subject's ability to identify the problem and the other to measure the subject's ability to structure a problem. Third is the **Research Design**. The hypotheses were tested using multiple regression analysis. The dependent variable was the number of problems correctly identified. Fourth is the **Research Subjects**. The subjects consisted of graduate students from The Ohio State University. These students were all enrolled in graduate education classes and volunteered to participate.

Level 3 consists of Chapter 4 (Analysis of Data) and achieves objective 4. The following two activities were performed in level three. First was **Data Analysis**. The
major steps in the data analysis phase were scoring the GEFT, scoring the problems, and analyzing the resulting scores. Once the scoring had been performed, the relevant data were entered into a data file in a computer. A multiple regression analysis was applied using Statistical Analysis System (SAS). The second activity was Statistical Hypotheses Testing. The statistical hypotheses tested the proposed method of problem identification and structuring and the hypothesized relationship between an individual's analytical ability and his/her ability to identify and structure problems.

Level 4 relates to Chapter 5 (Summary, Conclusions, and Implications) which achieves objective 5.

1.9 Operational Definitions

Task structure. A concept that describes the general nature of a task and the processes related to accomplishing it.

Perceived task structure. The structure of a task based upon the perception, beliefs, attitudes, and knowledge of the individual performing the task in addition to the contextual factors surrounding the task. Contextual factors can include time and clarity of the information concerning the task.

Ill-structured problem. A problem where the individual solving the problem perceives that the
consequences of the problem are unknown, the characteristics of the problem are obscure, ambiguous, and complex, and/or the procedures for solving the problem are indeterminate.

**Travel problem.** A problem of getting to New York from Chicago in the most appropriate way.

**Decision support system (DSS).** A device or mechanism designed for the specific purpose of supporting and enhancing user's problem solving/decision making ability.

**PSICAT — Problem Structuring and Identification using Concept Acquisition Techniques.** A DSS that was created using a computer aided instruction system called Phoenix. PSICAT consists of an instructional component to teach the subjects how to use the system for problem solving/decision making and a support system dealing with travel problems of going from Chicago to New York. A further explanation of the system is found in chapter 3 and in Appendix A (PSICAT Instructional Booklet).

**DTT — Decision Tree Technique.** A DSS based upon a decision tree. The system, in guidebook form, leads the user through the process of selecting from alternatives associated with a series of questions. The questions focus on the identification of the problem. A further explanation of DTT is found in chapter 3 and in Appendix B (DTT Instructional Booklet).

**Identify.** A process that includes selecting the most
appropriate set of characteristics of a problem. In
PSICAT, the process is one of selecting the most ap­
propriate current situation, goal, and method by dis­
criminating between the types of components described in
the system. Whereas in DTT, the process is one of
selecting the most appropriate answers to the series of
questions about the problem's characteristics.

**Problem identification.** In this study, problem
identification is an intermediate step in the problem
solving process which culminates in the selection of the
most appropriate set of characteristics of a problem. The
principal task in this step is the selection of the
components from previously defined components. Hence in
PSICAT, this step is the ascertainment of the components
of the problem: (a) the initial problem situation, (b) the
desired goal to be reached when the problem is solved, and
(c) the method for reaching the goal given the initial
situation. Examples of problem structure using PSICAT can
be found in Appendix A.

In DTT, the step is the ascertainment of which are
the most appropriate answers to a series of prespecified
questions about the problem characteristics. The prin­
cipal task in this step using DTT is the selection of
answers for questions.

Problem identification does not include the execution
of the method necessary to achieve the goal and solve the
problem. Problem solving is not complete until the problem has been identified, the method has been executed, and the desired goal achieved. For example, none of the travel problems are solved until the traveler has used the suggested method and is in New York. Once the traveler is in New York, the problem of getting from Chicago to New York is solved.

Problem structuring. In this study, problem structuring is an intermediate step in the problem solving process which results in a description of a new set of characteristics of a problem component and thus a new problem. In PSICAT the new characteristics will be in the form of descriptions of new components. The step is executed when a component has not and cannot be selected from those previously defined. The objective of the step is the definition of the component. Problem structuring is the production of a definition of the component. Examples of problem structuring can be found in Appendix A.

In DTT the new characteristics will be in the form of new questions and answers. The step is executed when a question and answer cannot be selected. The objective is the creation of a question or answer which will lead to the selection of the most appropriate characteristics. Example of problem structuring using DTT can be found in Appendix B.
CHAPTER II
REVIEW OF LITERATURE

The purpose of the review of the literature was to analyze and determine what effect a selected CAI technique (concept acquisition) has on the identification and structuring of ill-structured problems which are the focus of DSS. This review served as the substantiating evidence needed for the study as well as providing the rationale for conducting further research and development.

Before reviewing the selected literature, a structure must be provided to guide one in this task. The structure used was a series of questions focusing on answering the first two objectives of this study and to provide the foundation to achieve the other three:

1. How interchangeable are CAI and DSS?
   What are the basic differences between them?
   How important are the basic differences with respect to the potential use of CAI techniques on problems for which DSS was designed to help solve?

2. What is the role of concept acquisition in problem solving?
   What cognitive skills are necessary to identify and structure ill-structured problems?
3. What are the measures of cognitive skill relevant to those necessary for the identification and structuring of ill-structured problems?

To answer these questions, selected literature from a number of fields was analyzed and synthesized. Selected literature from the areas of DSS and CAI was compared and contrasted in order to answer question 1. Literature on concept learning, content constructs, problem solving, and cognitive processing was examined to answer question 2. Finally, research on human factors relevant to support systems was reviewed to determine the use of measures of this construct to assess the relationship between an individual's level of cognitive skill (analytical ability) and the identification and structuring of ill-structured problems. Before the literature was reviewed, the nature of the adaptive process was examined to show the relationship between learning and problem solving/decision making.

2.1 Adaptive Process

Learning and decision making/problem solving has been thought of as the same adaptive process— that is, a series of behaviors taken by a system to modify itself or its environment in order to obtain greater goal seeking efficiency (Ackoff, 1972). The relationship between learning and decision making/problem solving was shown by Kolb (1974). He also described the series of behaviors
that constituted the process.

Kolb referred to his model of learning as the experiential learning model (ELM). He named it that for two reasons. First the model had its intellectual origins in the work of Lewin. Second the model was to emphasize the importance of experience on the learning process.

The series of behaviors described in the ELM were concrete experience, reflective observation, abstract conceptualization, and active experimentation. The behaviors associated with concrete experience were ones that allowed the individual to be fully and openly involved in new experiences. Reflective observation entails behavior that allowed individuals to reflect on and observe their new experiences from different perspectives. Abstract conceptualization included the behaviors of creating concepts that integrate one's experiences into sound theories. Also, active experimentation has the individual testing the implications of the newly created concepts on new situations (Kolb, 1974).

Related to the four behaviors are four learning styles which represent dominant combinations of behaviors measured using the Learning-Style Inventory (LSI) to identify individual's strength and weaknesses as a learner (Kolb, 1974). The four styles are divergence, assimilation, convergence, and accommodation. Individuals exhibiting a divergent style are best at concrete
experiences and reflective observation. Individuals exhibiting assimilation are best at abstract conceptualization and reflective observation. Convergers, individuals exhibiting a convergent style, are best at abstract conceptualization and active experimentation. Finally, individuals exhibiting accommodation are best at concrete experience and active experimentation (Kolb, 1974). Kolb pointed out that all four styles are necessary for optimal learning. In Figure 2 the personality traits that tend to be associated with each of the four styles based upon Kolb (1974) are listed.

The ELM categories of behaviors are generally the same categories of behaviors as those described in problem solving/decision making models. Kolb overlaid a typical model of problem solving on the ELM. In Figure 3 a general correspondence between the sequence of behaviors of the ELM and a model of problem solving developed by Pound (1965) are shown. Kolb described the correspondence between the two models in the following manner:

The diverger's problem solving strengths lie in identifying the multitude of possible problems and opportunities that exist in reality. The assimilator excels in the abstract model building that is necessary to choose apriority problem and alternative solutions. The converger's strengths lie in the evaluation of solution consequences and solution selection. The accommodator's
problem solving strengths lie in executing solutions and in initiating problem finding based on how he envisions things should be.

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<th>LEARNING STYLE</th>
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<td>Divergence</td>
<td>1. Good at generation of ideas</td>
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<td></td>
<td>2. Interested in people</td>
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<td></td>
<td>3. Imaginative and emotional</td>
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<td></td>
<td>4. Broad cultural interests</td>
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<tr>
<td>Assimilation</td>
<td>1. Excel in inductive reasoning</td>
</tr>
<tr>
<td></td>
<td>2. Less interested in people</td>
</tr>
<tr>
<td></td>
<td>3. More concerned about abstract ideas</td>
</tr>
<tr>
<td>Convergence</td>
<td>1. Good at hypothetical-deductive</td>
</tr>
<tr>
<td></td>
<td>2. Relatively unemotional</td>
</tr>
<tr>
<td></td>
<td>3. Likes to deal with things more than with people</td>
</tr>
<tr>
<td>Accommodation</td>
<td>1. Excel at carrying out plans</td>
</tr>
<tr>
<td></td>
<td>2. Likes to become involved in new experiences</td>
</tr>
<tr>
<td></td>
<td>3. Greater risk taker</td>
</tr>
<tr>
<td></td>
<td>4. Greater faith in &quot;facts&quot; than in theory</td>
</tr>
</tbody>
</table>

Figure 2. Personality traits associated with learning style.

2.2 Computerized Support Systems

A comparison of both CAI and DSS revealed that though they support the adaptive process previously discussed (Kolb, 1974) the systems are different. CAI systems using a number of strategies facilitate the learning process with the aid of computers. Among the most common are generated practice exercises, rule-example-practice, and simulation. The one strategy that aids in the acquisition
of concepts is rule-example-practice. The strategy includes providing the user with a definition of the concept (a concept definition is a rule), examples of the concept, and practice in applying the concept to unencountered instances (Bunderson, 1981). In using this strategy, the sequence of providing examples and practice are repeated until the individual has acquired the concept (Merrill & Tennyson, 1977). The rule-example-practice strategy exemplifies the use of CAI systems to support the user in the adaptive process as described in the ELM.

Figure 3. Decision making/learning adaptive process.

By giving the user a definition and examples, one has provided concrete experiences for the user to observe and
reflect. Based upon this observation and reflection, the user has formulated an understanding of the concept. Practice allows the user to test his/her understanding of the concept to new situations. The cyclical nature of the process is exhibited in situations where more examples and practice are needed in order to acquire a better understanding of the concept. Likewise DSS assists the user in the same adaptive process as described by the modified problem solving model of Pound (1965). However, the two systems are different due to the tasks each system supports. Before one can illuminate upon the similarities and differences a discussion of task structure and the presentation of a framework to compare the two systems will follow.

2.2.1 Task Structure

In order to develop an understanding of task structure, a number of issues need to be discussed that concern this concept and how it affects the comparison of CAI and DSS systems. The issues are: 1) the definition of task structure, 2) the two main ways of viewing task structure, 3) the subtasks that need to be considered in determining the degree of structure, and finally 4) the degree of task structure that is associated with CAI and DSS systems.

Task structure is the most often used term for the concept that describes the general nature of a task and
the processes related to accomplishing it. The descriptions are in terms of how well structured or ill structured the task is. Other terms often used include well or ill defined (Reitman, 1964) and programmed or nonprogrammed (Simon, 1960). In Figure 4 the different terms, and their definitions and examples are given.

As one can observe from Figure 4, there is a high degree of basic consistency in the definitions of well- or ill-structured tasks. For example, well-structured, well-defined, and programmed tasks have the following common characteristics: (1) There is a definite and clear set of problem attributes. (2) There is a definite set of procedures for accomplishing the task. (3) There are definite and clear consequences of performing the task. Likewise, the definitions of ill-structured, nonstructured, ill-defined and nonprogrammed tasks all have the following characteristics: (1) The set of attributes is obscure, ambiguous, and complex. (2) The procedures are indeterminate. (3) The consequences are unknown. Though there is agreement concerning the clarity of the attributes, procedures, and consequences of well structured tasks, there is less agreement concerning whether task structure is a descriptor of actual characteristics of the task (objective task structure) or of the perceived characteristics of the task (perceived task structure.)
**WELL STRUCTURED**

**PROGRAMMED:** "Decisions are programmed to the extent that they are repetitive and routine to the extent that a definite procedure has been worked out for handling them so that they don't have to be treated de novo each time they occur." (Simon, 1960)

**STRUCTURED:** Ability to specify algorithms or decision rules that would allow the individual to find the problem, design the alternative solutions, and select the best solution.

Key Words: replacement, solutions, procedures, automation.

Examples: 1. Inventory reordering 2. Credit Scoring 3. Airline reservations

(Keen & Morton, 1978)

**WELL DEFINED:** "The problem situation evokes a high level of agreement over a specified community of problem solvers regarding the referents of the attributed in which it is given, the operations that are permitted, and the consequences of those operations." (Rietman, 1964)

---

**ILL-STRUCTURED**

**NONPROGRAMMED:** "Decisions are nonprogrammed to the extent that they are novel, unstructured, and sequential. There is no cut-and-dried method of handling the problem because it hasn't arisen before, or because its precise nature and structure are elusive or complex or because it is so important that it deserves a custom-tailored treatment. The system has no specific procedure to deal with situations like the one at hand." (Simon, 1960)

**UNSTRUCTURED:** An unstructured task is one where the individual is unable to define the conditions allow him to recognize how to create methodologies to solve the problem that has been defined, and do not have clear criteria for choosing a best solution from among those created.

Key Words: Learning, interaction, support, evolution

Examples: 1. Hiring managers

(Keen & Morton, 1978)

**ILL-DEFINED:** "The problem evokes a highly variable set of responses concerning referents of attributes, permissible operations, and their consequences."

Example: Composing a fugue

(Rietman, 1964)

---

Figure 4. Definitions of task structure.
The objective structure of a task is the structure that is inherent in the task. For example, the task of determining the variance of a group of numbers has an objective structure that is well structured. The attributes of that type task, the method that is appropriate, and the type of results that can be expected are all clear and can be found in any good basic statistics book.

Perceived structure is the structure of a task based upon the perceptions, beliefs, and knowledge of the individual performing the task in addition to the contextual factors surrounding the task. For example, strictly from the perceptive of objective structure, the variance problem is well structured. Notwithstanding that fact, from the perspective of a subject with no knowledge of statistics, the task is not well structured.

Contextual factors such as time and clarity of the information concerning the task can affect the perceived structure of the tasks. Assume that an individual is given the task of determining the variance of a group of numbers. There are a number of methods available to calculate the variance of a group of numbers, each appropriate for a specific type of problem. This individual knows which methods should be applied to which problems if given enough time to understand the problem. When the individual is given enough time, the problem is well structured. But if the individual is not given
enough time, then the problem is not well structured. Now assume the individual is given all the time he/she needs. The problem however, is stated in such a way that he cannot understand it. If he/she cannot understand the problem, the attributes will not be clear to him/her. In such a case, the task is also not well structured.

While both the objective and perceived views of task structure are important in comparing CAI and DSS systems, the perceived view is more important. The structure of a task supported by a CAI system tends to be based upon the perception of the support staff (i.e. the instructor.) In many cases the instructor's perceived view of the task structure is the same as the objective view. For example, the instructor's perceived view and the objective view for the variance problem should be very similar if not the same. If the task concerns teaching the concept of problem solving, then it is less likely that the perceived view will be the same as the objective one. Evidence of that is the lack of a consensus on a theory of problem solving.

While the task structure of a task supported by a CAI system tends to be based upon the support staff, the task structure of a task supported by a DSS system tends to be based upon the perception of the user. The user's perceived view is predominate because he/she supposedly knows the most about the task. More will be said about this in
In determining the degree of structure of a task, an examination of the task's subtasks are necessary. Most learning/problem solving/decision making tasks are made up of many subtasks. Each subtask is measured using the same criteria as those mentioned for tasks. A well structured task needs to have well structured subtasks. And yet, a task where all the subtasks are well structured is not a sufficient condition to define a task as being well structured. If all the subtasks are well structured, but the sequence of the subtasks needed to complete the task is not clear, then the task is less well structured than the subtasks. One of the more common examples of this is the situation of the father on Christmas Eve trying to assemble a child's cycle. The subtasks include such acts as attaching the handle bar to the frame, attaching the brake mechanism to the frame, and attaching the wheels to the frame. Each subtask entails relatively simple acts. The subtasks of assembling the cycle are not ill-structured (causing the problem), but the sequence of subtasks that may be ill-structured (frustrating the father). Does one attach the brakes before or after one attaches the wheels? Tasks that are CAI system supported are generally more structured than those that are supported by DSS systems. CAI systems support tasks where the objectives and methods can be specified and where clear verification
of the objectives exist. These specifications stem from the use of traditional instructional development (ISD) models which call for directed learning of prespecified objectives that are verifiable (Gagne & Briggs, 1974; Bunderson, 1981.) Tasks that are ill structured generally have objectives or methods that have not been specified and/or no clear verification method to determine if the objectives were met. By definition this is the type of task that DSS systems support (Keen & Scott Morton, 1978.) Thus, the type of tasks that are supported by the two systems lie on different points of the same well structured to ill structured continuum. The significance of having CAI and DSS systems support tasks with different structures will become clear when the systems are compared using a framework developed by Keen (1980.)

2.2.2 Adaptive Framework for Support Systems

Keen (1980) produced an adaptive framework for DSS that proves useful in a comparison of CAI and DSS system types. The framework provides insights into the interaction between the system, user, support staff, and task. The insights highlight the difference between a system predominately influenced by the user (DSS) and a system that is predominately influenced by a support staff of instructors and instructional designers (CAI).
In Figure 5 the major components and how they are related to one another are shown. The major components are the computerized support system, the user of the CSS, the support staff, and the task representation. (The support staff includes individuals that facilitate the adaptive process and designers of the CSS.) Two sets of interactions are represented by the framework. The one set of relationships reflect the dominate influence one component has on the other. These relationships are those between task representation and the other components. The other set of relationships reflects a more mutual influence between the components. This set of relationships is between the CSS, the user, and the support staff.

(Learner)

COGNITIVE LOOP

USER

IMPLEMENTATION LOOP

(Task representation)

(Decision Maker)

(DSS)

SYSTEMS

(CAI)

EVOLUTION LOOP

(Support Staff)

(Designer/Facilitator)

(Instructor/Instructional Designer)

Figure 5. Adaptive framework for DSS/CAI system.
Keen called these relationships adaptive loops. The framework has three adaptive loops; the cognitive loop (the relationship between the user and the system), the implementation loop (the relationship between the user and the support staff), and the evolution loop (the relationship between the system and the support staff.)

The cognitive loop focuses on the influences the system has on the user and vice versa. The system influences the user by encouraging him to "explore new alternatives and approaches to the task" (Keen, 1980) which can include broadening an individual's perspective of a task or aiding the individual in acquiring skills needed for a particular approach or alternative to a task (i.e. skill acquisition). The user influences the system by using it in new ways. An example would be a concept acquisition system that the user employs as a reference system. Another example would be the use of a statistical package such as Statistical Analysis System (SAS) to keep and analyze data on a university football team's opponents.

The implementation loop consists of the interaction of the user with the support staff. The user influences the support staff because the support staff must understand and be responsive to the needs of the user. The influence the support staff has on the user is that of a change agent which tries to aid the user in utilizing the
system. The role of the support staff as change agent has been called a number of things in the literature such as integrating agent (Bennet, 1976), intermediary (Keen, 1976), and chauffeur (Grove, 1976).

The evolution loop is the interaction between the system and the support staff. As the user clarifies or changes his/her needs, the system needs to be changed to respond to those needs. As a result, pressures are placed on the support staff to change the system to meet the change in needs. For example, when the user asks the system to run a loglinear analysis and the system does not have that capacity, the need for a loglinear analysis produces a pressure on the support staff to create that capacity for the system. The support staff, reacting to the user's pressures, change the system by developing a loglinear capacity.

The relationship between the task representation and the system, the user, and the support staff is more dominant than mutual in influence. It is clear that the task representation has an influence upon the other components of the framework. However, many times two individuals can perceive the same task as being different. The task representation of the user may not be the same as that of the support staff.

The influence of the task representation on the other components is dependent upon which perception
predominates. For example, with the task of learning the analysis of variance concept the support staff's (i.e., the instructor and instructional designer) perception of how the task should be represented predominates. The support staff's perception has a major influence on the system and upon the user's perception of the task. The direction of influence would be from the support staff through the task representation to the system and the user.

A stock broker buying stock for a client is an example of the user having the predominant perception of the task rather than the support staff. The task is to buy the stock that would most benefit the client. The user is the client's stock broker. The support staff includes stock analysts who provide detailed analyses of prospects for particular stock and industries. The analysts investigate various stocks the broker thinks will most benefit the client. The stock broker normally has more influence upon the task representation than the analysts because the broker possesses a better understanding of the needs of the client through discussions with him. The direction of influence is from the stock broker through the task representation to the stock analysts.
2.3 CAI and DSS Systems Compared

With a basic understanding of task structure and of Keen's Adaptive Framework, CAI and DSS systems can now be compared. Similarities and differences between the CAI and DSS systems become evident when one compares the relationships between the user, support staff, and task representation. The examination of the relationship will start with the set of relationships affecting task representation followed by the comparisons of their implementation loop, cognitive loop, and evolution loop. A summary of the comparison will be at the end of this section.

2.3.1 The Influences on Task Representation

The task representation in CAI systems is influenced more by the support staff than the user while in DSS systems the user has more influence. According to traditional ISD models (Gagne, 1974; Bunderson, 1981) learning should be systematically designed, planned, and directed by the support staff (i.e. instructor or instructional designer.) The support staff's perception of how the task should be represented is the predominant one.

The user of DSS systems have more influence than does the support staff in defining the task representation. As discussed previously tasks supported by DSS tend to be ill structured. The task representation cannot be well
specified prior to performing the task. The task representation is clarified by the individual performing the task (i.e. the user).

2.3.2 The Implementation Loop

The implementation loop is the relationship between the user and the support staff. This relationship can be divided into two components: 1. how the user influences the support staff, and 2. how the support staff influences the user. A comparison of the implementation loops of the CAI and DSS systems will precede a review of the literature pertaining to each system's loop.

The implementation process for DSS is considered a part of the iterative design process (Keen, 1980; Sprague & Carlson, 1982) because theoretically, the system continually changes in response to the clarification of needs. Continual change of the system calls for continual implementation of those changes.

The DSS implementation process is viewed by some experts to be user driven (Keen, 1980). Others (Sprague & Carlson, 1982; Alter, 1980; and even Keen & Scott Mortan, 1978) mention the possibility of additional important sources of influence such as the user's superiors. These other sources of influence may initiate the change process but there seems to be consensus that without the user's influence in the implementation process
a successfully working system is unlikely. The intended effect of the implementation process being user driven is to cause the support staff to learn, clarify, and monitor changes in the user's needs (Keen, 1980).

The intended focus of the implementation process may be responsiveness of the support staff to users' needs, but much of the literature focuses on the influence of the support staff on the successful implementation of the system. Sprague and Carlson described the implementation process as consisting of three non-sequential steps: user education, installation, and evaluation. User education includes the introduction of DSS concepts, discussion of choices and requirements of the system, and user operation of system. Installation is essentially having the DSS ready for operation by the user without technical or acceptance difficulties. The intent of evaluation is to determine the effect of the DSS on the decision making process. Measures of DSS effect are event logging, attitude survey, cognitive tracking, system analysis, cost/benefit analysis, risk analysis, and value analysis (Sprague & Carlson, 1982).

Though there is consensus on the importance of implementation to DSS success (Alter, 1980; Bennet, 1976; Keen, 1976) there are different opinions regarding which implementation strategy should be used. Keen and Scott Morton (1978) based upon the work of Ginzberg (1975)
identified a number of strategies which they labeled "wise old men" strategies. These "how to" strategies were based upon the experience of implementors of early computer based systems. The strategies of Ackoff and Argyris were placed into this category. Ackoff advocated a strategy where the implementor obtains and uses if necessary the power needed for successful implementation. However, the strategy of Argyris consisted of trying to minimize the use of power and have the members of the organization less threatened. The strategy advocated by a number of DSS authorities such as Keen, Scott Morton, and Alter can best be characterized as a clinical approach. The Kolb and Frohman's Model of Change (Kolb & Frohman, 1970) is often associated with it. (See Figure 6.)

The literature related to CAI characterized the implementation relationships as a triad between the instructional designer (IDS), the subject matter expert (SME), and the learner. Numerous researchers have examined the relationships of the triad (Bratton, 1979; Bratton, 1983; Coscarelli & Stonewater, 1979; Davies, 1975; Den-Parker, 1979; Price, 1978; Rosenberg, 1978; Rutt, 1979). Bratton discussed the relationship in depth. He noted that the relationship was one where "the IDS is a professional helper (consultant) who provides assistance to a subject matter expert (client) regarding the instructional needs of the learner (benefactors)" (Bratton, 1983).
1. Scouting: User and support staff see if they can help each other.

2. Entry: User and support staff develop goals and objectives.

3. Diagnosis: User and support staff better define the problem and goals.

4. Planning: User and support staff define operational objectives and examine ways to meet these objectives.

5. Action: User and support staff implement best way to meet objective.

6. Evaluation: User and support staff determine how well objectives and goals are met.

7. Termination: User and support staff ensure that control rests in the hands of the user.

Figure 6. Kolb and Frohman model of change.

The desired set of relationships (see Figure 7) is one where the IDS is allowed to communicate freely with the learner; thus the learner becomes an active participant in the process. In order to have the ideal relationship, there has to be a high degree of trust between the IDS and the SME (Bratton 1983).

Both systems' implementation loops are similar. Each relationship has a consultant-client component. The DSS literature on implementation stresses the use of organizational development (OD) techniques. The literature related to CAI seems to stress the same techniques. The focus on implementation strategies or techniques with
respect to instructional systems development has not been as distinct as has been the focus in the DSS literature.

Currently the major difference between the implementation process of the two systems is the nature of the consultant-client relationship. The client in the DSS dyad relationship is generally the user. Whereas, the client in the CAI triad relationship is not the user but the subject matter expert. This triad relationship is why traditional OD consultant-client relationship does not apply to most instructional system development efforts,

2.3.3 The Evolution Loop

The evolution loop is the relationship between the support staff and the system. The relationship concerns the development and change of the system. The comparison of this loop for the CAI and DSS systems will follow an examination of the design process typically associated with each system.
The design process of a DSS is one of middle-out design (Ness, 1975), iterative design (Sprague & Carlson, 1982), or l'approche evolutive (Courbon, Grajeiu, & Tolovi, 1980.) This design process was meant to allow a greater frequency of change to the system than that which could be allowed for by traditional systems development models (Sprague & Carlson, 1982.) The process can be characterized as having the following attributes based upon the work of Courbon, Grajeiu, and Tolovi (1980), Sprague and Carlson (1982), and Ness (1975). (1) The support staff, user, and other interested parties (i.e. users supervisor) jointly identify a rather well structured subproblem. (2) A quickly-as-possible system is developed to be used by the user to deal with the selected subproblem. (3) The use of multiple as-short-as-possible cycles to expand and/or modify the system as the needs change or become more clear. (4) The system is evaluated constantly.

The intended effect of the process is fast modification of the system and relatively smooth, trauma-free implementation. The hoped-for fast modification is in response to the volatility of the task. Changes in the structure of the task, the user's perceptions, the environment can all result in modifications to the system. The effort to have user cooperation, the short development cycle, and much user evaluation is intended to increase
the chances of a successful implementation.

The design objectives or functional specifications of the design process are not viewed as indicators of a finished system. First DSS is never considered finished systems (Sprague & Carlson, 1982). They continually evolve until the benefits of the system are less than the costs incurred by the system's use. Second due to the evolutionary character of the design process, the performance objectives are viewed more as intermediary objectives of the whole design process or as terminal objectives of one of the other design cycles.

The design process of a CAI system is one that follows traditional instructional system development (ISD) model. In a study entitled A State of the Art Assessment of Instructional Development Logan (1979) defined ISD as a general systems approach:

With multiple components called phases which, operating amongst a certain set of constraints is used to produce an instructional system. The phases are sequential sets of activities called analysis, design, development, implementation, and control. (p. 23)

Gagne and Briggs (1974) identified 12 steps in the design of an instructional system (see Figure 8). Though the procedure has 12 steps in which the end result is an instructional unit, the design process is cyclical or iterative in nature. As they put it:

The design of instruction is based on one hand in logical, systematic thinking and planning,
making use of all theory and research evidence available, and on the other hand upon empirical test and factfinding. (p 213)

The outcome of the design process is a product that meets the design objectives. An example of a design objective is the following: The product will be considered satisfactory when 80 per cent of the students pass the minimum standard set for 90 per cent of the task objectives. Though there can be an evaluation of the broader effects of the product than those specified by the design objectives, the necessary effects are those specified by the design objectives.

---

**Step 1** Analysis and identification of needs  
**Step 2** Definition of goals and objectives  
**Step 3** Identification of alternative ways to meet needs  
**Step 4** Design of system components  
**Step 5** Analysis of (a) resources required, (b) resources available, (c) constraints  
**Step 6** Action to remove or modify constraints  
**Step 7** Selection or development of instructional materials  
**Step 8** Design of student assessment procedures  
**Step 9** Field testing; formative evaluation and teacher training  
**Step 10** Adjustments, revisions, and further evaluation  
**Step 11** Summative evaluation  
**Step 12** Operational installation

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Figure 8. Steps in instructional system development. The key to comparing the CAI and DSS systems is the number of cycles or iterations that are required to develop the system. The DSS iterative design process is to allow for more cycles in a given period of time than
allowed by the traditional system development models including the traditional ISD models. Nevertheless, there is not a total association between iterative design and DSS or between traditional system development processes and CAI. The number of cycles in the design process for DSS can be affected by such a factor as the size of the user group. A large diverse user group can result in relatively few iterations due to the cost of trying to obtain agreement on modifications to the system (Sprague & Carlson, 1982). Bunderson (1981) makes mention of a design procedure developed by Wilson (1977) that is iterative in nature. This procedure based upon what Bunderson called "iteration theory" is supposedly simpler and more responsive to economic and political realities than more traditional ISD models. In summary, though there are differences in the design processes associated with the evolution loop of each system, environmental, user, and probably task factors could result in the evolution loop of one system to take on many of the attributes of the other.

2.3.4 The Cognitive Loop

The cognitive loop is the relationship between the system and the user. The loop represents the way the user utilizes the system's capabilities. Though the set of relationships are referred to as the cognitive loop the
major focus of this comparison of the CAI and DSS systems is on the user's ability to control the system and the system's ability to adapt to changes in the needs of the user. The intent of this focus then is to concentrate more on the degree to which the system supports the user than on the cognitive processing that takes place. The subject of cognitive processing will be discussed later. As with the previous sections the procedure for comparing the two systems will consist of a discussion of each system's loop followed by a comparison of the two.

In the DSS literature a number of ways to classify DSS systems are indicated. One classification proposed by Alter was "the degree to which the system's output can directly determine the decision." Alter's (1980) classification (see Figure 9) had seven distinct DSS types based upon a study of 56 systems. Another DSS taxonomy was proposed by Sprague and Carlson (1982) based upon the degree of adaptability the system had with meeting the needs of the user. This taxonomy called the Taxonomy of Flexibility focuses on the DSS flexibility of the DSS design process.

Sprague and Carlson felt that a DSS system could be classified based upon the type of flexibility exhibited in the design process allowed. The taxonomy had four levels that reflected types of flexibility: F1, F2, F3, F4. (See Table 1.) Each level will be discussed below.
File Drawer System: data items immediately accessible

Data Analysis System: data manipulable by means of operators

Analysis Information System: data bases and models accessible

Accounting Model: actions based on accounting terms

Representational Model: actions based on partially nondefinitional estimates.

Optimization Model: guidelines for action based on optimal solution.

Suggestion Models: specific suggested decision generated from mechanical work on structured task.

Figure 9. "Alter's Taxonomy of Decision Support Systems" (Alter, 1980)

F1 represents "the ability of a specific DSS to handle a group of related or similar problems in the problem domain under the direct control of the user" (Sprague & Carlson, 1982). An example of a F1 level DSS is a Project Management System (PMS) which supports the day-to-day and long term decisions of project personnel in their administration of projects. There are a specific set of management aids in the system that are used to provide support for a specific set of decisions. These
management aids allow personnel to track the progress of the project and perform "what if" analyses to help with decisions concerning resource allocation, funding requests, and modifications in schedule dates. The aids cannot be modified by the user.

Table 1.
Sprague and Carlson's DSS classification system.

<table>
<thead>
<tr>
<th>Levels</th>
<th>Amount of Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>A hardware/software system that allows a user to deal with a specific set of related problems.</td>
</tr>
<tr>
<td>F2</td>
<td>A system that provides the user with capabilities to build F1 type systems quickly and easily, and is flexible and adaptable enough to facilitate the design process.</td>
</tr>
<tr>
<td>F3</td>
<td>A system that provides the user with capabilities to modify the DSS generator. Modifications can be made in the way the generator manages dialog, data or models.</td>
</tr>
<tr>
<td>F4</td>
<td>A system that provides the user with capabilities to modify the DSS generator faster and quicker.</td>
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</table>

F2 has the ability to change the specific DSS system so it can handle a different or expanded problem domain. F2 is more able to deal with changes in context or problems than F1. This capacity is due to what is called a DSS generator. A DSS generator is simply a "package of related hardware and software which provides a set of
capabilities to build specific DSS systems quickly and easily" (Sprague & Carlson, 1982, p. 11). An example of a F2 level DSS system is the same as the above Project Management System except that the user has control over the features that are available through the DSS generator. In place of the system having one specific way to track projects, analyze risks, allocate resources, or to run "what if" scenarios, the user has the option to select any one of several ways to perform each analysis. The user also has the ability quickly to perform the analyses on a different project. Most Project Management Systems are F2 systems. They allow the user to select from different analyses and to perform the analyses on data from many different projects.

A F3 level DSS system provides the ability to make modifications to the DSS generator. This ability results in the F3 level system being more adaptable to changes in the problem or task than the F2. This adaptability is due to the ability of the user to add or change procedures provided by the DSS generator. For example, there are two kinds of modifications to the DSS generator: types of dialog, data management, or modeling capacities; and instances of an existing type of capacity (Sprague & Carlson, 1982). Types of capacities include graphics, menus, hierarchical or relational data structures, regression, or log linear modeling approaches. Figure 10
provides an example of a menu.

INSTRUCTIONS: Push the number that corresponds to the desired option listed below.

1. HELP
2. ENTER THE FILE
3. EXIT THE FILE
4. EXIT MENU
5. LIST FILES

Figure 10. EXAMPLE OF A MENU'

An F4 level DSS system evolves as new software and hardware techniques change. While, F3 has the ability to modify the DSS generator, it does not have the ability to control the adaptability of the DSS generator. F4 has that ability. An F4 level DSS system has the ability to increase the power of the DSS generator to be modified (Sprague & Carlson, 1982). Statistical Packages for the Social Sciences (SPSS) and Statistical Analysis System (SAS) are statistical systems that are similar to examples of DSS generators. SAS possesses routines for analyzing data and procedures for developing additional routines. The ability of SAS to allow one to develop routines is an F3 ability. An F4 level ability is one that allows for the improvement of the F3 ability.

How the four abilities relate to one another is shown in the following example. A user has a program to analyze quantitative data using factor analysis. The ability to
analyze the data is an F1 ability. The user wants to modify the program in order to analyze other quantitative data using analysis of variance (ANOVA) techniques. The user can do this by using a master program that allows an ANOVA routine to be substituted for a factor analysis routine. That ability to modify the program with the master program is an F2 ability. Now the user wants to modify the program again in order to analyze categorical data using loglinear techniques. But, he can not modify the program with the master program because the master program does not contain categorical data analysis routines. The user decides to modify the master program so that it will contain the loglinear routines he needs. The user modifies the master program with a grand master program. The grand master program contains routines for changing the master program. The ability to modify the master program is an F3 level ability. Finally the user wants to decrease the time required by the computer to analyze data. Such modifications require modifications to the grand master program. The ability to modify the grand master program is an F4 ability.

A modified form of a taxonomy of user control of instructional programs is used to classify CAI systems. In order to compare CAI and DSS systems, a taxonomy comparable to that used to classify DSS systems is needed. A modified version of a taxonomy of user control proposed
by Snow (1980) meets that need. The taxonomy reflects the user's ability to control the system and the system's ability to direct or guide the user. The taxonomy used had five levels: LC1, LC2, LC3, LC4, LC5 (see table 2). The five levels are described in descending order of user control. A system at the LC1 level specifies the goals and methods and controls the process variables. A system at the LC2 level specifies the goals and methods for the user. The user has control of the process variables. The system also provides remediation. A system at the LC3 level allows the user to select from a prespecified set of alternative methods. The user still has control of the systems process variables such as the pace of instruction, scheduling, and sequencing. An example of a LC3 level system is similar to the LC4 level quadratic equations system referred to by Snow except that the user gets to select from three alternative methods prespecified by the system for solving quadratic equations. LC4 level systems provide the user with complete control except of the goals. The goals of LC4 level systems are imposed by the system on the user. An example of a LC4 level system is a system to solve quadratic equations where the user has control of the selection of methods to solve the equations. LC5 systems provide the user with complete control, self direction, and self-evaluation. Snow identified this condition as the "Adult Scholar Model."
He noted that "this is the ideal toward which one might hope each learner will strive" (Snow 1980, p.153).

**TABLE 2.**

**Snow's Taxonomy of Learner Control**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Degree of learner control</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Educational goals and treatments imposed on the learner. System controls pace.</td>
</tr>
<tr>
<td>L2</td>
<td>Educational goals and treatments are imposed on the learner. Learner has varying control of sequence, scheduling, and pace of learning.</td>
</tr>
<tr>
<td>L3</td>
<td>Educational goals are imposed on the learner. Alternative instructional treatments are available for choice by the learner.</td>
</tr>
<tr>
<td>L4</td>
<td>Educational goals are imposed on the learner. Learners have complete control. There are periodic tests.</td>
</tr>
<tr>
<td>L5</td>
<td>Complete independence, self-direction and self-evaluation.</td>
</tr>
</tbody>
</table>

The key to the comparison of the cognitive loops of the CAI and DSS systems is the degree to which the system or the user controls the learning/decision making adaptive process. The DSS systems classified in the Taxonomy of Flexibility allow the user almost complete control of the adaptive process. The differences between levels were dependent upon the systems ability to adapt to changes in
needs. While, CAI systems classified in the Taxonomy of User Control allowed the system to provide varying degrees of direction and guidance to the user as the user proceeds through the adaptive process. Systems at the LC1 level had control of goals, treatments, process variables, and did not allow for remediation. Each preceding level provided less guidance and direction while the degree of user control increased until LC4 was reached. A system at the LC4 level could only impose the goals on the user.

Since LC1 through LC4 are the only levels that allow the system to guide or direct the user in successfully completing the task, then most CAI systems can only be one of those level systems. It is a widely held assumption that instructional systems are to direct or guide learning. "Unplanned and undirected learning, we believe, is almost certain to lead to the development of individuals who are in one way or another incompetent to derive personal satisfaction from living in our society of today and tomorrow." (Gagne & Briggs, 1974 p. 5).

The LC5 level links the two taxonomies together. The attribute of complete user control is one that is shared by both LC5 level systems and all the systems classified in the Taxonomy of Flexibility. Each higher level system in the taxonomy enhances the user's control going through the adaptive process.
2.3.5 Taxonomy of Support Systems

In Figure 11 a Taxonomy of Support Systems (TSS) of the learning/decision making process that reflects the degree and nature that the system aids the user going through the adaptive process is presented. The TSS was developed by synthesising the "Taxonomy of Learner Control" (TLC) with the "Taxonomy of Flexibility" (TF). Such a synthesis results in a taxonomy with eight levels: SS1 through SS8. Level SS1 reflects the system's nearly complete control in guiding and directing the user through the adaptive process. At the other end of the continuum, SS8 reflects the maximum system adaptability as the user directs himself through the adaptive process.

2.3.6 CAI and DSS

The basic difference between CAI and DSS system types is highlighted in Figure 12. In each set of relationships between the system and the task representation, the user, and the support staff, the factor that had a major effect upon the relationship was task structure. The difference between the systems concerning task representation was due in large part to who had the most knowledge about the task and the actual structure of the task. DSS systems typically deal with tasks that are not well structured because they are specifically designed to deal with that type task. Generally CAI systems support
tasks that are well-structured because the instruction needs to be directed and planned.

<table>
<thead>
<tr>
<th>Level</th>
<th>Characteristics</th>
<th>Level of TLC</th>
<th>Level of TF</th>
</tr>
</thead>
</table>
| SS1   | Goals and means prespecified  
System has control of process variables | L1           |             |
| SS2   | Goals and means prespecified  
User has varying control of process variables such as sequence and pace of support | L2           |             |
| SS3   | Same as SS2 except there exists a set of alternative means for the user to select | L3           |             |
| SS4   | Same as SS3 except the set of alternative means are not prespecified for the user | L4           |             |
| SS5   | Goals and means are not prespecified however the system is designed to deal with a specific domain of possible goals and means | L5           | F1          |
| SS6   | Same as SS5 except the system can change the domain of goals and means | L5           | F2          |
| SS7   | Same as SS6 except that the system has the ability to change the entire domain | L5           | F3          |
| SS8   | Same as SS7 except that the system has the ability to change itself through changes in hardware and software | L5           | F4          |

Figure 11. 'TAXONOMY OF SUPPORT SYSTEMS'
Related to the actual structure of the task is the factor of who has the most knowledge about the task. It is generally assumed in the DSS literature that the user's representation of the task is based upon more or better knowledge than that of the support staff. Thus the task represented by the user is more well structured than that of the support staff. But, it is generally assumed in the CAI literature that the support staff's representation of the task is more well structured than that of the user.

The difference in the assumption as to whether the user or the support staff is the better source to represent the task is also reflected in the difference between the systems regarding the relationships of the implementation loop. The set of CAI implementation process relationships is characterized as being a triad between the instructional designer, the subject matter expert, and the

<table>
<thead>
<tr>
<th>Features</th>
<th>DSS</th>
<th>CAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Structure</td>
<td>Tends to be ill-structured</td>
<td>Tends to be well-structured</td>
</tr>
<tr>
<td>Task Representation</td>
<td>User's representation</td>
<td>Subject matter's representation</td>
</tr>
<tr>
<td>Design Process</td>
<td>Iterative in nature</td>
<td>Instructional Systems Design model</td>
</tr>
<tr>
<td>Implementation Process</td>
<td>Dyad between the designer/facilitator and the user</td>
<td>Triad between user, instructional designer, and subject matter expert.</td>
</tr>
<tr>
<td>User Control</td>
<td>Total user control</td>
<td>User control tends to be limited</td>
</tr>
</tbody>
</table>

Figure 12. Highlights of CAI and DSS Comparison
user. By contrast, the set of DSS implementation process relationships is characterized as being a dyad between the support staff and the user. The difference is due to a belief in who has more knowledge of the task. In the CAI relationship, it is believed that the support staff (subject matter expert) has more knowledge. But in the DSS relationship, it is believed that the user has more knowledge. The difference between the design process of the two systems is the number of iterations that are required to obtain a stable system to support the user with the task. Tasks that are well structured generally require fewer design cycles than those that are not well structured. Finally, the difference between the degree of user control in CAI versus DSS systems reflects the differences in the task structure. Normally the knowledge that is required for tasks that DSS systems support cannot be prespecified. The knowledge is acquired as the user works on the task. The user controls the system because the user is the one who provides the task knowledge to the system.

The influence of the task structure on the system should not lead to the conclusion that task structure is the only or primary source of the difference between the systems. The decision that a task has a certain structure can be influenced by a number of factors besides the "actual" task structure. One's perception of the
structure of a particular task can be influenced by organizational, environmental, and personal factors just to mention the major ones.

The source of differences between the systems is not as important as the fact that the systems support tasks with different structures. CAI systems generally support tasks that are well structured from the point of view of the system and designer. The goal of this system is to have the user gain understanding of the well structured task. The task representation is that of the support staff and thus the system. In DSS the tasks are different. DSS systems generally deal with tasks that are not well structured from the point of view of the system, designer, or user. The goal of the system is to have the user gain understanding of the task. How the user represents the task has an effect upon the system and designer.

It is interesting to note that though most instruction is based upon the transfer of prespecified knowledge about problems that have known answers, much of today's problems are known as 'messes.' That is many of today's problems are ill structured where the problem solver/decision maker lacks sufficient understanding of the problem to solve it. The knowledge about the problem is not prespecified and the answers are not known.

It would seem desirable to have instructional systems that can deal with tasks that are not well structured
since that is what the learner will be asked to cope with in the 'real' world. At the same time, it would seem desirable to have DSS that once the task is well structured, the user can gain understanding via methods incorporated in CAI systems. It is inefficient to spend the resources necessary to change repeatedly an ill-structured task into a well structured task when that process has already been performed, the skill needed to go through the process has been acquired, and the resulting knowledge is ready to be used. Thus it would seem advantageous to incorporate features of one system into the other in order to improve the systems support to the user as the user proceeds through the adaptive process. Such an effort should increase the user's performance with respect to the adaptive process.

2.4 The Role of Concepts in Problem Solving

Concept learning systems are one feature often associated with CAI systems that may be useful in problem solving/decision making. To examine the potential of using concept learning techniques for the type of problem solving associated with DSS systems, selected literature on types of knowledge, problem solving, concept learning, and cognitive behavior was reviewed in that order. Specifically: First, selected works on knowledge taxonomies were explored to determine the relationship between
two types of knowledge—concepts and rules. Second, Reitman's (1964) definition of problem, the relationship between rule and problem, and techniques for problem analysis were discussed. Third, concept learning was defined and concept learning strategies were reviewed. Finally, the use of concept acquisition techniques was examined as a possible way to identify the components of a problem.

Before starting with the review, an aid to understanding will be introduced. The aid is a concept map. A concept map is a diagram that shows the relationship among concepts. For example, Figure 13 shows the relationships among the concepts of dog, poodle, collie, full size poodle, and miniature poodle. The following are relationships shown by the map. Collie and poodle are types of dogs. Miniature and full size poodles are types of poodles. Poodles are different than collies. Miniature poodles are different than full size poodles. The concept map shows that collie and poodle are types of dog. It also shows that miniature and full size poodle are types of poodles.

2.4.1 Structure of Knowledge

There are numerous ways to structure knowledge, of which one of the more common ways is into subject matter fields (e.g. mathematics, English, history). Another way
is by the type of content (i.e. facts, concepts, rules). It is the latter way to structure knowledge that will be examined in order to establish the first link in the relationship between concept learning and problem solving, the association between concepts and rules. Specifically, a knowledge taxonomy based upon a set theory like approach by Merrill and others (Merrill 1973, Merrill & Wood 1975, Reigeluth, Merrill, & Bunderson 1978) was critiqued first to define concept and rule as content constructs. Next, the elements of content constructs; domain, operation, and range, were delineated in order to facilitate the explanation of the relationship between concepts and rules. Finally, operations were discussed to improve one's ability to differentiate among examples of concepts and rules.

Figure 13. An example of a concept map.

2.4.1.1 Types of knowledge - content constructs

Merrill and Wood (1975) proposed a method to structure knowledge based upon the type of operation that is a
part of what they call content constructs. Their taxonomy lists three types of knowledge: identities, concepts, and rules. Figure 14 summarizes the different types of knowledge. The key to identifying the different types of knowledge is the type of operation component of these content constructs. With concept constructs, operations are processes that describe the range concept using domain concepts (Range and domain concepts are explained on page 63). With rule constructs, the operations are processes for changing instances of the domain concepts into instances of range concepts.

<table>
<thead>
<tr>
<th>TYPES OF KNOWLEDGE</th>
<th>TYPES OF OPERATION</th>
<th>PURPOSE OF OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identity</td>
<td>Identity</td>
<td>Direct match of instance in domain to one in the range</td>
</tr>
<tr>
<td>2. Concept</td>
<td>Descriptive</td>
<td>Describes the range concept using domain instances</td>
</tr>
<tr>
<td>3. Rule</td>
<td>Productive</td>
<td>Processes for changing instances of the domain concepts into instances of the range concept</td>
</tr>
</tbody>
</table>

Figure 14. Types of knowledge and corresponding operations.

Identity. An identity "is a symbol, object, or event associated on a one-to-one basis with another symbol, object, or event" (Merrill & Wood, 1975). For example, when one hears the words "area of a circle" one often has
a mental image of the area of a circle. Such a response is a one to one correspondence between the name and the image. Other examples of identities are events such as an individual's graduation from college, December 7, 1941, or symbols such as the American flag, the Christian cross, the star of David (symbols).

**Concept.** A concept "is a set of objects, symbols, or events which have been grouped together because they share some common characteristics". (Merrill & Wood, 1975) For example, the class of symbols: 1,2,3,4,5,...100,101,... can be referred to as the concept "natural numbers". Another example is the class of objects; Corvette, Buick Park Avenue, Chrysler Imperial, can be referred to by the concept "automobile".

**Rule.** A rule "is an ordered relation consisting of a set of initial concepts, an operation, and a set of final concepts. (Merrill & Wood, 1975). Examples of rules are; "The area of a circle is Pi times the radius of the circle squared" and "hydrolysis of water produces hydrogen and oxygen" (see Figure 15).

2.4.1.2 The elements of content constructs

All three types of content constructs consist of three ordered sets of referents: a domain, an operation, and a range (Reigeluth, et al, 1978.) According to Merrill (1973), the elementary component of knowledge is
A referent (or instance) is an object, event, or symbol which exists, or could exist in our real or imaginary environment" (Reigeluth, et al, 1978).

Examples of referents that are objects are New York City, Corvette, Buick Park Avenue, Santa Claus, and atomic particles. Examples of referents that are events are the beginning of the solar system, the first man landing on the moon, and the cow jumping over the moon. Examples of referents that are symbols are words, numbers, and names.

<table>
<thead>
<tr>
<th>INITIAL SET</th>
<th>RELATIONSHIP</th>
<th>FINAL SET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pi</td>
<td>Pi times r squared</td>
<td>Area of Circle</td>
</tr>
<tr>
<td>Radius of Circle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 15. Relationship among rule domain, operation, and range.

The three ordered sets of referents that define identity, concept, and rule are domain, operation, and range. A domain is a group of referents that is acted upon by an operation. It is the first component of the content construct. For example, consider the definition of the "area of a circle" The "area of a circle" is defined as the outside surface of a circle as measured in square units." As shown in Figure 16, the range referent is "area of a circle." Other referents (instances) are
related to "area of a circle" by an operation.

An operation is a procedure which specifies the relationship between the referents in the domain and the referents in the range. For example, in the definition of "area of a circle", "area of a circle" is the same as "the outside surface of a circle as measured in square units." The procedure describes the concept "Area of a Circle" by means of referents of other concepts, specially "outside, surface of a circle, and measured in square units."

<table>
<thead>
<tr>
<th>SETS OF REFERENTS (INSTANCES)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>DOMAIN</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>- IDENTITY</td>
</tr>
<tr>
<td>CONTENT CONSTRUCT</td>
</tr>
<tr>
<td>- CONCEPT</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>- RULE</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Figure 16. The ordered sets of referents for content construct.

A range is a group of referents that is the result of an operation upon the domain. In the definition of
"free", the range is the phrase "not under the control of some other person." The differences between the domain and range is that the range is the result of an operation acting upon the domain. The operation on the referents in the domain results in the corresponding set of referents in the range. It is possible for a specific referent to be either a domain or a range. For example, when one hears the name "New York City" one thinks of the place New York City. In this case, the referent of the domain is the name "New York City". The referent of the range is the place, New York City. Both referents refer to the same concept, New York City. The operation was the process of associating the name to the place. Now if one sees the place New York City and thinks the name "New York City", the situation is different. In this situation, the referent of the domain is the place, New York City. The range referent is the name, "New York City". The operation was the process of associating the place to the name. As one can see, the name "New York City" can be an referent of the domain or range depending upon whether the operation acts upon it or whether it is the result of the operation respectively.

2.4.1.3 Key to differentiating among content constructs

The key in differentiating among identities, concepts, and rules is the kind of operation that is part of
a construct. Merrill and Wood (1974) defined three primary kinds of operations; the identity, the descriptive, and the productive operations (See Figure 17).

The identity operation. The identity operation is a one to one mapping between a referent in the domain and one in the range. The process of associating the words "New York City" to the place is an identity operator. Facts such as 2+2=4 and Columbus discovered America in 1492 are constructs that have identity operators.

<table>
<thead>
<tr>
<th>OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDENTITY</td>
</tr>
<tr>
<td>DESCRIPTIVE</td>
</tr>
<tr>
<td>PRODUCTIVE</td>
</tr>
</tbody>
</table>

Figure 17. The three types of operations.

A descriptive operation. The descriptive operation classifies referents of the range concept(s) based upon the combinations of referents of two or more domain concepts. There are two common types of descriptive operations; (1), Classification by Example Operations that describe the range concept(s) by means of a list of domain referents, (2) Classification by Attribute Operations that describe the range concept(s) by means of specifying referents of the domain concepts that are attributes of the range concept(s).

Figure 18 illustrates an example of the use of description by example to define the concept motor.
vehicle. The domain contains a list of referents of a motor vehicle. By examining the list one should be able to develop a prototype of the concept "motor vehicle".

<table>
<thead>
<tr>
<th>DOMAIN</th>
<th>RANGE CONCEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referents (instances)</td>
<td>Motor Vehicle</td>
</tr>
<tr>
<td>Car</td>
<td></td>
</tr>
<tr>
<td>Truck</td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td></td>
</tr>
</tbody>
</table>

Figure 18. Descriptive operation: List of examples.

An example of the use of a description by attribute operation is Ackoff's (1972) definition of a system (see Figure 19.) That is, he defined a system as being an entity composed of more than one element and relations between each and every element. The domain concepts are (a) entity, (b) composed of more than one element" and (3) "relations between each and every element." The range concept is "system". The operation here states the characteristics a referent of "system" must possess. That is, a "system" (range concept) must be an "entity" (domain concept) "composed of more than one element" (domain concept) and "having relations between each and every element" (domain concept).

The manner in which the domain concepts are combined helps classify referents of the range concept. Referents of the domain concept "entity" can be the mechanism involved in getting fuel to a gasoline powered automobile.
Referents of the domain concept "composed of more than one element" can be the fuel pump, fuel filter, and carburetor that are elements of the mechanism. Referents of the domain concept "having relations between each and every element" can be the event that if, for example, the fuel pump were not part of the fuel mechanism, then the mechanism would not function. Combining the referents of the domain concepts one has the referent of the range concept—a fuel system for a gasoline powered automobile.

<table>
<thead>
<tr>
<th>DOMAIN CONCEPT Referent (instance)</th>
<th>RANGE CONCEPT Referent (instance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entity</td>
<td>Fuel mechanism</td>
</tr>
<tr>
<td>Composed of more than one element</td>
<td>Carburetor, fuel, filter, fuel pump</td>
</tr>
<tr>
<td>Relations between each and every element</td>
<td>Event that all elements must work in order for mechanism to work</td>
</tr>
<tr>
<td></td>
<td>System fuel system for gasoline powered auto</td>
</tr>
</tbody>
</table>

Figure 19. Example of the use of a descriptive operation.

A productive operation. A third type of operation produces referents of the range concept from referents of two or more domain concepts. It is the process, act, or method of creating a referent or referents of the range concept(s) by grouping the referents in the domain in such a way that the referents of the range concept(s) are qualitatively different from the referents of the domain concepts. (Merrill & Wood, 1975). An example of a productive operation is addition (see Figure 20). In the addition example, there were referents of two domain
concepts, the concept "a set of 12 things" represented by 12 vertical lines. and the concept "a set of 10 things" represented by 10 vertical lines. Notwithstanding that fact, there are examples of rules where the production operation does not act upon referents of two domain concepts. One example is the American political election (see Figure 21). In the election example, there was only one domain concept, not two or more as was stated as being necessary for a production operation by Merrill and Wood.

<table>
<thead>
<tr>
<th>DOMAIN CONCEPT</th>
<th>OPERATION CONCEPT</th>
<th>RANGE CONCEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCEPT Referent (instance)</td>
<td>CONCEPT Referent (instance)</td>
<td>CONCEPT Referent (instance)</td>
</tr>
</tbody>
</table>

A set of 12 things \[ \begin{array}{c} \hline \hline \hline \hline \hline \hline \end{array} \] Addition + A set of 22 things

A set of 10 things \[ \begin{array}{c} \hline \hline \hline \hline \hline \end{array} \]

Figure 20. Example of a productive operation.

<table>
<thead>
<tr>
<th>DOMAIN CONCEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-election administration (Carter Administration)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OPERATION CONCEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Election</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RANGE CONCEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post election administration (1980 Presidential Election)</td>
</tr>
</tbody>
</table>

| Pre-election administration (Carter Administration) | Election | Post election administration (Reagan Administration) |

Figure 21. Example of a productive operation on one domain referent (instance).

The definition of a productive operation needs to reflect the possibility of having only one domain concept.
A modified version that reflects this possibility reads: a productive operation produces referents (instances) of the range concept(s) from referents (instances) of the domain concept(s) in which the range concept referents (instances) have characteristics (used to classify the referents (instances) different from those of the referents (instances) of the domain concept(s).

The modified definition also clarifies the distinction between a concept and a rule. Merrill and Wood (1975) have pointed out that the distinction between concepts and rules is sometimes confusing because of the relationship between them. In order to decrease the possibility of confusion, the following convention is used. "A given piece of content is classed as a concept if its definition involves a descriptive operation, but as a rule if its definition involves a change operation" (Merrill & Wood, 1975). The modified definition points out that the result of the change operation is reflected in the range referent(s) (instance(s)). By pointing out what is changed by the operation, it should aid in making the distinction according to the convention.

It is this last type of operation, a productive operation, and its corresponding construct, a rule, that parallels problem solving. Specifically, the problem solving represented in Reitman's model of problem solving will be examined in the next section.
2.4.2 Problem Solving

The purpose of this section is to continue to establish the relationship between concept learning and problem solving. The previous section showed the relationship between concept and rule. This section will start to lay the foundation for examining the relationship between rule and problem. This section will also examine how problem structuring and identification fit in the problem solving process. Finally, a problem analysis technique called the decision tree technique will be defined. In order to establish the relationship between rule and problem, the term "problem" must be defined.

1.4.2.1 Problem - a definition

Reitman defined problem as a three component vector taken together with its associated problem requirement. This three component vector consisted of an initial state, an operator, and an end state. The problem requirement specified what referents of each component should be found so that the application of the operator referent on the domain referent will result in a referent of the range. If some vector of referents is found to satisfy this requirement, then the problem is said to have been solved (Reitman, 1964).

Reitman's definitions of the components are such that it is necessary to refer back to Ashby's work in order to
understand the nature of the components. An initial state is a set of events, objects, or symbols that is acted upon by a set of operators. Examples of initial states are cold soil, unexposed photographic plate, and A (see Figure 22). An operator is the factor or factors that acts on the initial state to change that state. Examples of operators are sunshine, shutter opened, and \( -> \). An end state is a set of events, objects, or symbols that is the result of the operator acting on the initial state. Examples of end states are warm soil, exposed plate, and B. The emphasis of the two states is on "what" is the nature of the state. The emphasis on the operator component is on "how" to change the initial state into the end state (Ashby, 1958).

<table>
<thead>
<tr>
<th>INITIAL STATE</th>
<th>OPERATOR</th>
<th>END STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Soil</td>
<td>Sunshine</td>
<td>Warm Soil</td>
</tr>
<tr>
<td>Unexposed Photographic Plate</td>
<td>Shutter opened</td>
<td>Exposed Plate</td>
</tr>
<tr>
<td>A</td>
<td>( -&gt; )</td>
<td>B</td>
</tr>
</tbody>
</table>

Figure 22. Examples of problems.

2.4.2.2 Problem identification and structuring techniques

There exist a number of techniques to aid individuals with problem identification and structuring that reflect Reitman's definition of problem. One of the more pre-
dominant ones is the decision tree technique. Another which will be discussed later in the section on concept learning is strategies used for concept learning. Since decision trees are more commonly associated with the problem solving/decision making process, the techniques associated with it will be discussed first. Before the decision tree technique is discussed, more needs to be said concerning how problem identification and structuring fit in the problem solving process. To establish this fit, one needs to reexamine Pound's (1965) problem solving model.

Previously in the section on adaptive process, Pound's problem solving model was compared to Kolb's experiential learning model. Pound's model consisted of eight steps. The steps of the process, as listed in Figure 23, start with the selection of a goal and continue on through execution of the operator on the initial state to reach the goal. Problem identification and structuring is that portion of the process that includes the first seven steps in the process. It includes selection of the components of the problem (initial state, end state, and operator) but it does not include the execution of the operator on the initial state.

The decision tree technique is a technique which is used for problem structuring and identification. A decision tree is a graphical model that shows the sequence
of decisions and alternatives that comprise a sequential
decision process (Andrews, Klem, Davidson, O'Malley, &
Rodgers, 1974). The fundamental use of the decision tree
is to aid the problem solver/decision maker structure the
problem. Brown (1970) noted that the contribution of
decision trees to the decision making process seems to
come more from forcing meaningful structure on informal
reasoning.

Choose a model or goal
Compare it with reality
Identify differences (problems)
Select a problem
Consider alternative solutions
Evaluate consequences of solutions
Select a solution
Execute the solution

Figure 23. Steps of Pound's problem solving model.

An example of the use of the decision tree technique
is A Guide for Selecting Statistical Techniques For
Analyzing Social Science Data (Andrews et al., 1974). The
guide is a sequence of questions and answers by which the
user is led to an appropriate statistical technique.
Figure 24 illustrates a short sequence of questions and
answers from the guide. The user starts the process by answering the first question, How many variables does the problem have? If the user's answer is that there are two variables, the user then answers the next question, How do you want to treat the variables with respect to the scale of measure? If the response is both interval, then the guide instructs the user to turn to page 5. On page 5, the user will find other questions to answer before the guide suggests which statistical technique to select.

STARTING POINT

How many variables does the problem have?

<table>
<thead>
<tr>
<th>One variable</th>
<th>Two variables</th>
<th>More than two variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do you want to treat the variables with respect to scale of measurement?</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both interval</td>
<td>Both nominal</td>
<td>1 interval, 1 nominal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both ordinal</td>
<td>1 interval, 1 ordinal, 1 nominal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Go to page 4 Go to page 5 Go to page 7 Go to page 8 Go to page 10 Go to page 11 Go to page 13 Go to page 14

Figure 24. Example of a decision tree segment.

Though the decision tree technique represents a relatively simple way to represent a problem for identification and to aid with problem structuring, this technique has its deficiencies. Saleh, Kim, Leal, & Pearl (1979) identified the most serious deficiency as being the
constraint of representing knowledge in tree form. Saleh elaborates on this deficiency by stating "Decision Analysis is founded on the paradigm that the reliability of human judgments increases when the format of these judgments are made more compatible with the internal format used by people to encode experience." He finishes by saying that though decision trees decompose the problem so more reliable judgments can be made, the technique is too crude. For this reason, another technique is examined. The technique is one used to aid the learning of concepts.

2.4.3 Concept Learning

Concept learning techniques can be used to aid with problem identification and structuring. In order to explain how the techniques can aid this process, a discussion of concept learning and a description of the technique is necessary.

2.4.3.1 Concept learning - a definition

Concept learning is a process which results in the individual correctly identifying the class membership of a specific object, symbol, or event (Gagne, 1970; Merrill & Tennyson, 1977). For example, if an individual is taught the concept "dictionary" and when given any instance of a dictionary can correctly classify the instance as an
example, then the individual has learned the concept "dictionary."

The classification of an object as a dictionary requires that the individual be able to generalize to newly encountered examples of dictionary and to discriminate between example and nonexamples of the concept (Carroll, 1964; Mechner, 1965; Tennyson & Park, 1980). These two abilities are called generalization and discrimination (Merrill & Tennyson, 1977).

2.4.3.2 Concept learning strategies

In a review of instructional strategies for computer based education, Hall et al. (1982) identified two concept learning techniques that they felt may be useful in instructional development. The two techniques were learning concepts by prototype acquisition and learning concepts by attribute isolation and identification.

2.4.3.2.1 Prototype acquisition strategy.

Hall et al. (1982) characterized the prototype formation strategy as described by Wilson (1963). It causes the learner to deduce the definition of a concept by presenting examples of the concept. The sequence of presentation of the examples start with the global and general progresses through successive steps of refinement. Not all of the successive steps are used in all teaching
incidents. (The steps are defined in appendix E.) They noted that this technique may be useful for ill defined or abstract concepts where specificity of the characteristics of the concept do not exist initially but as the learner gains knowledge the concept is refined and expanded.

Tennyson, Chao, & Youngers' (1981) two phase concept learning process exemplifies prototype formation strategies. Park (1984) described this strategy as based upon the nonanalytical model of concept formation proposed by Millward (1980). This theory proposed that concepts are learned by deriving meaningful dimensions from examples and then stored as a prototype or abstraction in memory. These meaningful dimensions are abstract and internally organized around the learner's cognitive structure.

The two phases of the process were 1) presentation of a number of examples that best represent the concept, and then 2) presentation of examples and nonexamples of the concepts. The first phase was to cause the learner to create a prototype of a concept class. The second phase was to cause the learner to develop the cognitive skills necessary to discriminate and generalize.

2.4.3.2.2 Attribute isolation strategy.

The other concept learning strategy, attribute isolation and identification was characterized by Hall et al. (1982) based upon a review of the work of a number of
researchers (Clark, 1971; Entwistle, 1978; Gagne, 1962; Tennyson, 1980). Hall identified the major components of the strategy (see Figure 26). This approach is based upon classical attribute isolation theory of concept formation.

Concept name
Concept definition which includes:
- Relation to class of concepts that it is a member
- Critical attributes
- Variable attributes

Three to five matched sets of examples and nonexamples in expository form
Sufficient inquisitory presentations of instances (with attribute isolation feedback) for the learner to achieve mastery.

Figure 25. Attribute Isolation Strategy. (Hall et al., 1982)

2.4.3.2.3 Attribute isolation and prototype formation compared.

Attribute isolation strategy and prototype acquisition strategy were compared in a study by Park (1984). Each of two groups of subjects were taught a number of concepts using one of the two strategies. Three measures were taken during the study, a measure of the classification errors during the learning task, a posttest, and a retention test given a week later. The attribute isolation group made fewer classification errors than did the prototype formation group. On the other hand, the prototype formation group performed better on the posttest
and the retention test. The following are the other conclusions of the study. The prototype formation group provided better definitions (written in terms of critical attributes and relationships) and examples. The nature of the definitions and examples implies that both attribute isolation and prototype formation groups stored in memory a prototype abstraction of the concepts and not a list of critical attributes and relations or a particular example. Based upon these conclusions and studies by Tennyson and others, Park concluded that the better on-task performance of the attribute isolation group over the prototype formation group suggests that the combination of both strategies might result in better concept learning achievement than either strategy.

2.4.3.2.4 Combined strategy - The problem identification and structuring technique.

In Figure 26 show a formative strategy developed by Hall that is a flexible strategy that accommodates both the attribute isolation strategy and the prototype-formation strategy is given. This strategy allows for procedures usually found in the attribute isolation strategy -- namely, presentation of the concept definition (critical and variable attributes), an expository presentation of instances of the concept, an inquisitorial presentation of instances followed by feedback. The flexible approach can also accommodate many of the steps
found in the prototype-formation strategy. The central meaning of the concept can be described in terms of attributes that do not require a high degree of specificity. The combined strategy allows the presentation of clear and unequivocal examples of the concept (model case step) along with concepts that are nonexamples (contrary case step). Related concepts (related case step) can be described in terms of superordinate, coordinate, and subordinate concepts and the relationships shown in a concept tree which will be discussed later. Examples in which it is not clear whether the concept applies or not (borderline case step) can be presented in the form of inquisitory instances. Much of the information from other steps such as the social context pertaining to the concept and biases of persons using the concept can be specified in the elaboration section for a concept or example. The structure in which concepts are represented (Figure 27) allows for the use of either approach depending upon which strategy is felt to be the most appropriate.

Hall et al. (1982) also advocated the use of concept maps to relate the concept name to the superordinate and coordinate concept names mentioned above. For example, consider the concept "poodle." The superordinate concept is "dog." The coordinate concept is "collie." The relationship can be pictured in a concept map (see Figure 28).
Figure 26. Hall’s Strategy

Concept Name
Superordinate Concept Name
Coordinate Concept Name
Definition:
  Relation to Superordinate Concept
  Critical Attributes
  Variable Attributes
Examples
Elaboration

(Definitions of terms in Appendix) Hall et al. 1982

Figure 27. Element of Hall’s Approach.
2.4.4 Concept Learning in Problem Solving

Based upon the literature, Hall's combined concept learning technique is a valid method for aiding the user in problem identification and structuring. A problem as defined by Reitman is a three component vector consisting of an initial state, an operator, and an end state. Merrill and Wood defined a rule as an ordered relation consisting of a set of domain concepts, a productive operation (also a concept) and a set of range concepts. The initial state of a problem is a set of domain concepts. The operator of a problem is a productive operation. The end state of a problem is a set of range concepts. Therefore, each component of a problem is a concept.

Given this relationship, the components of a problem are concepts. Based upon Reitman's definition of a problem, a problem is a type of rule. Remember, a rule is a three vector model in which the operator changes the set of range referents into a set of domain referents where both sets are qualitatively different. A problem is also
a three vector model where the initial state and end state are different due to the application of an operation. The examples of problems in Figure 22 show initial states and end states that are qualitatively different (i.e. cold soil is different from warm soil; an unexposed photographic plate is different from an exposed plate). Problems are types of rules and each component of a problem is a concept.

Since each component of a problem is a concept, concept learning techniques are valid methods for identifying and structuring the components. Concept learning can be used in the identification of the problem's components by aiding the user in generalizing to all examples of that class of problem components and discriminating between examples of that class of problem component and other classes. The skills of generalization and discrimination would aid the problem solver in determining what type of problem he is facing. Specifically the problem solver would be able to determine: (1) What is the initial state (instance(s) of the domain concept(s)), (2) What is the goal, end state, or ideal he wants (instance(s) of the range concept(s)), and (3) What process could change the initial state into the end state (instance(s) of the operation concept(s)).

To summarize, concept learning techniques can aid problem identification and structuring since the
components of a problem are concepts. It was shown that the initial state of a problem, the end state, and the process for obtaining the goal are all concepts. It was also shown that the skills of generalization and discrimination were needed to determine these concepts. Nonetheless, as will be discussed in the next section, the level of cognitive processing needed to generalize and discriminate is dependent upon the knowledge the user brings to the task and the knowledge that is provided.

2.4.5 Levels of Cognitive Skills

The focus of this section is on the levels of learning/problem solving/decision making necessary to identify and structure ill-structured problems and the cognitive processing associated with those levels. Four topics will be discussed in the following order. First, the levels of learning associated with instruction (CAI) are examined and related to the levels of behavior necessary for task performance. Second, the factors that help determine the levels of behavior needed to perform a specific task are described. Third, the task taxonomy based upon the necessary level of behavior and type of construct is explained. Fourth, descriptions of the levels of behaviors associated with problem solving are given.
2.4.5.1 Levels of learning

Levels of learning are actually levels of instructional objectives (Hall, 1983). There exist a number of such taxonomies - Bloom's (Bloom et al., 1956), Gagne's (Gagne, 1962), and Merrill's (Merrill, 1971). Hall et al. (1982) selected Bloom's taxonomy because:

(1) validated communicability, usefulness, and suggestiveness, (2) emphasis on types of learning tasks generally encountered in instructional environments, (3) quality documentation, and (4) tasks learners are expected to perform within the structure of knowledge. (p. 3)

Bloom's taxonomy (see Figure 29) has six levels of cognitive objectives or behaviors. The six levels are divided into two parts: behaviors of recall and recognition of knowledge (the knowledge level) and behaviors of intellectual skills and abilities (the other five levels). The behavior associated with the knowledge level is "little more than the remembering of the idea or phenomenon in a form very close to that in which it was originally encountered (Bloom et al., 1956). Although the behavior associated with all the other five levels are the abilities and skills to "find appropriate information and techniques in (ones) previous experience to bring to bear on new problems and situations." (Bloom et al., 1956)
The six levels of behavior are observed when individuals perform tasks. Figure 30 shows a task that generally requires recall and recognition of knowledge. In the example, the individual is required to recall the fact that a collie is a dog. Figure 31 illustrates a task that generally requires comprehension. To accomplish the task, the individual needs to interpret the previously learned formula for correcting for guessing.

Knowledge: Recall and recognition of specific universal methods, processes, pattern, and structure.

Comprehension: Understand of the literal message contained in the communication

Application: Selection of the correct abstraction (theory, principle, idea, or method) in which no abstraction is specified

Analysis: Breakdown of material into elements and detection of the relationships between the elements

Synthesis: Process of combining elements into a pattern or structure not clearly there before

Evaluation: Making judgments about content based upon criteria and standards

Figure 29. Bloom's Taxonomy.

A collie is a type of ______.

1) DRINK  2) DOG  3) LASSIE  4) HORSE

Figure 30. Example of recall and recognition of knowledge.
In the formula to correct for guessing, the number of items guessed is estimated on the basis of:

A) THE OBSERVED SCORE  
B) THE NUMBER RIGHT  
C) THE NUMBER WRONG  
D) THE NUMBER OMITTED

Figure 31. Example of comprehension.

2.4.5.2 Factors affecting cognition skills

The classification of a task at a particular level of behavior is dependent upon the knowledge of the individual performing the task, the information provided to the individual, and the nature of the task. The behavior required to perform a task for one individual is not necessarily the same for another. For example, the behavior required by a plumber to fix a leaking faucet is likely to be at the comprehension or application level while the behavior required for the same task by a child would likely be at the analysis, synthesis, and evaluation levels. The reason is that the behavior required depends upon the prerequisite knowledge of the individual performing the task. One would expect the plumber to have the prerequisite knowledge of how to fix the faucet. By contrast, one would not expect the child to have that same prerequisite knowledge. Therefore the child would have to create the knowledge in order to fix the faucet. The creation of knowledge is a much different type of behavior than the use of that knowledge.
The information provided to the individual can affect the level of task. For example, assume two plumbers with the same prerequisite knowledge are each given the task of installing a new type of faucet. The one plumber is given the instruction sheet while the other is not. A case can be made that the behavior of the plumber using the instruction sheet is one of comprehension while the behavior of the plumber without the instructions is at the application or higher level.

Finally, the nature of the task can affect the level of behavior associated with the task. Two characteristics of the task are of concern here. First, the case where multiple behaviors are needed and second, where tasks are associated with either identities, concepts, or rules. Normally a task that requires all six levels of behavior is an evaluation type task due to the hierarchical nature of the taxonomy. However, that is not always the case. For instance, in an earlier example, the behavior of the plumber with the instructions was that of comprehension. But the plumber may have used analysis in understanding the instructions as part of the task. In such cases, the behavior associated with the task appears to be the one of most emphasis. In the above instance, the behavior of most or primary emphasis was that of comprehension, even though analysis may have been used.
The other aspect that can affect the behaviors required by a task is the type of construct associated with the task. For example, the plumber seeing a picture of the faucet and associating the picture to the actual faucet requires the plumber to use an identity construct, picture of faucet and faucet. The task which encompasses the plumber understanding the instructions requires the plumber to use the concepts he has learned being a plumber. The task requiring the use of identity constructs requires knowledge level behavior, whereas the task that requires the use of concepts requires at least comprehension level behavior. Both the level of behavior required by the one performing the task and the type of content construct associated with the task have been used by Hall to classify cognitive tasks.

2.4.5.3 Task taxonomy

Hall (1982) classified tasks based upon the level of behavior required by the one performing the task and the type of content construct (identity, concept, and rule). The result was a taxonomy as shown in Figure 33. Based upon the taxonomy, association learning tasks require recall and recognition (a behavior) of identities (a construct). Concept learning tasks necessitate all six levels of behavior classified by Bloom. (It was felt that the behaviors of analysis, synthesis, and evaluation
are so often present together that combining them into one behavior seemed appropriate.) Problem solving tasks required the behaviors of comprehension; application; and analysis, synthesis and evaluation (ASE). Recall and recognition were determined not to be a behavior which alone would result in problem solving. Problem solving results in the application of a productive operator which results in the instance of the range being qualitatively different from the instance of the domain. Therefore, the range and domain cannot have instances that are qualitatively equivalent. But recall and recognition is associated with the application of identity operators which relate an instance of the range to a qualitatively EQUIVALENT instance of the domain. The task categories are discussed in greater detail next.

Association learning
Concept Recall and Recognition
Concept Comprehension
Concept Application
Concept Analysis, Synthesis, and Evaluation
Problem Solving Comprehension
Problem Solving Application
Problem Solving Analysis, Synthesis, and Evaluation

Figure 33. Hall's Taxonomy.

Association learning is present in situations where the learner needs to recall or recognize a previously learned identity construct. The learner, given a domain
referent, provides the appropriate range referent. For example, a learner is shown a picture of Lincoln and the correct response is for the learner to say "Lincoln." The behavior associated with concept recall and recognition is primarily the ability to recall a previously learned concept construct. There are several possible situations where the concept learning is at recall and recognition level. For instance in one situation the information pertaining to the task may include one or more previously learned examples of the concept. The learner recalls what concepts the examples are. In another situation the information may include the characteristics of the concept. The individual recalls what concept the characteristics describe. Lastly, a situation may be the kind in which the information may include the name of the concept. The problem solver recalls the characteristics and/or the examples associated with the concept.

The behavior associated with concept comprehension is the ability of the problem solver to use different examples or a different phrasing of the characteristics than the one previously learned in order to describe one of the components. For example, assume that a problem solver is given a class of problems that he had faced before. The information provided to the problem solver told him that he had previously dealt with that class of initial states. The behavior of interpreting the
problem in order to describe a previously learned class of initial states is concept comprehension.

Concept Application and Concept ASE (Analysis, Synthesis, and Evaluation) type behaviors are represented in situations where the problem solver, faced with a not-before-encountered problem, identifies the problem components as examples of concepts that he had previously learned. For example, assume a problem solver had dealt with problems of strength of association between two nominal variables using a certain procedure. The contingency table associated with the problem is 6 by 10. The problem solver has dealt with the same class of problems but only with tables that are 2 by 2. The problem solver's task is to determine if he has encountered that particular class of problem before, and if so, what class of problem is this.

What differentiates the behaviors associated with concept application and concept ASE is whether the problem solver needs to analyze, synthesis, or evaluate the situation in order to determine the type of problem the problem solver is facing. If the problem solver can determine the correct concepts without an analysis, synthesize, or evaluation, then the task is a concept application task. For example, consider the previous situation where the problem solver was given the 6 x 10 contingency table problem. If he had remembered that one
of the procedures for dealing with contingency tables would work on any size table, then he did not have to analyze, synthesize, or evaluate the task in order to apply the correct procedure in dealing with the task. On the other hand, if the problem solver has to analyze, synthesize or evaluate the situation to identify the correct concepts, then the behavior is a concept ASE type behavior.

Problem solving comprehension. If the three components of the problem are specified, and the problem solver has enough prior knowledge to execute the operation component, then the level of cognitive skill required for the problem is problem solving comprehension. For example, the user is given the following problem to solve. Use the Lens Maker's Formula to find the focal length of a glass lens (n is 1.5) with one flat surface and one with a radius of 10 cm. The user here is told the existing state, lens n is 1.5 with one flat surface and one with a radius of 10 cm; the end state, focal length; and the operation, Lens Maker's Formula. The user apply the Lens Maker's Formula to obtain the end state. The common characteristics of this class of problem solving is that the three components are known by the problem solver.

The problem solver of the problem identified in the previous paragraph knew the existing state, end state, and what operation to use. The problem solver needs the
cognitive skills to comprehend what the components are and to be able to execute the operation on the existing state.

**Problem solving application.** If the task does not identify all the components, but for at least one of the components provides sufficient knowledge to allow the problem solver to identify that component correctly, and the problem solver has sufficient knowledge to execute the operation, then the level of cognitive behavior exhibited for the problem is problem solving application. For example, the user is given the following problem to solve.

A long glass cylinder (index of refraction = 1.5) is 10 cm in diameter and one end is a hemispherical surface with radius of 5 cm. A small object is placed on the axis. Find the position, size, and nature of the image if the object is: (A) 20 cm from the hemispherical end, (B) 5 cm from the hemispherical end.

Here the problem solver is given the end state, find the position, size, and nature of the image. He is also given the initial state, long glass cylinder with index of refraction of 1.5, 10 cm in diameter, one end a hemispherical surface with a radius of 5 cm, and the object is 20 cm and 5 cm from the hemispherical end. What the problem solver is not given is the operation for the problem.

Let us assume, however that the problem solver brings to the problem, knowledge of several formulas to obtain the position, size, and the nature of the image. The cognitive behaviors necessary for problem solving
application are the skills to determine the correct formulas and to apply the formulas to the initial state in such a manner as to produce the referents of the end state.

Problem solving analysis, synthesis, and evaluation (ASE). If the situation is such that the information provided does not allow for classification of the components or for the execution of the operator or the rationale for the interaction between the components, and the problem solver creates or discovers what is necessary to solve the problem, then the level of cognitive skill required by the problem is problem solving analysis, synthesis, and evaluation. For example, the user is given the following problem to solve.

On certain occasions, sailors have thought they could see a ship or an island of land floating in the sky above the horizon. Explain why this could happen.

The user here is to provide the rationale for what the sailor thought he saw. The end state is an image of a ship or an island of land floating in the sky above the horizon. The initial state is that it happens on certain occasions. The operation that results in the image is not provided. If the rationale for this class of occurrence has not been acquired by the user previously, then the user needs to use the cognitive skills of analysis, synthesis, and evaluation to create or produce the rationale for this class of occurrences.
2.4.5.4 Application to ill-structured problem solving

The behaviors most relevant to the determination of the components of most ill-structured problems are concept application, concept ASE, and problem solving ASE. The rationale for excluding concept comprehension was that in tasks requiring comprehension, the component is specified (Bloom et al; 1956). As noted earlier, ill-structured problems have at least one component that is not specified.

The rationale for including problem solving ASE and not problem solving comprehension and problem solving application was that problem solving ASE is the only behavior that can result in the creation of a new component (rule) that had not previously been learned by anyone. For example, assume that the initial state of a problem has not been defined before by anyone involved with the problem situation. Also assume that the problem solver is provided with what he feels are several examples of this initial state but he is not sure. His task is to define the initial state. The problem solver must determine the common characteristics of each example and how the characteristics relate to each other, i.e. analysis.

The problem solver must take that information and define the initial state that was not clearly defined before, i.e. synthesis. In this situation the problem
solver starts with a set of examples. He ends with a
definition of a concept, i.e. initial state. The opera­tion calls for analysis, synthesis, and perhaps evaluation
in order to identify the common characteristics of the
referents and to determine that the grouping is one that
had not previously been acquired by the problem solver.

The tasks and associated cognitive behaviors used to
identify and structure the initial state, end state, and
operator of a problem are necessary but not sufficient
conditions to solve problems. As was discussed previous­ly, problem solving involves more than just identifying
the problem. It includes implementing the solution and
comparing the actual results with the goal. If the actual
results are not satisfactory, then the process continues
through another cycle until the results sufficiently match
the desired goal. Identification of the problem results
in a knowledge of what the initial state, end state, and
operator is. But as noted by Ashby (1958) knowing what
the operator is, is not as important as knowing how to
execute the operator to change the initial state into the
end state.

2.4.6 Summary of the role concepts play in problem
solving

The role of concept acquisition in problem solving is
one of aiding the problem solver in identifying and
structuring, if necessary, the components required for
problem solving. It was shown that problems are rules and the components of a problem are concepts. Therefore, concept acquisition should be helpful in the identification and understanding of the components required for problem solving.

The problem solver needs to possess certain cognitive skills in order to understand and identify the problem solving components. Based upon an analysis of Hall's Taxonomy, the cognitive skills needed to deal with ill structured tasks (problems) are concept application; concept analysis, synthesis, and evaluation (concept ASE); and problem solving analysis, synthesis, and evaluation (problem solving ASE). Since problem solvers need to possess certain cognitive skills, a measure of the problem solvers cognitive skill is necessary to determine if the benefit of concept acquisition techniques upon problem identify and structuring is dependent upon the problem solvers ability. The next section addresses the measurement of concept acquisition behavior. The effect of these cognitive skills upon problem identification and structuring was raised in this study's hypotheses. It was assumed that subjects with varying levels of cognitive skills measured in terms of analytical ability would perform equally well. The next section addresses the issue of measuring this ability.
2.5 Ability: Measurement of Concept Acquisition Behavior

The need for problem solvers to acquire components of ill structured problems raises the issue of their ability. In the previous section it was stated that the two behaviors most relevant in the acquisition of components in ill structured problems are application and analysis, synthesis, and evaluation (ASE) which vary from individual to individual (Bloom et al, 1956). Therefore, given a component acquisition task, will individuals with different levels of ability perform differently using the concept acquisition techniques described in the previous section?

Field independence, one of the more studied individual factors, is closely associated with the ability to analyze and synthesize. Based upon an examination of that relationship, it was decided that a common measure of field dependence (Embedded Figures Test) would be used to measure the effect ability has on component identification. The examination proceeded in the following manner. First, selected literature on human information processing requirements was reviewed to identify the individual factors that have been studied with respect to accomplishing tasks with the aid of support systems. The construct, field independence, was one of those factors. Second, the history of the construct was reviewed. Third, selected literature dealing with the relationship between
the construct and cognitive traits were examined with a focus on the relationship between the construct and the abilities needed to acquire the components.

2.5.1 Human Factors of Interest in Support Systems

It is indicated in the research that individual and contextual factors have an effect upon the human, the human information processing requirements for decision making (Chervany & Dickson, 1978; Mason & Mitroff, 1973; Mason & Moskowitz, 1972; Taylor, 1975) and learning. Three individual factors are most relevant to the success of management information systems as classified by Zmud (1979): cognitive styles, personality, and demographic/situational factors. Demographic/situational variables include such personal characteristics as general intelligence, abilities, experience, content knowledge, and education. Individual factors related to CAI as classified by Hall (1982) consist of three classes also: cognitive style, learning style, and contextual factors such as those of task and environment.

Among the individual factors that have been identified, the one that has received the most attention has been cognitive style. As noted, Zmud differentiated between style and personality. Guilford (1980), however, stated "writers generally agree that cognitive styles are in the general family of personality traits, where traits
are commonly conceived as variables or dimensions along which individuals of a population differ."

2.5.2 Origin of Field Dependence

Field Dependence (FI) originated in investigations of perception of the visual space. The investigations had subjects perform tasks that would produce perceptions derived from the visual environment that were different from perceptions derived from sensations from within the body resulting from the pull of gravity. One of these tasks was the Rod and Frame Test (RFT) (Witkin et al., 1977). The subject seated in complete darkness views a large luminous frame and a luminous rod which are both rotated independently of each other from the same center. The subject's task is to adjust the rod to the upright position. Some subjects completed the task successfully while others adjusted the rod in alignment to the frame.

Another task was called the Body Adjustment Test (BAT) developed by Witkin et al. (1977). In this task the subject, again in complete darkness, views a small room. Both the subject and the small room can be tilted. The subject's task is to position the chairs in the small room so that the subject experiences them as upright. Performance on the BAT was similar to that found on the RFT.

Another task that was used was the embedded figures test (Witkin et al., 1977), which is unlike the other two
tasks in that it does not invoke perception of the upright or the body. Performance on this task has been found to be correlated substantially with the other two tasks. The task consists of the subject being shown a single figure. The figure is then removed and the subject is shown a complex figure. The subject's task is to locate the simple figure embedded within the complex figure. The results of these investigations supported the hypothesis that

The individual differences we have been observing in terms of degree of dependence on the structure of the prevailing field, ranging from great dependence, at one extreme, to great ability to deal with the presented field analytically, or to separate an item from the configuration in which it occurs, at the other. (Witkin et al., 1954, p. 34)

Over the years the interpretation of the variable has expanded. Based upon years of accumulated evidence, (Witkins et al., 1977) stated that the individual differences dimension first identified in perception shows itself equally in the problem solving domain. The key feature in this broadened construct was called the articulation—global dimension.

The articulation-global dimension was applicable to the processing of information both from an immediately present stimuli configuration as in perception—or from symbolic material as in intellectual functioning." (Witkin et al., 1977)

A field independent (articulated) person perceives elements within the environment as discrete from that
environment when the environment is structured. When the environment is not structured, the individual will impose structure on the environment and so perceive the environment as being structured when the environment has little inherent structure. A field dependent (global) person would process information in a manner that is governed by the structure of the environment. The individual would be less likely to impose a structure on the environment or to restructure the environment. From their perspective, the structure of the environment, including the tasks, is given (Witkin et al., 1977; Goodenough 1976).

2.5.3 Cognitive Traits Associated with Field Dependence

The articulated-global dimension of the construct field dependence has the abilities of analysis and structuring associated with it. Analysis defined here is the capacity to extract items from an embedding context (Witkin et al., 1977). Structuring is the capacity to restructure the field or environment.

Kessler and Konenberger (1967) and Ehri and Muzio (1974) have examined how the articulated-global dimension of field dependence can assess the ability to analyze and synthesize. Kessler and Kronenberger (1967) compared groups of subjects that differed in levels of field dependence on their synthesizing ability. Thirty-two subjects were evenly divided into four groups based upon the
subject's scores on an embedded figures test and a dogmatism scale. The subjects were then given the Kohn Block Design test to measure their synthesizing ability. Field independent subjects evidenced significantly greater synthesizing ability than the field dependent subjects.

Ehri and Muzio (1974) conducted a study on the relationship field dependence has to solving problems that separate analytic and synthesizing aspects of problem solving. The subjects were divided into three groups based upon an embedded figures type test. Subjects were asked to determine whether horses on a merry-go-round moved faster on the inside or the outside. The results indicated that field independent subjects have superior analyzing and synthesizing abilities. Thus, based upon the work of Witkin and others, a measure of field dependence such as the Group Embedded Figures Test would differentiate between individuals with different analytical and structuring abilities.

2.6 Summary

The key issue addressed by the review of the literature was whether concept acquisition techniques developed for computer systems that aid learning (specifically computer aided instruction systems) could be used by computer systems that aid problem solving decision making (specifically decision support systems). Authorities on
decision support systems (DSS) explicitly have said that an examination of computer aided instruction (CAI) systems would not provide help in development of DSS. Authorities on CAI systems have implied that the techniques used in DSS are not appropriate for CAI systems. The purpose of the review was to compare the two types of systems and to determine if there was support in the literature for the possible use of concept acquisition techniques in DSS. The review started with Kolb's (1974) argument that learning and problem solving/decision making are essentially the same adaptive process. Kolb compared his experiential learning model (ELM) with a model of problem solving developed by Pound (1965). The comparison between Kolb's stages of his ELM and Pound's stages of his model indicate a general correspondence between the processes that each model represents.

Next, CAI and DSS systems were compared with each other. Keen's adaptive framework was used to show the relationships between the user, support staff, system, and task representation of each system type. The literature indicated differences between CAI and DSS systems in the design, implementation, and control of each system. Generally, DSS systems have design processes that are more iterative in nature, have implementation process which relys on more participation of the user, and have systems which are more under the control of the user. Though
these differences generally exist, the literature also indicates that these differences are not always present.

The key factor in differentiating between the two systems was the task structure. (The influence of the task structure on the system is not necessarily the only or primary source of the differences.) Tasks that are dealt with by CAI systems tend to be more well structured where the knowledge can be prespecified for the user and the answer is known. The tasks most often dealt with by DSS tends to be less well structured where the knowledge can not be prespecified.

Task structure, being the key factor in differentiating between the two types of systems, highlights the nature of those differences. The difference between the task structures associated with the two systems is one of degree more than of kind. That is, the structure of a task falls on a continuum and not into exclusive categories. The implication of task structure falling on a continuum is that there is no clear break where tasks on one side are within the domain of a CAI system and those on the other are within the domain of a DSS system. The group of subtasks may contain a number of tasks that also fall within the domain of CAI systems and also a number within the domain of DSS systems.

Based upon the review of the literature up to that point, it seemed desirable to use CAI techniques in DSS
systems where the performance of the user can be improved. Specifically, concept acquisition techniques developed for use in CAI systems could potentially aid the user in problem solving/decision making tasks.

A case was then made for the potential benefit of using concept acquisition techniques to aid problem solving. The work of Merrill and others on structuring knowledge was reviewed to define the different types of knowledge dealt with in concept acquisition and problem solving: identities, concepts, and rules. All three have a three component structure: a domain, an operation, and a range differentiate the three types of knowledge. The nature of the operation associated with concepts describes, while the operation associated with a rule produces. It is this last type of operation, a productive operation, and the type of knowledge associated with it, a rule (a productive construct), that was then compared to Reitman's model of problem solving.

Reitman's three component model (initial state, operation, and end state) parallels a productive construct (domain, operation, and range). Further, the components of the model can be considered concepts. That being the case, concept acquisition techniques used in identifying and understanding the components of problem solving should improve the problem solving process.
Next, the role of concept learning in component identification was examined. It was pointed out that component identification requires the skills of generalization and discrimination. It was also pointed out that there are two major concept acquisition techniques, prototype acquisition and attribute isolation.

A review of Hall's work on prototype acquisition and attribute isolation was undertaken. Prototype acquisition focuses on examples of a particular concept. On the other hand, attribute isolation focuses on the characteristics of the concept. Hall felt that combining the two approaches would be beneficial. His combined approach was outlined.

It was pointed out that no matter what technique is used, the problem solver needs certain cognitive skills in order to acquire the concept. Hall produced a taxonomy of cognitive skills needed to acquire different types of knowledge. It was determined that the cognitive skills needed for the acquisition of components associated with ill structured problems was concept application; concept analysis, synthesis, and evaluation; and problem solving analysis, synthesis, and evaluation. Based upon the taxonomy, individuals with concept application skills do not necessarily have the skills for concept analysis, synthesis, and evaluation. However, the converse is true.
It was assumed that not every individual has the same cognitive skills at the same levels. An individual may have concept application skills but may not have concept ASE skills. Also, one individual may have a higher analysis, synthesis, and evaluation skill level than another individual. If that is the case, then the question becomes will an individual's skill level affect his performance using the concept acquisition techniques. Since the task of structuring problems can require analysis, synthesis, and evaluation, then individuals without those skills may not perform as well as those with those abilities. In an attempt to address the issue, a discussion concerning the measurement of those cognitive skills took place. It was felt that the Group Embedded Figures Test was the most appropriate one to assess the problem solver's level of cognitive skills. Given the problem solver's level of cognitive skills, one can better assess his performance using the concept acquisition techniques.
CHAPTER III
THE DESIGN OF THE STUDY

The problem that this study examined was what effect does a selected CAI technique have on the identification and structuring of ill-structured problems. This chapter is a continuation of the examination by meeting objective 4 of the study: testing the proposed method of concept acquisition on selected subjects to determine the results of a number of hypotheses.

The research methodology (tests) required to meet objective 4 and resolve the problem is listed as follows required, (1) statistical hypotheses, (2) experimental treatments, (3) research design, (4) instrumentation, (5) research subjects, (6) data analysis, and (7) procedures. Each topic will be covered in order in the following pages.

3.1 Statistical Hypotheses

The following statistical hypotheses were tested. (1) Given an ill-structured problem in a familiar knowledge area (travel) that is an example of those described in both Problem Structuring and Identification Concept Acquisition Technique (PSICAT) and Decision Tree
Technique (DTT), subjects will not be able to identify the problem equally well using PSICAT or DTT. The subjects have varying levels of analytical ability. (2) Given an ill structured problem in a familiar knowledge area (travel) that is not an example of those described in both DTT and PSICAT, subjects will be able to identify the problem equally well using PSICAT than DTT. The subjects have varying levels of analytical ability.

3.2 Experimental Treatment

The subjects were provided with one of two support systems, Problem Structuring and Concept Acquisition Technique (PSICAT) and Decision Tree Technique (DTT). Both systems represented alternative techniques to assist the user in problem structuring and identification.

3.2.1 PSICAT

PSICAT (Problem Structuring and Identification using Concept Acquisition Techniques) is a support system which uses concept acquisition techniques to assist subjects with problem identification and structuring. The system consists of two parts: (1) an instructional component which teaches subjects how to use the system's decision aid for problem solving/decision making, and (2) the actual decision aid for identifying the travel problems of going from Chicago to New York. Appendix A contains an
instructional booklet that is very similar to PSICAT's instructional component. The rest of this section will focus on the PSICAT development process and the characteristics of the decision aid including several features designed to provide test information.

3.2.1.1 PSICAT Development Process

The development of PSICAT involved using both EASE and PACE authoring language of Phoenix, a computer based education package. EASE, a menu driven language has a number of features including full screen editing which cut development time. PACE is not menu driven and it only has line editing capability. Its advantage over EASE is that of greater flexibility.

The computer code was written in PACE which provided the framework for the entire system. Also, PACE was also used to create the component diagrams, and the mechanism to add additional components. Programs written with EASE were embedded within those written with PACE. EASE was used to provide the definitions and examples for the components that PSICAT described. Due to faster development times associated with using EASE, it was used wherever possible.

The development of PSICAT proceeded through a number of stages (see Figure 33). The first stage was to determine the problem domain that PSICAT would support.
The problem of traveling from Chicago to New York City was selected. There were two reasons for selecting this problem domain: (1) the subjects were more familiar with travel problems, and (2) the answers to the problems and the addition of new components to the systems were likely to be easier to evaluate.

The second stage started an iterative problem selection process that went on during much of the development of PSICAT. This iterative process involved selecting the problems to be described by the system and the problems that will not be described but could be added to the system by subjects. The process continued until two criterion were satisfied: (1) the system describes enough problems so that at least three problems could be identified without the subjects necessarily needing additional descriptions, and (2) at least three problems could be identified requiring the addition of at most two new current situation, goal, and method components each.

The initial step in this second stage was the identification and structuring of the set of problems of traveling from Chicago to New York City. The problems were structured using Rietman's three vector model of problem solving: (a) the current situation in which the traveler finds himself or herself, (b) the traveler's goal, and (c) the method for obtaining the traveler's goal.
The next step in this second stage process was to create the component diagrams, descriptions, and examples that are associated with the CAI concept acquisition techniques used in PSICAT. Beginning component diagrams, descriptions, and examples were created for the current situations, goals, and methods. Once those were created, decisions were made concerning which problem components would be described by the system and a general idea of which components could be added.

<table>
<thead>
<tr>
<th>Stages.Steps</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Determine the problem domain that PSICAT would support.</td>
</tr>
<tr>
<td>2.0</td>
<td>Select the problem to be described by the system.</td>
</tr>
<tr>
<td>2.1</td>
<td>Identify and structure the set of travel problems.</td>
</tr>
<tr>
<td>2.2</td>
<td>Create component diagrams, descriptions, and examples.</td>
</tr>
<tr>
<td>2.3</td>
<td>Make operational the sections of PSICAT that aid in identification and structuring.</td>
</tr>
<tr>
<td>3.0</td>
<td>Combine the current situation, method, and goal sections.</td>
</tr>
<tr>
<td>4.0</td>
<td>Develop an instructional aid on how to use PSICAT.</td>
</tr>
<tr>
<td>5.0</td>
<td>Review the entire system.</td>
</tr>
<tr>
<td>6.0</td>
<td>Field test PSICAT.</td>
</tr>
</tbody>
</table>

Figure 33. Sequence of Stages and steps in the Development of PSICAT.
The step after the initial development of the diagrams, descriptions, and examples was making operational the section of the system that aids in the identification and structuring of current situations. Since all three sections of the system (i.e. current situation, goal, and method) have the same form, once one was working correctly, the others were created by duplicating the original and making relatively minor modifications to the duplicates.

The third stage of PSICAT development after the current situation, goal, and method sections were created was to combine them. PACE was used to write the programs that combined the three sections into an operational aid. The system was designed so the subjects could enter into any section and exit from any section at one common point in the system in order to have the option of gathering information on the amount of time spent in any section.

The fourth stage in the development of PSICAT was the creation of an instructional aid on how to use the system. The entire instructional aid was written in EASE. The aid contains four sections: (1) How problems are divided into components, (2) How the components are described, (3) An example of how to use the system to identify a problem, and (4) An example of how to use the system to structure a problem. The subjects go through the instructional component followed by automatic entry into the decision
The fifth stage of PSICAT development was the review of the entire system. Though sections of PSICAT were reviewed during the various stages and steps of development, stage five was the first time that the entire system was formally tested. The test consisted of individuals going through the system as a subject would and critiquing the instructional aid, the decision aid, and the problem booklet for problems of clarity. Based upon this review, both the instructional aid and the problem booklet was modified to improve the coordination between the two.

The sixth and final stage involved field testing PSICAT. PSICAT was field tested on four graduate students. Committee members observed these behavior as the subjects used the system. The subjects were able to use the system to identify the problems. After the test, the subjects answered a one page questionnaire concerning the system. Overall, they felt the instructional aid was slightly tedious except for the instructional section on problem structuring.

3.2.1.2 PSICAT Decision Aid

The decision aid consists of a knowledge base and a methodology to use and expand that knowledge base. The knowledge base contains the component diagrams,
definitions and examples of the current situations, methods, and goals. Figure 34 shows the current situation, method, and goal diagrams. The methodology that was incorporated within the aid was similar to those used for concept acquisition. Specifically, the subjects were encouraged to compare the components of the problem with the components described in the system. This entailed differentiating between all the components described in the system and determining which of the components described could be generalized to include the particular problem component under consideration. The result is the correct identification of the problem components.
CURRENT SITUATION DIAGRAM

Current situation for travelers going from Chicago to New York

Can spend over $150 (CS3)

Cannot spend over $150 (CS2)

Does not own an auto (CS7)

Does own an auto (CS6)

GOAL DIAGRAM

Goals for getting to New York

6 hours or less (G1)

Next couple of days (G4)

METHOD DIAGRAM

Methods available for getting to New York

Auto (M4)

Bus (M5)

Airplane (M7)

Figure 34. Component diagrams.
The methodology incorporated in PSICAT is illustrated in Figures 35, 36, 37, and 38. The concept acquisition techniques are used in the process of comparing the components of the problem with those described in the system. The current situation, method, and goal sections of the methodology have identical comparison processes. The only difference is the knowledge compared in each process. Specifically, the knowledge used in the Current Situation Comparison Process consists of current situation definitions and related examples while that used in the Method Comparison Process consists of method definitions and related examples. A more comprehensive explanation of the descriptions is in Appendix A (Instructional Booklet for PSICAT).

As shown in Figure 36, two new current situation components can be added to the system. (Two new method and goal components can also be added.) The addition of new components is initiated by the subject in response to the question, "Do you want a better match?". If the subject responds "yes," then the subject is shown a menu with one of the options being the creation of a new current situation. Selection of that option results in the system aiding the subject in creating the new current situation. The system tells the subject that he needs to provide three types of knowledge about the new current situation, (1) the location of the new current situation
on the Current Situation Diagram, (2) the distinguishing characteristics of the new current situation, and (3) an example of the new current situation. Once the new components are created, they become a component in which the subject can select to identify a problem.
Figure 35. PSICAT overview.
Figure 36. Current situation section.
Figure 37. Identification and structuring process for the current situation section
Figure 38. Structuring component forms.
Though the aid in PSICAT is a functional decision aid, it was designed partially to provide information concerning the concept acquisition process. Thus the aid possessed certain features and limitations that were associated with providing this information. Specifically, once the subject created a new classification, he could go back and modify it. However, his first version was saved by the system. This feature allows the researcher to compare the subject's first version with the last version to determine if and how the first version was modified as more problems of the same type were given to the subject. For instance, differences in the list of distinguishing characteristics or in the amount of elaboration can be determined. The major limitation of the aid is that it can only accommodate the creation of six new classifications, two each for new current situations, goals, and methods classifications.

3.2.2 DTT

DTT (Decision Tree Technique) is a system that leads the subject through the process of selecting from alternatives associated with a series of questions about the characteristics of a problem. The system utilizes decision tree techniques. To familiarize the subject with the system, an instructional booklet was provided which contained four instructional sections: (1) How problems
are identified and structured by using a sequence of questions and answers, (2) How the decision tree assists with the identification and structuring of problems, (3) An example of how to use the system to identify a problem, and (4) An example of how to use the system to structure a problem. A more extensive explanation of DTT is provided in Appendix B (A Guide for Identifying and Structuring Travel Problems of Going from Chicago to New York- Instructions and Comments).

3.4 Research Design

The hypotheses were tested using multiple regression analysis. The dependent variable was the number of problems correctly identified in each set. There were three independent variables: (1) Level of analytic ability (Quantitative variable), (2) Type of decision aid (Dichotomous variable), and (3) Interaction between level of analytic ability and type of decision aid (Quantitative variable).

3.5 Instrumentation

The two measures used in the study were Group Embedded Figures Test (GEFT) and a set of 6 travel problems. The GEFT is a group administered test to measure the global-analytic dimension of cognitive functioning. The set of problems consists of two subsets
of three problems each to measure separate abilities. One subset was a measure of the subject's ability to identify the problem. The other subset was a measure of the subjects' ability to structure a problem. Both subsets of problems along with the GEFT are discussed next.

**GEFT.** The GEFT is a group administered test to measure the global-analytic dimension of cognitive functioning. Subjects are given 2, 5, and 5 minutes, respectively, to find a specified simple figure in each of 7, 9, and 9 complex figures. The GEFT score is the summed scores from the second and third parts. The first part was used only as a screening device to make sure that the subjects comprehended what they were to do on the test. The total estimated time to administer this test was 20 minutes.

**Problem Set.** The set of problems consisted of two subsets of three problems each to measure separate abilities. Subset 1 was a measure of the subject's ability to classify concepts at the analysis, synthesis, and evaluation (ASE) level. Subset 2 was a measure of the subject's ability to problem solve at the ASE level. Both are discussed in more detail below.

Concept classification at the ASE level was exhibited when the subject identified problems of the same type as those described in the aid. To identify problems, the subject was required to analyze the problem, and compare the components of the problem with the corresponding
components described in the aid.

Problem solving at the ASE level was exhibited when the subject structured a problem. To structure problems, the subject was required to create additional problem classifications to identify problems that had previously not been described by the aid.

Successful problem structuring encompasses correct problem identification. Before the subject could create a new classification, he needed to try to identify the problem using the components described by the system. If the aid does not describe one or more of the problem's components, then the subject needs to go through the process of structuring or creating the components needed to identify the problem. Therefore the concept classification task was embedded in successful completion of the second group of problems.

The six problems were contained in a six page booklet. Subjects using DTT or PSICAT were given the same six problems. Each page contained a problem and an answer box. The first three problems were those of Subset 1. The subjects were informed that these first three problems were identified with the classifications already contained within the system. The second three problems were those of Subset 2. There was a message at the top of each page containing a problem from Subset 2 informing the subject that at least one and at most two new classifications are
required to identify the problem. Informing the subject about the need for adding classifications was necessary since PSICAT could only allow six new classifications to be added to it. Once the subject had identified the problem, he put the chosen response in the answer box.

The answer box was customized to correspond to differences in answer formats. For DTT, the format of the answer was a number corresponding to a particular arrangement. For example, if the arrangement selected was "take a plane" on page two of the decision tree, the subject would enter "5" in the answer box. The format of the answer using PSICAT involved specifying the current situation, the goal, and the method. For example the answer to a problem is Current Situation 1, Goal 4, and Method 3.

3.6 Research Subjects

The subjects consisted of graduate students enrolled in research and evaluation courses in the college of education at The Ohio State University. These students were asked to volunteer because of their availability during the testing periods and because they were considered to be representative of the general population of graduate students. Information on how the subjects were assigned to the DTT and PSICAT groups can be found in Chapter IV, Analysis of Results.
3.7 Study Procedures

The subjects were given an overview of the sequence of events in the test. They were told that they would first be given the group embedded figures test (GEFT) after which they would be given materials to understand how to use their respective systems and the problem booklet. After they had taken the GEFT, the subjects were given additional instruction concerning the materials and the problems. The DTT group was given two booklets, the instructional booklet and the problem booklet. They were told to go through the exercises in the instructional booklet which referenced example problems in the problem booklet. They were also told that once they had finished the exercises in the instructional booklet, they were to turn in the instructional booklet for the decision tree booklet and identify the six problems in the problem booklet using the decision tree.

The PSICAT group was given the problem booklet and told that PSICAT consisted of two parts, an instructional section and a section which would help them solve the 6 problems in the booklet. They were then told to follow the instructions on the computer. The instructional part would reference the example problems in the problem booklet. After they finish the instructional section, they were to use the other part to identify the 6 problems. Both groups of subjects were told to ask
questions if they had any during the exercise.

3.8 Data Analysis

The major steps in the data analysis phase were scoring the answers to the problems and then analyzing the scores. Scoring the answers to the problems involved first the list of problem characteristics identified by the subjects and then having judges rate the list based upon the evaluation criterion, which is the degree of match between the list of attributes identified by the subject and those attributes of the problem which one identifies as being necessary to solve it. The lists of attributes were produced to eliminate the possibility of the judges knowing which aid was used to obtain an answer to a problem. The answer to a problem with the aid of DTT was a number associated with a particular outcome (particular position on the decision tree). The answer to the same problem with the aid of PSICAT consisted of three parts, names of the current situation, method, and goal.

Though the answers to the same problems were different depending upon which system the subject used, the difference may solely be due to the format and not to the content of the answer. For example consider one of the problems used in the instructional booklet for the two systems, specifically, the problem used as an example in the section on how the system can be used to identify a
problem. The answer to the problem using DTT was 43, while the answer to the problem using PSICAT was CS3, M7, G1.

Though the answer formats are different, the content of the answer is not. The attributes of the problem identified by the subject using DTT can be traced by the path he took in arriving at the answer. (The path can be identified because there is only one path between a particular outcome and the top of the tree.) The answer to the first question provides the first attribute identified by the subject: "Mr. Adams wants to get to New York within the next 6 hours." The answer to the next question provides the second attribute identified by the subject: "Mr. Adams can spend over $150." Based upon the answer to the two questions, the third attribute is provided to the subject: "Take a plane." The attributes of the problem identified by the subject using PSICAT can be determined by listing the attributes of the current situation, method, and goal that is the answer. The attribute of CS3 is: "Can spend over $150;" the attribute of G1 is: "6 hours or less;" and the attribute of M7 is: "Airplane." Once the list of attributes had been produced for each problem, a team of judges evaluated them. The evaluation consisted of two judges rating the list of problem attributes on a five point scale. The basis of the evaluation is the degree of match between the
list of characteristics identified by the subject and those characteristics of the problem which the judge identify as being necessary to solve it. The scale ranges from "no match (0)" to "excellent (4)."

The process started with the two judges being given all the problems after they received instructions and guidelines on how to score them. The instructions and guidelines appear in Appendix D. The judges read the instructions which include the evaluation criterion and rating scale. After reading the instructions, the judges read an example of the rating of five lists of attributes for a sample problem. Each list represented a different rating point on the five point scale. These lists acted as benchmarks to aid the judges in understanding the different points in the scale. The scores given by the two judges to each list were compared. If the difference was less than one point, then the score was averaged. If the difference was greater than one point, then a third judge was used to evaluate the list. The third judge selected which of the two scores was most correct. The total number of lists that the two judges needed to score was 210, 35 lists for each of the six problems.

3.9 Summary

The purpose of this chapter was to describe the methodology used in assessing whether concept acquisition
techniques can aid individuals in the identification and structuring of problems. To make this assessment, a number of systems and instruments were used including several which were developed specifically for this task. The two systems which represent alternative ways to support problem identification and structuring, PSICAT and DTT, were both developed. PSICAT incorporates the concept acquisition techniques whereas DTT incorporates the more familiar decision tree techniques. The instruments that were used in this study included measures of the subjects' identification and structuring performance in addition to one on their analytical ability, the Group Embedded Figures Test. The performance measures, two sets of three problems, were evaluated by three judges blind to which system the answers were from. Two judges scored the problems independently of the other. The scores of each judge were compared and the third judge arbitrated any differences of greater than one point on the five point scale. The next chapter discusses the results of the application of this methodology.
CHAPTER IV
ANALYSIS OF THE RESULTS

This chapter presents the results of tests of two hypotheses to determine the effect of the computer aided instruction (CAI) concept learning technique on the identification of problems by selected subjects using PSICAT. Hypothesis one: Given an ill-structured problem in a familiar knowledge area (travel) that is an example of those described in both PSICAT and DTT, subjects will not be able to identify the problem equally well using PSICAT than DTT. The subjects have varying levels of analytical ability. Hypothesis two: Given an ill-structured problem in a familiar knowledge area (travel) that is not an example of those described in both DTT and PSICAT, subjects will be able to identify the problem equally well using PSICAT than DTT. The subjects have varying levels of analytical ability.

4.1 Organizational Overview
Sections describing the participants, the treatment sessions, the preparation of the responses for judging, and the judging of the subject's responses will precede the final section containing the results of the tests of
4.2 Description of the Participants

The participants were 35 graduate students from The Ohio State University enrolled in graduate courses in research and evaluation in the College of Education in the Summer and Fall of 1986. The 18 subjects who used the DTT came from the same course. The 17 subjects who used PSICAT came from several courses due to the limited number of volunteers and the availability of computer terminals necessary to run PSICAT. Since a maximum of five subjects could access PSICAT at any one time, the subjects who used PSICAT were scheduled individually. Hence, over the testing periods, the subjects who used DTT did so as a group during one class period, whereas those subjects who used PSICAT did so in small groups.

4.3 Description of the Treatment Sessions

Generally, it took the subjects who used DTT less time to complete the treatment (administration of the GEFT, completion of the instructions on how to use the Decision Support System, and the identification of the problems) than those who used PSICAT. All the subjects who used DTT were finished in 70 minutes or less. It took the subjects who used PSICAT from 90 to 130 minutes to complete the treatment.
4.4 Preparation of the Responses for Judging

The sequence of operations for transforming the subjects' responses into a form which judges could objectively rate was performed. Table 3 shows the number of unique lists of characteristics for each problem. There was a total of 98 different lists for the six problems. Problem 1 had the least number of different lists, a total of 3 lists. Problem 6 had the most variety, a total of 29.

The larger number of unique lists for problems 4, 5, and 6 compared to problems 1, 2, and 3 would suggest that the two subsets of problems are different and that the problems contained in subset 2 are more ill-structured than those contained in subset 1. Reitman (1964) noted that ill-structured problems evoke a highly variable set of problem characteristics. The large number of unique lists for the problems in subset 2 indicates a more variable set of characteristics for those problems. Therefore the problems in subset 2 are likely to be more ill-structured than those in subset 1.

Table 3.
Unique Characteristics Lists

<table>
<thead>
<tr>
<th>Problem</th>
<th>Problem Subset</th>
<th>Number of Unique Lists</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>29</td>
</tr>
</tbody>
</table>
4.5 **Description of the Judging**

The two judges who rated the characteristics lists were both educators with over 20 years of experience. Judge 1 was an English teacher who is currently an instructional designer. Judge 2 is an elementary teacher. Each judge rated the lists and placed the ratings on their score sheets. All judging was done blind. Once they had completed the ratings, the ratings were compared. There were 8 lists (approximately 9 percent of the lists) with greater than a one point difference in the ratings each judge gave it. For those 8 lists, a third judge determined which of the two ratings would be used. For six of the lists, Judge 2's rating was used, but for two of the lists, Judge 1's rating was used. After the ratings were compared and differences of greater than one point in the ratings settled, a measure of interrater reliability was calculated. The interrater reliability for the two judges was approximately .86. Therefore for the 98 lists, there was a .86 correlation between the two judges with a 9 percent arbitration rate.

4.6 **Results of the Tests of Hypotheses**

The purpose of the following comparisons was to test the two hypotheses formulated to examine the effect of the computer aided instruction (CAI) concept learning technique on selected subjects using PSICAT. The
descriptive and inferential analyses were run using SPSS-PC. To run the analysis, a data set was produced from the information in the response booklets. Thirty-five records were produced. Each record contained the subject’s identification, a treatment group code which specified the system used, and the rating obtained for each problem. Seven records contained missing ratings because subjects had randomly omitted answers to some problems. The group mean rating (as shown in Table 4) was substituted for those missing ratings in five records which contained only one missing rating. Two PSICAT records were eliminated from further analysis since they contained more than one missing rating. The final number of records analyzed was 33. Once the situation concerning the records containing missing values was rectified, an average rating for subsets one and two were calculated for each subject.

Table 4.

<table>
<thead>
<tr>
<th>Group</th>
<th>Problem 1</th>
<th>Problem 2</th>
<th>Problem 3</th>
<th>Problem 4</th>
<th>Problem 5</th>
<th>Problem 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSICAT</td>
<td>4.34</td>
<td>3.38</td>
<td>3.41</td>
<td>3.63</td>
<td>2.83</td>
<td>2.29</td>
</tr>
<tr>
<td>DTT</td>
<td>4.61</td>
<td>4.56</td>
<td>3.09</td>
<td>2.76</td>
<td>2.50</td>
<td>1.79</td>
</tr>
</tbody>
</table>

4.6.1 Descriptive Analysis of the Data

The subset 1 and 2 means and standard deviations for the DTT and PSICAT groups appear in Tables 5 and 6. As
shown in Table 5, the DTT group mean is somewhat higher than the PSICAT group mean for subset 1. The opposite is true for subset 2 as shown in Table 6. Also a comparison of the DTT and PSICAT group means for subset 1 and 2 problems indicate a degradation in performance on subset 2 problems. This decrease in performance further validates the more ill structured nature of problems in subset two.

Table 5.
Means and Standard Deviations for Subset 1

<table>
<thead>
<tr>
<th>Problem Set</th>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subset 1</td>
<td>DTT</td>
<td>4.085</td>
<td>.779</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>PSICAT</td>
<td>3.713</td>
<td>.896</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 6.
Means and Standard Deviations for Subset 2

<table>
<thead>
<tr>
<th>Problem Set</th>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subset 2</td>
<td>DTT</td>
<td>2.353</td>
<td>.701</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>PSICAT</td>
<td>2.918</td>
<td>.679</td>
<td>15</td>
</tr>
</tbody>
</table>

The GEFT means for both groups are shown in Table 7. The PSICAT group mean is higher than that for DTT.
Table 7.
Means for GEFT

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTT</td>
<td>12.833</td>
<td>18</td>
</tr>
<tr>
<td>PSICAT</td>
<td>14.200</td>
<td>15</td>
</tr>
</tbody>
</table>

4.6.2 Inferential Analysis of the Data

The same basic multiple regression analysis was performed to test the two hypotheses. The only difference was the dependent variable. To test hypothesis one, the dependent variable was the average rating for subset 1. The dependent variable to test hypothesis two was the average rating for subset 2.

The results of the analyses performed to test hypotheses one and two appear in Tables 8 and 9 respectively. There is no significant interaction between the two systems (DTT and PSICAT) and the GEFT. The GEFT does not account for a significant increment in the proportion of the variance of the subset 1 ratings. Finally, the two systems are not significantly different in regard to subset 1. The results of the analysis performed to test hypothesis two indicate that there is not a significant interaction between the two systems (DTT and PSICAT) and the GEFT. The GEFT does not account for a significant increment in the proportion of the variance of the subset 1 ratings. However, the two systems are significantly different.
Table 8.
Summary of Regression Analysis to Test Hypothesis One
Dependent Variable: Average rating for subset 1

<table>
<thead>
<tr>
<th>Source</th>
<th>Proportion of variance</th>
<th>df</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (DTT vs. PSICAT)</td>
<td>.0207</td>
<td>1</td>
<td>.64</td>
</tr>
<tr>
<td>GEFT</td>
<td>.0001</td>
<td>1</td>
<td>.00</td>
</tr>
<tr>
<td>Group x GEFT</td>
<td>.0165</td>
<td>1</td>
<td>.50</td>
</tr>
<tr>
<td>Error</td>
<td>.9627</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.00</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

* significant at the .05 level

Table 9.
Summary of Regression Analysis to Test Hypothesis Two
Dependent Variable: Average rating for subset 2

<table>
<thead>
<tr>
<th>Source</th>
<th>Proportion of variance</th>
<th>df</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (DTT vs. PSICAT)</td>
<td>.1565</td>
<td>1</td>
<td>5.59 *</td>
</tr>
<tr>
<td>GEFT</td>
<td>.0088</td>
<td>1</td>
<td>.31</td>
</tr>
<tr>
<td>Group x GEFT</td>
<td>.0521</td>
<td>1</td>
<td>1.90</td>
</tr>
<tr>
<td>Error</td>
<td>.7826</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.000</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

* significant at the .05 level
4.7 Summary

The purpose of this chapter was to present the results of the tests on using concept acquisition techniques to aid individuals with problem identification and structuring. The performance of 35 subjects using either DTT or PSICAT were evaluated by three judges. The inferential data analysis of their evaluations indicated that there was not a significant difference between the DTT and PSICAT groups on the subset one problems, identification problems. There was a significant difference between the two groups on subset 2 problems, structuring problems. A discussion of these results is found in the next chapter.
CHAPTER V
DISCUSSION AND CONCLUSIONS

The objective of the discussion and conclusion chapter is to identify what new knowledge resulting from the study can be added to our understanding of the computer supported cognitive processing needed to improve learning and problem solving. To accomplish this objective, the chapter includes four main sections; (1) a summary of the study problem, (2) a brief summary of the work performed to meet the other objectives of this study, (3) an interpretation of the results of the tests of hypotheses including limitations of the tests, and (4) implications of the findings of the study.

5.1 Summary of the Study Problem

The computerized support systems (CAI and DSS) aid/support the learner/decision maker in the same adaptive process. This relationship between decision making/problem solving and learning has been noted numerous times in the literature (Kolb, 1974; Einhorn, 1980; Sage, 1981).

Even though CAI and DSS support the same adaptive process, they operate in two very different ways, due to
the systems' methods of aiding the user in acquiring the knowledge needed to accomplish tasks. In CAI the support is directed or planned to meet objectives set prior to instruction because the knowledge necessary to meet the objectives can be prespecified. This is not the case in DSS, where objectives can change often and/or it is not known what knowledge is necessary to obtain the objectives. As a result, DSS aids the user in determining the objectives desired and in specifying the knowledge needed to obtain the objectives in addition to supporting the user in meeting the objectives.

Advocates of each system (CAI or DSS) believe the other is inappropriate for their use. Gagne and Briggs (1974), both authorities on instructional design, believed that undirected support (which is often characteristic of DSS) leads to incompetent individuals. By contrast, authorities on DSS believed CAI systems cannot be used as models for DSS due to the prespecified nature of the knowledge that is dealt with by the system (Fisk & Sprague, 1981).

This study focused on this difference and demonstrated the use of CAI techniques for decision support systems. Hence, the problem central to this study was what effect does a selected CAI technique (from education) have on identification and structuring of problems that are typical of the type DSS (from business).
The selected CAI technique was a method for learning concepts which was described by Hall (1982), and the types of problems to which the techniques were applied were those that were ill-structured. Therefore, what was not known was the effect of a method for learning concepts from education (CAI techniques) had on identifying and structuring problems where: (a) the set of characteristics of the problem is obscure, ambiguous, and complex; (b) the procedures for solving the problem are indeterminate, and/or (c) the consequences are unknown (a DSS situation).

5.2 Summary of the Work on Objectives One, Two, Three, and Four.

The following five objectives were established to serve as milestones in the study. (1) Determine the degree of interchangeability of two types of computerized support systems. (2) Determine the role concepts have in decision making/problem solving as found in selected literature. (3) Develop two decision support systems, one which utilized concept acquisition techniques and a second which utilized a decision tree technique. (4) Test the two systems. (5) Identify what new knowledge resulted from the study that can be added to computer supported cognitive processing, the objective of this chapter. The rest of this section summarizes the work associated with each of these objectives.
5.2.1 Objective One

The first objective of the study was to determine the degree of interchangeability of CAI and DSS. It was determined that the basic difference between CAI and DSS system types is the structure of the task. CAI systems generally support tasks that are well structured from the point of view of the system and designer, because as the goal of these systems is to have the user gain understanding of the well-structured task. The task representation is that of the support staff and thus the system. However, in DSS the tasks normally are quite different from the perspective of task structure. DSS systems generally handle tasks that are not well structured from the point of view of the system, designer, or user, because the goal of the system is to have the user gain understanding of the task.

5.2.2 Objective Two

The focus of the second objective was to determine if it is advantageous to incorporate features of one system into the other to improve the support of the user. Specifically, as found in selected literature the role concepts have in decision making/problem solving was determined by: (a) defining a method of using concept learning techniques to aid in the identification and structuring of ill-structured problems, and (b) specifying
the levels of cognitive skills necessary to use the proposed method to identify and structure ill-structured problems.

The PSICAT (Problem Structuring and Identification by Concept Acquisition Technique) method was created by applying Hall's (1982) combined strategy for learning concepts to the identification and structuring of problems. This method involves comparing and contrasting the initial state, operators, and end state of the problem as described by the subject with those described in the computerized support system to obtain a match. If no match is found, then the method assists the user to add additional initial states, operators, and end states, to the computerized support system.

In using the PSICAT method to understand and identify the problem solving component, the user needs to possess certain cognitive skills. In this study, based upon an analysis of Hall's Taxonomy, the cognitive skills needed to deal with ill-structured tasks (problems) are concept application; concept analysis, synthesis, and evaluation (concept ASE); and problem solving analysis, synthesis, and evaluation (problem solving ASE).

5.2.3 Objective Three

A DSS was constructed to test the PSICAT method as to how well this type of system identifies and structures
ill-structured problems. The system was named after the method, PSICAT. PSICAT consists of two parts, an instructional component which teaches subjects how to use the system's decision aid for problem identification and structuring, and a part which is the actual decision aid.

In order to judge the effectiveness of PSICAT, another DSS was developed as a suitable comparison that was based upon the decision tree technique and named DTT. DTT is a system that leads subjects through a sequence of questions enroute to the identification of a problem. Like PSICAT, DTT has an instructional section. Unlike PSICAT, DTT was not computerized.

5.2.4 Objective Four

As a means of lending support to the premise that the PSICAT method did support problem identification and structuring, two hypotheses were tested. (1) Given an ill-structured problem in a familiar knowledge area (travel) that is an example of those described in both PSICAT and DTT, subjects will not be able to identify the problem equally well using PSICAT or DTT. The subjects had varying levels of analytical ability. (2) Given an ill-structured problem in a familiar knowledge area (travel) that is not an example of those described in both DTT and PSICAT, subjects will be able to identify the problem better using DTT than PSICAT. The subjects had
varying levels of analytical ability. Both hypotheses were rejected at the .05 level of significance.

5.3 Interpretation of the findings

The interpretation of the findings is the most important section in this chapter. The section includes possible reasons why the results occurred including how the results fit into previous research, and discusses limitations of the study in light of possible flaws and problems that occurred. The discussion in this section focuses on the results of the tests of hypotheses, part of objective four.

5.3.1 Possible reasons why the results occurred

The findings concerning the degree of interchangeability between PSICAT and DTT on the subset 1 problems was clear and expected. The reasons for these findings are less clear. Though the DTT subjects performed better than the PSICAT subjects, the difference was not statistically significant. One possible reason is the sample size might not have been large enough to fully utilize the ability of the test to identify a significant difference. A second possible reason is that the subjects' familiarity with travel along with the system containing all the information necessary to identify the problems made the identification task easy. Both PSICAT's and DTT's method
of decomposing the problem to support identification
performed sufficiently well that there may have been a
ceiling effect on the ratings.

Another possible reason why no differences were
detected is the similarity in the structure between the
decision tree format used in DTT and the component map
format used in PSICAT. The subjects who used PSICAT
tended to rely heavily on the concept maps during the
task. The component maps contained enough information
that they did not need to depend upon the components'
descriptions. For example, the method component map
listed car, train, airplane, and bus on the map. The
subjects know what a car, train, airplane, and bus are.
They did not have to read a description of the component
to identify the component. Perhaps, if the subjects had
been much less familiar with the knowledge area, the
results would have been different. Then the examining of
the component descriptions may have produced results
similar to those of the problem identification and
structuring task involving the second subset of problems.
For example, if the subjects were unfamiliar with
statistics and were asked to determine which of two
statistical methods should be used on a problem, Goodman
and Kruskal's tau b or Asymmetric Lambda, this kind of
subject would need more than the names of the two methods
on a component map to make the correct decision. They
would need descriptions of both methods to determine which one is correct or best. When the subjects depend more on the descriptions, they are relying more on the concept learning strategies to identify the problems.

The finding that subjects using PSICAT outperformed subjects using DTT to identify and structure problems in subset two was to be expected. As noted by Saleh, Kim, Leal, and Pearl (1979), the decision tree format of decomposing problems is not sufficiently compatible with the way people internally encode the knowledge necessary to structure and identify problems. It is too crude. However, the concept learning technique used in PSICAT was designed to be much more compatible with the way people internally encode the knowledge. The technique was designed to support individuals in the identification of a problem and in the process of internally encoding in memory a protocol abstraction of the components of a problem.

The findings that analytical reasoning ability did not have a mediating effect upon the results of the identification and structuring of problems was unexpected given previous research. Previous DSS research using GEFT as a measure of cognitive style (Field dependent-field independent) indicated a difference between the two groups on tasks supported by a DSS.
A number of possible reasons explain why the study's results did not match those of previous research, the first one being that the GEFT score was treated differently in this study compared to previous studies. This study used the GEFT as a measure of analytical reasoning ability and considered the measurement scale to be interval. Previous studies considered the measurement scale a dichotomy based upon the premise that the GEFT classifies subjects' cognitive style as being either field dependent or field independent.

Another possible reason for different results was that both DTT and PSICAT methods provided the means for subjects with lower analytical reasoning ability to perform equally well with subjects of higher analytical reasoning ability. Both DTT and PSICAT methods could have enhanced the analytical reasoning ability of those subjects who have low GEFT scores to such a degree that their performance was not different from those subjects with high GEFT scores.

A third possible reason was the small sample size in conjunction with the skewed distribution of GEFT scores. There was an increased yet statistically not significant interaction between the GEFT and the groups for subset 2 compared to subset 1. The small sample size might not have produced enough power to test for an interaction. Also the GEFT scores were heavily skewed toward the upper
end of the scale indicating the relative homogeneity of the GEFT scores. Therefore, the effect of both the small sample size and the skewed distribution might have resulted in GEFT and GEFT x group interaction variances two low to utilize the full power of the test.

5.3.2 Limitations of the Study

Most of the limitations of the study were mainly due to problems in the execution of the study. Flaws and problems that were inherent in the research design will be discussed first followed by problems that occurred in the execution of the study. After that, alternative explanations of the observed results will be pondered.

Before preceding with the discussion, an important delimiting fact needs to be mentioned concerning the PSICAT method. It was realized before the start of the study that a prototype support system designed to solve real world problems was required to test fully the PSICAT method. However, the development of this type of prototype would require more monetary and technical resources than were available.

The restriction on monetary and technical resources along with several other factors caused a number of problems and flaws in the execution of the study. Three of the problems were computer related. One problem was the use of PHOENIX and a mainframe computer system to run
PSICAT. Prior to the start of the PSICAT development, different software packages were evaluated. At that time, PHOENIX was determined to be the best package available. Also, there was limited access to personal computers (PC) and limited available software to use on the PC. The current situation is dramatically different. The current features available on PCs along with the large amount of available software would allow for faster development, greater portability, a more sophisticated man/machine interface, and the addition of an inference engine which more fully support the user's cognitive processing.

Another computer related problem was access to PSICAT at Ohio State. It was not possible to reserve time to access PHOENIX. Access to PHOENIX was first-come-first-served. To maintain access to PHOENIX, commands had to be input to it at least once every one-half hour. Also only five terminals could access PHOENIX at any one time. Under those conditions, it was preferable to schedule at most only three subjects at a time on PSICAT. Hence subjects had to be obtained according to system availability constraints and were not as randomly assigned to the DTT and PSICAT groups as was desired. The PSICAT subjects came from several different graduate classes. As a result, while the DTT subjects all came from one graduate class, classes were from the same population regarding the important dimensions.
There are two possible alternative explanations of the observed results that need to be discussed. One, PSICAT could have performed better than DTT because the instructional section for PSICAT is better than that for DTT, although great care was taken to create clear instructions for both systems and they were field tested. Two, the PSICAT subjects spent twice as much time on the problems than did the DTT subjects. The longer time used by the PSICAT subjects to identify and structure the problems could have been due to the PSICAT technique requiring a greater amount of cognitive processing time.

5.4 Implications and Recommendations

It is interesting to note that though most instruction is based upon the transfer of prespecified knowledge about problems that have known answers, much of today's problems are known as 'messes.' That is, many of today's problems are ill-structured, so that the problem solver/decision maker lacks sufficient understanding of the problem to solve it. The knowledge about the problem is not prespecified and the answers are not known.

Therefore, it is desirable to have instructional systems that can handle tasks that are not well structured since that is what the learner/user will be asked to cope with in the 'real' world. Likewise, it is also desirable to have decision support systems use CAI techniques where
the user needs effectively to gain understanding of a well-structured task. It is inefficient to spend the resources necessary to change repeatedly an ill-structured task into a well-structured task when that process has already been performed, the skill needed to go through the process has been acquired, and the resulting knowledge is ready to be used.

This leads to certain implications in how problem solving and learning are perceived and on the design and development of computer systems that support learning, problem solving and decision making. Instead of using an instructional design perspective that focuses on the application of techniques and practices that support learning, and instead of a decision support perspective that focuses on the application of practices and techniques that support decision making/problem solving, one should focus on the practices and techniques of both in support of the adaptive problem solving/decision making/learning process. This would require utilizing techniques from each type of system to maximize the current and future task performance of the user.

This perspective would have an effect upon the design and development of computer systems that support learning, problem solving and decision making. Features from one system should be incorporated into the other in order to improve the support of the system to the user as the user
proceeds through the decision making/problem solving/learning process. Such an effort should increase the user's performance with respect to the process not only at present but also in the future.

The success of the PSICAT system over the DTT demonstrated the effectiveness of using CAI techniques for decision support. Shumway (1982) noted that:

problem solving is time consuming and hard work. It makes no sense to repeat the same problem solving again and again if one can identify a problem class and a procedure for solving problems of that class. (p. 134)

The use of the PSICAT method did exactly that. It aided the user in identifying the problem better than the DTT method.

The demonstrated effectiveness of the PSICAT method raises further research questions on the specific use of the PSICAT method and on the use of other CAI and DSS techniques. Several research questions center on the use of the PSICAT method to support problem solving in education. The subjects who participated in this study were graduate students. The effectiveness of this approach on undergraduates, secondary, or even primary students has yet to be determined. Young children may not yet possess the cognitive skills necessary to use systems which utilize the PSICAT method. If that is the case, how old do students have to be in order to take advantage of the PSICAT method? Other research questions focus on what additional features could be added to the PSICAT
system to further improve an individual's performance. One possible feature would allow individuals the ability to easily switch from one component section into another and back. For example, one could switch from (Cannot spend over $150) to (Next couple of days) component definition and then back again. Another feature would be the capability of the system to reduce the lists of choices for any particular component based upon an individual's current selection of other components. For example, the system may advise him that based upon his selection of (Cannot spend over $150), his choice for a goal is (Next couple of days), and his choice for a method is (Auto) or (Bus). The addition of such a feature would necessitate the inclusion of an additional requirement for adding new components to the system. The additional requirement would have the user indicate which other type of components are valid possibilities when identifying a problem. This list of possible components would be chosen from the superordinate list of valid components. For example, the valid set of goal components for the current situation (Can spend over $150) are (6 hours or less) and (Next couple of days). The valid set of method components are (Auto), (Bus), and (Airplane). Assume that an individual created a new current situation called (Fear of flying) and its superordinate current situation is (Can spend over $150). The subject would select the list of
valid components for (Fear of flying) from the list of valid components for (Can spend over $150). The (Can spend over $150) list is the only valid one because (Fear of flying) inherits all the critical attributes of (Can spend over $150). Therefore the list of valid components for (Fear of flying) is the list of valid components for (Can spend over $150) minus the method component, (Airplane).

The use of DSS techniques to aid individuals in education raises another set of questions. Specifically, which DSS techniques could and should be used to support learning in the elementary and secondary education. Under what conditions would the DSS interactive design approach produce instruction better or faster or with less expense? What are the effects of interactions between CAI and DSS techniques as they are applied to the accomplishment of different subtasks of a task. What would be the consequences to education if learners were provided with a set of tools like those found in DSS generators and the ability to add to those tools as the learner progresses through school. For example, one could use the PSICAT method to help students understand and structure problems in such areas as sociology, history, statistics, etc. Since the PSICAT method utilizes concept learning techniques, it could be used to aid educators in making comparisons and to teach distinctions among the
circumstances surrounding a problem or decision, the goals of the problems or decision, and the methods used to achieve the goals. Thus the differences among socio­logical techniques, the way people have dealt with problems throughout history, etc. could be compared and distinctions taught. Also one could teach how people have handled similar problems differently. If students were given additional tools of this type, would it allow instructors to spend more time on how to use the tools, more time on how to learn, and less on what to learn?

Besides research questions on the use of DSS techniques in education, there are similar questions concerning the use of CAI techniques in problem solving/decision making in business and industry. Training is generally recognized as an important and vital function of excellent industrial and business organizations. The use of computers and CAI techniques to deliver training have been increasing. What has been recognized is the potential use of CAI techniques in the accomplishment of every day on the job tasks. The application of PSICAT method to ill structured problems of the type faced by individuals performing commonplace tasks in travel demonstrated the potential of CAI techniques on those tasks. Additional research needs to be conducted to answer further questions such as; would one obtain the same results if the PSICAT method was used on more complex
problems and directly on the job. Finally a set of related on the job type research questions concerns the relationship between the PSICAT method and artificial intelligence techniques in general and expert system techniques, in specific. Traditional expert systems provide expertise about specific domains of knowledge to individuals with less knowledge of that particular domain. Expert systems work best with knowledge domains that are rather well structured. Could the use of PSICAT method in expert systems increase the capability of such systems to deal with ill-structured problems? Could the PSICAT method best be utilized as a technique to help define the characteristics of the ill-structured problem in such a way so that more traditional expert system techniques can then be applied to enhance the cognitive processing of individuals? The key phrase is "enhance the cognitive processing of individuals."

All the research performed in this study and the questions raised in this section focus on enhancing the cognitive processing of humans. That fact needs to be kept in mind in evaluating and applying this research.
APPENDIX A:

INSTRUCTION BOOKLET FOR PSICAT

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The instruction booklet is very similar to the instruction section in PSICAT. The major differences are the booklet does not contain the questions in the section nor the type of feedback the subject would see if he answered any of the questions incorrectly.
The system is designed to aid you in problem identification and structuring. To facilitate this, an informational section is included. The section:

1. Shows how problems are divided into components
2. Shows how the components are described,
3. Provides an example of how to use the system to identify a problem, and
4. Provide an example of how to use the system to structure a problem.

Each area will be covered in the above order.
I. HOW THE PROBLEMS ARE DIVIDED

The system aids you in problem identification and structuring by dividing the problem into three types of components. They are:

1. The goal associated with the problem.
2. The current situation of the problem, and
3. The method for reaching the goal given the current situation.

For example, a travel agent assists people in making arrangements for travel from Chicago to New York. In suggesting ways the traveler can get to New York, the agent identifies the following things.

1. The goal of the traveler. (i.e. When does the traveler want to get to New York? in 6 hours? in the next couple of days?)
2. The current situation. (i.e. Does the traveler have an auto? How much can the traveler spend? more or less than $150.)
3. The available methods of transportation. (i.e. an auto, a bus, a plane)

Knowing the goal, the current situation, and the available methods, the agent can suggest certain arrangements. For example, Mr. Jones wants to get to New York within the next 6 hours (GOAL). He has no fear of flying and is willing to spend more than $150 (CURRENT SITUATION). The agent suggests flying
Another example is Mr. Smith who wants to get to New York in the next couple of days (GOAL). He is not willing to spend more than $150 and he does not own a car (CURRENT SITUATION). The agent suggests taking a bus (METHOD).
As you may have noticed, the three components of problem solving are the:

Current Situation,
Goal, and
Method.

Each component will next be described in greater detail.

The CURRENT SITUATION is the situation that you want to change.
Example: Mr. Jones is in Chicago and can spend more than $150 for travel.

The GOAL is the situation that you want.
Example: Mr. Jones wants to get to New York within 6 hours.

The METHOD is the way you can change the current situation into the goal.
Example: Mr. Jones decides to take the plane.
II. HOW THE COMPONENTS ARE DESCRIBED

To facilitate your understanding of the components, they are described by the system:

A diagram,
A definition, and
Examples.

A DIAGRAM is a graphical representation of how each type of component relates to one another.

Example:

![CURRENT SITUATION DIAGRAM]

Elaboration: -CS2 and CS3 are types of the current situation for travelers going from Chicago to New York.
Example 2:

**GOAL DIAGRAM**

- 6 hours or less (G1)
- Goals for getting to New York
  - Next couple of days (G4)

Elaboration: - G1 and G4 are both types of goals for getting to New York.

Example 3:

**METHOD DIAGRAM**

- Auto (M4)
- Bus (M5)
- Airplane (M7)

Elaboration: - M4, M5, and M7 are all types of methods available for getting to New York.
A DEFINITION provides a list of the component's distinguishing characteristics.

Example 1: Current situation CS6 is a type of current situation CS2 (REFER TO THE CS DIAGRAM) in which the Distinguishing Characteristic is

1. The individual owns an auto.

Elaboration: REFER TO THE CURRENT SITUATION DIAGRAM IN YOUR BOOKLET.
- CS6 is a type of CS2.
- CS6 is distinguished from CS7 based on auto ownership: the traveler owns an auto (CS6) instead of NOT owning an auto (CS7).

Example 2: G1 is a goal of getting from Chicago to New York in which the Distinguishing Characteristic is

1. Getting there in 6 hours or less.

Elaboration: REFER TO THE GOAL DIAGRAM IN YOUR BOOKLET.
- G1 is a type of Goal for getting from Chicago to New York.
- G1 is distinguished from G4 is based upon when the traveler needs to be in New York: the traveler must be in New York in 6 hours (G1) instead of the next couple of days (G4).
Example 3: Method M7 is a method for getting to New York in which the
Distinguishing Characteristic is
1. The use of an airplane

Elaboration: REFER TO THE METHOD DIAGRAM IN YOUR BOOKLET
-M7 is a type of method for getting to New York
-What distinguishes M7 from M4, and M5 is that it is travel by airplane (M7) instead of by auto (M4) or bus (M5).

An EXAMPLE is an instance of the component along with other features that enhance the clarity of the component. The features are:

1. Examples of other components (called nonexamples.)
2. Elaboration that provides information about the examples and nonexamples.

Example 1:
GOAL 1 (G1):
Example: Mr. Jones wants to get to New York in 6 hours.
Elaboration: The goal is for Mr. Jones to get to New York in 6 hours.

Example 2:
CURRENT SITUATION 7 (CS7):
Example: Mr. Jones is not willing to spend over $150 and does NOT own an auto.
Elaboration: -Since he is not willing to spend over $150, CS7 is a type of CS2.
Nonexample: Mr. Jones is not willing to spend over $150, but he does own an auto.
Elaboration: An example and a nonexample helps show the difference between the components.
III. HOW THE SYSTEM CAN BE USED TO IDENTIFY A PROBLEM

As you have seen, when a traveler goes to a travel agent, the agent aids the traveler by identifying the current situation, goal, and method. Since the agent is an expert in travel, he knows the typical current situations, goals, and methods, and which combinations are workable.

However, if the descriptions of the current situations, goals, and methods could be put into a computer and the computer were to aid the traveler in using the system, then the traveler would have the same descriptions as the agent. The traveler would have the knowledge to plan his/her own travel.
Below is one possible way a traveler might proceed with the aid of such a system.

IT MAY BE HELPFUL TO REFER TO THE CURRENT SITUATION DIAGRAM, THE GOAL DIAGRAM, AND THE METHOD DIAGRAM ON PAGES 4 AND 5.

FIRST: The problem:

______________________________________________________________
Mr. Adams wants to get to New York within the next 6 hours. He can spend more than $150.
______________________________________________________________

SECOND He used the Current Situation Diagram, the current situation component definitions, and the corresponding examples to determine if his current situation matched those in the system. CS3 was a match.

THIRD: With the knowledge that CS3 was the problem's current situation, he examined the goal diagram, the goal definitions, and the corresponding examples to determine if the problem's goal matched those described by the system and was possible based upon CS3. Goal G1 was a match.

FOURTH: He now knew two of the three components he needed to identify the problem; CS3 and G1. With that knowledge, he examined the method diagram, the method definitions, and the corresponding examples to determine if his problem's method matched those described by the system and was possible based upon CS3 and G1. Method M7 was the most appropriate.

Thus the results were:

Mr. Adams wants to get to New York within the next 6 hours. He can spend over $150. He decides to take a plane.

______________________________________________________________
CURRENT SITUATION  CS3
METHOD            M7
GOAL              G1
______________________________________________________________
IV. HOW THE SYSTEM CAN BE USED TO STRUCTURE PROBLEMS

Occasionally, the travel agent is faced with a problem in which the current situation, goal, and/or method is different from the typical. In such cases the travel agent adds a new current situation, goal, or method.

With the use of a computer as an aid, the traveler with the assistance of the aid add new current situations, goals, or methods. Below is one possible way the traveler might proceed with the assistance of such an aid.

IT MAY BE HELPFUL TO REFER TO THE CURRENT SITUATION DIAGRAM, THE GOAL DIAGRAM, OR THE METHOD DIAGRAM ON PAGES 4 AND 5.

FIRST: The problem:

Mr. Brown wants to get to New York in the next couple of days. He cannot spend over $150 and does not own an auto. However, he does own a large motorcycle.

SECOND: He examined the Current Situation Diagram, definitions, and corresponding examples to determine if his current situation matched those in the system. He determined that CS7 was the best match. However, it did not reflect that he owns a motorcycle.

THIRD: He decided to create a new CS to reflect the fact that he owns a motorcycle.

FOURTH: Once he had decided to create a new CS, the system told him that the new CS would be called.

FIFTH: He was then told that he needed to provide three pieces of information. They were:
1. The location of the new CS on the CS diagram
2. The new CS's distinguishing characteristic, and
3. An example of the new CS.
SIXTH: He decided to locate the new CS on the CS diagram first.

SEVENTH: He then decided to list the new CS's distinguishing characteristics. Below is that list of distinguishing characteristics

<table>
<thead>
<tr>
<th>Distinguishing Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The traveler owns a motorcycle</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
</tbody>
</table>

EIGHTH: Last, he decided to provide an example of the new CS.

| Example: Page number 1 |

NINTH: Once he had created a new CS, he continued and determined was the problem's goal and method. He determined that the goal was G4; Next couple of days.

TENTH: Given his new CS (CS 9) and the goal G4, he determined was the problem's method. He noted that motorcycle was not one of the possible methods. Therefore he created a new method. He went through the same process and created a method for motorcycles.

So the problem was structured and identified as having the following components.

<table>
<thead>
<tr>
<th>CURRENT SITUATION</th>
<th>CS9</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHOD</td>
<td>MB</td>
</tr>
<tr>
<td>GOAL</td>
<td>G4</td>
</tr>
</tbody>
</table>

The next time Mr. Brown uses the system, the components that he has created will be part of that system.
APPENDIX B:

INSTRUCTION BOOKLET FOR DTT
1. INTRODUCTION

This system is designed to aid you in problem identification and structuring. To facilitate this, an informational section is included. This section:

1. Shows how problems are identified and structured by using a sequence of questions and answers.
2. Shows how the decision tree assists with identification and structuring of problems.
3. Provides an example of how to use the system to identify a problem.
4. Provides an example of how to use the system to structure a problem.
II. PROBLEM IDENTIFICATION VIA QUESTION AND ANSWER

This system aids you with problem identification and structuring by having you select answers to a sequence of questions about the characteristics of your problem. For example, a travel agent assists people in making arrangements for travel from Chicago to New York. In order to suggest ways the traveler can get to New York, the agent asks a number of questions. Such as:

1. How soon do you need to get to New York?
2. How much money can you spend?
3. Do you own a car?

The problem has been identified when the agent knows the answers to these questions and has suggested a travel plan. For example, Mr. Jones wants to go from Chicago to New York. The agent asks him how soon does he want to be there? (Question) Mr. Jones responds that he wants to be there in the next couple of days. (Answer) The agent then asks if he wants to spend over $150? (Question) Mr. Jones responds that he can. (Answer) The travel agent suggests that he travel by plane. (Arrangement)
Another example, Mr. Smith is asked by the agent how soon does he want to get to New York? (Question) Mr. Smith responds that he wants to get to New York in the next couple of days. (Answer) The agent then asks if he can spend over $150? (Question) Mr. Smith responds that he cannot. (Answer) The agent asks if he owns a car? (Question) Mr. Smith says that he does not. (Answer) The agent then suggests that he travel by bus. (Arrangement)

The examples show that the problems were identified through a process of having the traveler answer a sequence of questions asked by the agent. A decision tree is a graphical representation of that process.
III. HOW DECISION TREES ASSIST IN PROBLEM IDENTIFICATION

A decision tree is a graphical method of expressing in chronological order, the questions and alternative answers that are available to the problem solver/decision maker. Figure 1. is an example of the decision tree to identify how to get to New York.

![Decision Tree Diagram]

Figure 1. DIT Decision Tree
IV. HOW THE DECISION TREE CAN BE USED TO IDENTIFY A PROBLEM

As you have seen, when a traveler goes to a travel agent, the agent asks the traveler a sequence of questions. Based upon the answers, the agent provides the traveler with a suggested travel plan. The agent can do this because of his knowledge of travel between Chicago and New York.

However, if the agent's knowledge could be structured in a form that the traveler could understand, then the traveler could determine his/her own travel plans. Such a structured form would be an aid. Below is one possible way a traveler might proceed to use such an aid.

1. PLEASE TURN TO PAGE 7 IN YOUR PROBLEM BOOKLET,

2. READ THE EXAMPLE PROBLEM, AND

3. THEN TURN THIS PAGE.
FIRST: Mr. Adams starts with the first question which is on page 1 of the decision tree (see figure 2). The question is:

How soon do you want to be in New York?

Mr. Adams uses the checklist to help him. He decides that there is a good answer to the question. The answer is:

Within the next 6 hours.

Based upon the answer, Mr. Adams looks for the conclusion. However, there is no conclusion, so he follows the arrow and turns to page 2 of the decision tree (see figure 3.)
SECOND: Mr. Adams then reads the next question (see figure 3):

**How much can you spend?**

He uses the checklist again. Mr. Adams examines the possible answers and then selects:

**Over $150**

There is a conclusion to this answer,

**CONCLUSION 5: Take a plane**

Based upon Mr. Adams' answers, the decision tree suggests that he take a plane to get from Chicago to New York.

**PLEASE WRITE "5" IN THE ANSWER BLANK ON PAGE 7 IN YOUR PROBLEM BOOKLET.**

**TURN TO THE NEXT PAGE IN THIS INSTRUCTION BOOKLET.**

---

**Figure 3.**

**CHECKLIST:**

1. Is there a good answer to the question?
   - Yes, then look at page 7 in the problem booklet.
   - No, then go to the next specified step.

2. Is there a conclusion to the answer?
   - Yes, then look at page 3 in the problem booklet.
   - No, then place the conclusion number in the answer blank in your problem booklet.

3. Is the conclusion reasonable?
   - Yes, then look at page 3 in the problem booklet.
   - No, then go to the next specified step.
V. HOW THE DECISION TREE CAN BE USED TO STRUCTURE A PROBLEM

For some problems, you will not be able to identify the problem because the right questions and/or answers do not exist in the decision tree. In such cases, you are to create the questions and/or answers needed. Below is an example.

1. PLEASE TURN TO PAGE 8 IN YOUR PROBLEM BOOKLET,
2. READ THE EXAMPLE PROBLEM, AND
3. THEN TURN THIS PAGE.
FIRST: Mr. Brown starts by reading the first question on page 1 of the decision tree (see figure 4). The question is:

How soon do you want to get to New York?

Mr. Brown uses the checklist to help him go through the decision tree. He decides that there is a good answer:

Within the next couple of days.

He looks for the corresponding conclusion to the answer. However, there is no conclusion so he followed the arrow and turned to page 3 in the decision tree (see figure 5).

Figure 4.
SECOND: Mr. Brown then reads the next question (see figure 5):

How much money can you spend?

Mr. Brown selects the answer:

$150 or less

This answer has no corresponding conclusion, so Mr. Brown following the arrow, he turns to page 4 in the decision tree (see figure 6).

Figure 5.
THIRD: The next question is (see figure 6):

Do you own a car?

Mr. Brown selects the answer:

No

Figure 6.

FOURTH: There is a conclusion with this answer. Using the checklist, Mr. Brown determines if the conclusion is reasonable. He does not think the conclusion is reasonable because he has a motorcycle that he could ride to New York. The checklist tells Mr. Brown to turn to page 3 in the problem booklet.

PLEASE TURN TO PAGE 3 IN YOUR PROBLEM BOOKLET.
FIFTH: Mr. Brown follows the steps which start on page 3 of the problem booklet. Specifically,

STEP 1. He crosses out the conclusion, Take a bus.

STEP 2. Mr Brown turns to page 16 (see diagram 4 on page 4 in the problem booklet) of the decision tree and writes a question that reflects the fact that he owns a motorcycle. The question he writes:

Do you own a motorcycle?

STEP 3. On the same page, he writes the possible answers (see diagram 5 on page 5 in the problem booklet):

No, Yes

STEP 4. Mr. Brown then specifies the conclusions for each answer. For Yes the conclusion is take a motorcycle. For No the conclusion is Take a bus (see diagram 6 on page 6 in the problem booklet).

SIXTH: Based upon Mr. Brown's answers, the decision tree suggests that he take a motorcycle (CONCLUSION 63).

PLEASE WRITE "63" IN THE ANSWER BLANK ON PAGE 8 OF YOUR PROBLEM BOOKLET.

TURN TO PAGE 9 OF THE PROBLEM BOOKLET.

YOU HAVE FINISHED THE INSTRUCTIONS ON HOW TO USE THE DECISION TREE. PLEASE RAISE YOUR HAND SO THAT YOUR INSTRUCTIONAL BOOKLET CAN BE EXCHANGED FOR THE DECISION TREE BOOKLET.
APPENDIX C:

PROBLEM BOOKLET FOR PSICAT
CURRENT SITUATION DIAGRAM

Current situation for travelers going from Chicago to New York

- Can spend over $150 (CS3)
- Cannot spend over $150 (CS2)
- Does not own an auto (CS7)
- Does own an auto (CS6)

GOAL DIAGRAM

Goals for getting to New York

- 6 hours or less (G1)
- Next couple of days (G4)

METHOD DIAGRAM

Methods available for getting to New York

- Auto (M4)
- Bus (M5)
- Airplane (M7)
A Definition provides a list of the part's distinguishing characteristics.

Example: Current Situation 3
Distinguishing Characteristic:
1. Individual can spend over $150.

An Example is an instance of the part.

Example: An example of CS 3 can be found in the problem on page E 1.

Example: Goal G 1 Example 1:
Mr. Adams wants to go from Chicago to New York in 6 hours.
EXAMPLE 1

Mr. Adams wants to go from Chicago to New York within the next 6 hours. He can spend over $150.

PLACE YOUR SELECTIONS IN THE APPROPRIATE BLANKS BELOW.

Current Situation (ex CS 1) __________
Method (ex M 1) __________
Goal (ex G 1) __________

ONCE ALL PARTS ARE SELECTED, PLEASE TURN TO THE NEXT PAGE.
EXAMPLE 2

Mr. Brown wants to go from Chicago to New York in the next couple of days. He cannot spend over $150 and does not own an auto. However, he does own a large motorcycle.

PLACE YOUR SELECTIONS IN THE APPROPRIATE BLANKS BELOW.

Current Situation (ex CS 1) _________
Method (ex M 1) _________
Goal (ex G 1) _________

ONCE ALL PARTS ARE SELECTED, PLEASE TURN TO THE NEXT PAGE.
SUBSET 1

INSTRUCTIONS: Use the system to identify the parts as in Example 1. You may refer to the diagrams, definitions, and examples provided in the booklet for additional help. Place your selections for each part of a problem in the appropriate blank. Do not create any new parts.
Ms. Robinson wants to leave Chicago for a one week vacation. She has decided to go to New York City. She has reservations for Friday at Howard Johnson's Hotel at $50 per night for six nights. She has budgeted herself $40 per day for meals. Her travel budget (i.e. budget for travel, hotel, and meals) is $650. She does not have a drivers license.

Today is Tuesday.

CURRENT SITUATION

METHOD

GOAL

ONCE THE PARTS ARE SELECTED, PLEASE TURN THE PAGE AND CONTINUE.
REMEMBER TO PLACE YOUR SELECTIONS IN THE APPROPRIATE BLANKS.

PROBLEM 3

It is the 5th. Ms. Sherman has an interview in New York City on the 8th. She wants to take her husband with her. She knows that she can drive, take a bus, or fly to New York from Chicago. She is open to other options. The company will pay $400 for transportation. She would like to have both she and her husband get to New York and back for that sum.

<table>
<thead>
<tr>
<th>CURRENT SITUATION</th>
<th>METHOD</th>
<th>GOAL</th>
</tr>
</thead>
</table>

ONCE THE PARTS ARE SELECTED, PLEASE TURN THE PAGE AND CONTINUE.
SUBSET 2

INSTRUCTIONS: Use the system to identify and create if necessary the parts of the following problems. You may refer to the diagrams, definitions, and examples provided in the booklet for additional help. Place your selections for each part of a problem in the appropriate blank.

PLEASE TURN THE PAGE AND CONTINUE.
PROBLEM 4

Mr. McClure is a railroad engineer for AMTRAK. He wants to get to New York City from Chicago in the next 36 hours. He can spend more than $150. He does not want to fly because he has a fear of flying and he does not own an auto.

CURRENT SITUATION

METHOD

GOAL

PLEASE TURN THE PAGE AND CONTINUE.
Problem 5

Ms. Turner has retired several months ago from teaching in the Chicago schools. Since then, she has bought a new car, been to Hawaii, and now wants to go to New York City. She has saved $2000 for the trip. She wants to see the countryside on her way there.

<table>
<thead>
<tr>
<th>CURRENT SITUATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>METHOD</td>
<td></td>
</tr>
<tr>
<td>GOAL</td>
<td></td>
</tr>
</tbody>
</table>

PLEASE TURN THE PAGE AND CONTINUE.
PROBLEM 6

Mr. Olsen is planning his vacation. He wants to go from Chicago to New York City. He has come in to the travel agency a month before he plans to go in order to obtain information. He has a $2000 budget for the two week vacation. He and his wife are going. He does own a car.

CURRENT SITUATION

METHOD

GOAL
APPENDIX D:

PROBLEM BOOKLET FOR DTT
How soon do you want to get to New York?

**ANSWER**

- Less than 6 hours
  - Conclusion

- Next couple of days
  - Conclusion

How much money can you spend?

**ANSWER**

- $150 or more
  - Take a plane
  - **5**

- Less than $150
  - Not possible
  - **7**

- Less than $150
  - Conclusion

- $150 or more
  - Take a plane
  - **9**

Do you own a car?

**ANSWER**

- Yes
  - Take a car
  - **13**

- No
  - Take a bus
  - **15**
IF THERE IS NOT A GOOD ANSWER TO THE QUESTION,

THEN PERFORM THE FOLLOWING STEPS TO CREATE ONE IN YOUR DECISION TREE BOOKLET.

STEP 1. Add an additional answer in one of the two answer spaces represented by circles (see example in diagram 1).

Example

Diagram 1.
STEP 2. If the answer you added allows you to specify which method the traveler should use to get to New York City, then write that method in the conclusion space represented by a octagon (see example in diagram 2). Then write the number of the conclusion in the problem's answer blank.

Else, leave the conclusion space blank and proceed to the page specified under the conclusion.

Example

Diagram 2.
IF THERE IS A GOOD ANSWER TO THE QUESTION, BUT THE CONCLUSION IS NOT REASONABLE,

THEN PERFORM THE FOLLOWING STEPS TO CREATE A REASONABLE CONCLUSION IN YOUR DECISION TREE BOOKLET.

STEP 1. Cross out the conclusion space and proceed to the page specified under the crossed out octagon (see example in diagram 3).

Example

Diagram 3.
STEP 2. On the page you turned to, write the question that will allow for a reasonable conclusion in the conclusion space (see example in diagram 4).

Example

---

Diagram 4.
STEP 3. On the same page, write in the possible answers to the question (see example in diagram 5).

Example

**CHECKLIST**

1. Is there a good answer to the question?
   a) No, then look at page 5 in the problem booklet.
   b) Yes.

2. Is there a conclusion to the answer?
   a) No, then go to the next specified page.
   b) Yes.

3. Is the conclusion reasonable?
   a) No, then look at page 3 in the problem booklet.
   b) Yes, then place the conclusion writer in the answer blank in your problem booklet.

**QUESTION**

Do you own a motorcycle?

**From page 4**

**ANSWER**

**CONCLUSION**

61

**ANSWER**

No

**CONCLUSION**

62

**ANSWER**

Yes

**CONCLUSION**

63

**ANSWER**

**CONCLUSION**

64

**Figure 5.**
EXAMPLE PROBLEM 1

Mr. Adams wants to go from Chicago to New York City within the next 6 hours. He can spend over $150.

PLACE YOUR CONCLUSION NUMBER IN THE APPROPRIATE BLANK BELOW.

Conclusion Number

ONCE YOU HAVE SELECTED THE CONCLUSION, PLEASE TURN TO THE NEXT PAGE.
EXAMPLE PROBLEM 2

Mr. Brown wants to go from Chicago to New York in the next couple of days. He cannot spend over $150 and does not own an auto. However, he does own a large motorcycle.

PLACE YOUR CONCLUSION NUMBER IN THE APPROPRIATE BLANK BELOW.

Conclusion Number

ONCE YOU HAVE SELECTED THE CONCLUSION, PLEASE TURN TO THE NEXT PAGE.
SUBSET 1

INSTRUCTIONS: Use the decision tree booklet to come to a conclusion on which method should be used to get to New York from Chicago. For this subset of problems, the decision tree contains reasonable answers and conclusions. Therefore DO NOT create new questions, answers, or conclusions. Place your conclusion number for a problem in the specified blank.

PLEASE TURN TO THE NEXT PAGE AND START.
PROBLEM 1

Mr. Quinn is a resident of Chicago who has a conference to attend in New York City the day after tomorrow. He has a transportation budget of $500. He wants to return in seven days.

CONCLUSION NUMBER __________

REMEMBER TO PLACE YOUR CONCLUSION IN THE APPROPRIATE BLANK.

ONCE YOU HAVE MADE YOUR CONCLUSION, PLEASE TURN THE PAGE AND CONTINUE.
PROBLEM 2

Ms. Robinson wants to leave Chicago for a one week vacation. She has decided to go to New York City. She has reservations for Friday at Howard Johnson's Hotel at $50 per night for six nights. She has budgeted herself $40 per day for meals. Her travel budget (i.e. budget for travel, hotel, and meals) is $650. She does not have a drivers license.

Today is Tuesday.

CONCLUSION NUMBER

REMEMBER TO PLACE YOUR CONCLUSION IN THE APPROPRIATE BLANK.

ONCE YOU HAVE MADE YOUR CONCLUSION, PLEASE TURN THE PAGE AND CONTINUE.
PROBLEM 3

It is the 5th. Ms. Sherman has an interview in New York City on the 8th. She wants to take her husband with her. She knows that she can drive, take a bus, or fly to New York from Chicago. She is open to other options. The company will pay $400 for transportation. She would like to have both she and her husband get to New York and back for that sum.

CONCLUSION NUMBER

REMEMBER TO PLACE YOUR CONCLUSION IN THE APPROPRIATE BLANK.

ONCE YOU HAVE MADE YOUR CONCLUSION, PLEASE TURN THE PAGE AND CONTINUE.
SUBSET 2

INSTRUCTIONS: Use the decision tree to come to a conclusion and create if necessary the questions, answers, and conclusions in order to come to a reasonable conclusion on which method should be used to get to New York from Chicago. Use the decision trees, lists of steps, and examples for help. Place your conclusion number for a problem in the specified blank.

PLEASE TURN TO THE NEXT PAGE AND CONTINUE.
PROBLEM 4

Mr. McClure is a railroad engineer for AMTRAK. He wants to get to New York City from Chicago in the next 36 hours. He can spend more than $150. He does not want to fly because he has a fear of flying and he does not own an auto.

CONCLUSION NUMBER

PAGE 4
Problem 5

Ms. Turner has retired several months ago from teaching in the Chicago schools. Since then, she has bought a new car, been to Hawaii, and now wants to go to New York City. She has saved $2000 for the trip. She wants to see the countryside on her way there.

CONCLUSION NUMBER
PROBLEM 6

Mr. Olsen is planning his vacation. He wants to go from Chicago to New York City. He has come in to the travel agency a month before he plans to go in order to obtain information. He has a $2000 budget for the two week vacation. He and his wife are going. He does own a car.

CONCLUSION NUMBER

WHEN YOU HAVE FINISHED, PLEASE TURN IN BOTH THE DECISION TREE AND THE PROBLEM BOOKLET. THANK YOU.
APPENDIX E:

SEQUENCE OF STEPS IN WILSON'S CONCEPT ANALYSIS TECHNIQUE
Table 10  Steps in Wilson's concept analysis technique (Hall et al, 1982)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central meaning</td>
<td>Describe the central meaning of the concept</td>
</tr>
<tr>
<td>Model case</td>
<td>Describe the instances which are clearly and unequivocally examples of the concept.</td>
</tr>
<tr>
<td>Contrary case</td>
<td>Describe what the concept 'is not'</td>
</tr>
<tr>
<td>Related case</td>
<td>Describe other concepts that are related and in some way importantly connected.</td>
</tr>
<tr>
<td>Borderline case</td>
<td>Identify instances in which it is not clear whether the concept applies or not.</td>
</tr>
<tr>
<td>Invented case</td>
<td>Describe a hypothetical instance which is outside our normal experience or is an imaginary example of the concept.</td>
</tr>
<tr>
<td>Social context</td>
<td>Describe the nature of the situation or circumstances which may be important in understanding the concept.</td>
</tr>
<tr>
<td>Underlying anxiety</td>
<td>Consider the underlying mod or biases of the persons using the concept.</td>
</tr>
<tr>
<td>Practical results</td>
<td>What are the practical results if the concept is used in different ways.</td>
</tr>
<tr>
<td>Results in the language</td>
<td>Select the most useful criteria for the concept. Some concepts may be so vague or have no clearly defined central meaning, but some meanings rather than others, may seem to be appropriate.</td>
</tr>
</tbody>
</table>
APPENDIX F:

DEFINITIONS OF ELEMENTS IN HALL'S CONCEPT STRUCTURE
A concept is a set of objects, symbols, or events which are grouped together on the basis of shared characteristics.

A target concept is the concept which is to be learned.

A superordinate concept is a set of coordinate concepts grouped together on the basis of shared characteristics.

A coordinate concept is a concept with the same superordinate concept as the target concept.

A concept definition identifies the superordinate concept, identifies the critical and variable attributes and specifies how these attributes are combined.

Critical attributes are characteristics which are used to discriminate examples of coordinate concepts from one another.

Variable attributes are the critical attributes of subordinate concepts.

An example is an instance of the concept.

Elaboration is a statement which adds more detail to ones understanding of a concept.

Presentation Strategy is a specified sequence of presentation forms which incorporates the critical elements and processes of the strategy.
APPENDIX G

INSTRUCTIONS AND DIRECTIONS FOR JUDGING THE LISTS OF CHARACTERISTICS
JUDGING THE LISTS OF CHARACTERISTICS

The following are the instructions and directions for judging the lists of problem characteristics identified by subjects as being necessary to solve the problem. First you will be given instructions on how to judge the lists. The instructions include examples of how to rate the lists. Next, you will be provided the directions to judge the lists. The directions include the evaluation criteria, the inventory of possible characteristics, and the benchmarks you are to use to rate the lists.

2 Instructions on How to Rate the Lists

You are to rate how well subjects identify those characteristics of a problem which are necessary to solve it. Your rating is to be based upon the degree of match between the list of characteristics identified by the subject and those characteristics of the problem which you identify as being necessary to solve it. You have five benchmarks to aid you in rating the lists.

The lists are produced by subjects after they read a problem. For example, five subjects read the following problem:

PROBLEM: Mr. Taka wants to go from Chicago to New York within the next couple of days. He cannot spend over $150 and does not own an auto.

Each subject produced a list of those characteristics which he thinks is necessary to solve the problem:

List 1.
Can spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a bus.

List 2.
Cannot spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a plane.

List 3.
Cannot spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a bus.
List 4.

Cannot spend over $150.
Needs to be in New York within the next couple of days.
Suggested method of transportation is a bus.

List 5.

Cannot spend over $150.
Does not own an auto.
Needs to be in New York within the next couple of days.
Suggested method of transportation is a bus.

Note that included in each list is the method of transportation that the subject thinks is most appropriate given the characteristics he listed.

As a judge, you rate numerically the lists of characteristics based upon the following evaluation criterion and benchmarks.

EVALUATION CRITERION AND RATING SCALE

The degree of match between the list of characteristics identified by the subject and those characteristics of the problem which you identify as being necessary to solve it.

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PROBLEM: Mr. Taka wants to go from Chicago to New York within the next couple of days. He cannot spend over $150 and does not own an auto.

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BENCHMARKS

List 1. Rating: 1

Can spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a bus.

For List 1 the rating is a 1 (Not a match) because the problem states that Mr. Taka cannot spend over $150 and that he
needs to be in New York within the next couple of days. Both characteristics are contrary to those in the problem.

List 2.  
Rating: 2

Cannot spend over $150.  
Needs to be in New York within the next 36 hours.  
Suggested method of transportation is a plane.

For list 2 you might rate it a 2 (Poor match) because though the list contains the characteristic, Mr. Taka cannot spend over $150 (thus the list is better than List 1), it still contains the incorrect characteristic that he needs to be in New York within the next 36 hours. Also, the method of transportation is not possible given that it requires over $150 to travel to New York from Chicago. The list also does not contain information about whether Mr. Taka owns an auto, which is a possible method of going to New York since flying is not possible. NOTE: If flying was possible, then the characteristic about owning an auto would not be important and would not have to be included.

List 3.  
Rating: 3

Cannot spend over $150.  
Needs to be in New York within the next 36 hours.  
Suggested method of transportation is a bus.

For list 3 you might rate it a 3 (Moderate match) because it still contains the incorrect characteristic that he needs to be in New York within 36 hours. Also no mention is made of the fact that Mr. Taka owns an auto. But list 3 is better than list 2 because the suggested method of transportation is a bus.

List 4.  
Rating: 4

Cannot spend over $150.  
Needs to be in New York within the next couple of days.  
Suggested method of transportation is a bus.

For list 4 you might rate it a 4 (Good match) because it does not contain any characteristics that are contrary to the information contained in the problem, but it also does not mention that Mr. Taka does not own an auto - a characteristic that is important for not suggesting the use of an auto.
List 5. Rating: 5

Cannot spend over $150.
Does not own an auto.
Needs to be in New York within the next couple of days.
Suggested method of transportation is a bus.

For List 5 you might rate it a 5 (Excellent match) because the list contains all the relevant information concerning the method for getting to New York and why the method was appropriate.

2.1 Rating the Two Sets of Problems

There are two sets of problems. The first set contains problems 1, 2, and 3. The second set contains problems 4, 5, and 6. The rating process will be different for each set.

2.1.1 Rating the First Set of Problems

For problems 1, 2, and 3, you are to rate the degree of match between the list of characteristics identified by the subject and those characteristics of the problem which you identify as being necessary to solve it GIVEN THE INVENTORY OF CHARACTERISTICS FROM WHICH THE SUBJECT HAD TO SELECT. Table 1. lists the inventory of possible characteristics.

Table 1. INVENTORY OF POSSIBLE CHARACTERISTICS FOR PROBLEMS 1, 2, AND 3.

- Can spend over $150.
- Cannot spend over $150.
- Does own an auto.
- Does not own an auto.
- Be in New York within the next 6 hours.
- Be in New York within the next couple of days.
- Method of transportation is an auto.
- Method of transportation is a bus.
- Method of transportation is an airplane.
For example a subject reads the following problem:

Mr. Taka wants to be in New York Friday. Today is Tuesday.

The subject has only two choices for describing when Mr. Taka needs to be in New York: (1) Within 6 hours, and (2) Within the next couple of days. The subject decides that choice number 1 was the most appropriate though not as accurate as he would like.

2.2.2 Rating the Second Set of Problems

For problems 4, 5, and 6, you are to rate the degree of match between the list of characteristics identified by the subject and those characteristics of the problem which you identify as being necessary to solve it.

Rating the second set (problems 4, 5, and 6) the subjects do not have to select from the characteristics provided them. They are free to create their own. Consider the characteristic that pertained to time in the previous problem. The subject did not think the characteristic, "Within the next couple of days," matched the time Mr. Taka needed to be in New York. With problems 4, 5, and 6, the subject could create the new characteristic, "Within the next 3 days".

2.3 Rating Process

Step 1. Start with the first set of problems.

2. Read one of the problems.

3. Read each and every list of characteristics produced by the subjects.

4. Rate each list using the following five point scale, the benchmarks, and taking into consideration the inventory of possible characteristics.

5. After you have rated all three problems in the first set, go on to the second set of problems.

6. Read one of the problems in the second set.

7. Read each and every list of characteristics produced by the subjects.

8. Rate each list using the five point scale and the benchmarks.
3 Directions for Judging

DIRECTIONS: Rate numerically the lists of characteristics based upon the following evaluation criteria and place the rating on the rating sheet.

3.1 Evaluation Criteria and Rating Scale

For problems 1, 2, and 3, rate the degree of match between the list of characteristics identified by the subject and those characteristics of the problem which you identify as being necessary to solve it GIVEN THE INVENTORY OF CHARACTERISTICS FROM WHICH THE SUBJECT HAD TO SELECT.

For problems 4, 5, and 6, rate the degree of match between the list of characteristics identified by the subject and those characteristics of the problem which you identify as being necessary to solve it.

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3.2 Inventory of Possible Characteristics for Problems 1, 2, and 3.

- Can spend over $150.
- Cannot spend over $150.
- Does own an auto.
- Does not own an auto.
- Be in New York within the next 6 hours.
- Be in New York within the next couple of days.
- Method of transportation is an auto.
- Method of transportation is a bus.
- Method of transportation is an airplane.
3.3 Benchmarks

PROBLEM: Mr Taka wants to go from Chicago to New York within the next couple of days. He cannot spend over $150 and does not own an auto.

List 1. Rating: 1

Can spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a bus.

For List 1 the rating is a 1 (Not a match) because the problem states that Mr. Taka cannot spend over $150 and that he needs to be in New York within the next couple of days. Both characteristics are contrary to those in the problem.

List 2. Rating: 2

Cannot spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a plane.

For List 2 you might rate it a 2 (Poor match) because though the list contains the characteristic, Mr. Taka cannot spend over $150 (thus the list is better than List 1), it still contains the incorrect characteristic that he needs to be in New York within the next 36 hours. Also, the method of transportation is not possible given that it requires over $150 to travel to New York from Chicago. The list also does not contain information about whether Mr. Taka owns an auto, which is a possible method of going to New York since flying is not possible. NOTE: If flying was possible, then the characteristic about owning an auto would not be important and would not have to be included.

List 3. Rating: 3

Cannot spend over $150.
Needs to be in New York within the next 36 hours.
Suggested method of transportation is a bus.

For List 3 you might rate it a 3 (Moderate match) because it still contains the incorrect characteristic that he needs to be in New York within 36 hours. Also no mention is made of the fact that Mr. Taka owns an auto. But list 3 is better than list 2 because the suggested method of transportation is a bus.
List 4. Rating: 4

Cannot spend over $150.
Needs to be in New York within the next couple of days.
Suggested method of transportation is a bus.

For list 4 you might rate it a 4 (Good match) because it does not contain any characteristics that are contrary to the information contained in the problem, but it also does not mention that Mr. Taka does not own an auto - a characteristic that is important for not suggesting the use of an auto.

List 5. Rating: 5

Cannot spend over $150.
Does not own an auto.
Needs to be in New York within the next couple of days.
Suggested method of transportation is a bus.

For list 5 you might rate it a 5 (Excellent match) because the list contains all the relevant information concerning the method for getting to New York and why the method was appropriate.
LIST OF REFERENCES


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