EXPERT CONCEPTUALIZATIONS OF THE DOMAIN OF INSTRUCTIONAL DESIGN:
AN INVESTIGATIVE STUDY ON THE DEEP ASSESSMENT METHODOLOGY FOR COMPLEX PROBLEM-SOLVING OUTCOMES

By

Deniz Eseryel

DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Education in Instructional Design, Development, & Evaluation in the Graduate School of Syracuse University
ABSTRACT

In simple, well-structured problem solving, assessment is straightforward since there is usually a single correct answer to such problems. In the case of complex, ill-structured problems, such as instructional design problems, typically, performance on actual problems, while generally desirable for determining actual level of expertise, is less appropriate since these often require teams of experts and specialists interacting over a period of months to develop an actual solution. Furthermore, it is hard to evaluate individual students on the basis of their actual performances since such problems do not have standard ‘correct’ responses.

Given this situation, the motivation underlying this study was the lack of a reliable assessment method to determine progress in higher-order learning in situations involving complex and ill-structured problems. One may argue that differences in performance-outcomes imply domain experts conceptualize ill-structured problems differently. Another alternative explanation may be that experts do conceptualize a given problem similarly but there are other factors that lead to different performance-outcomes of experts. In this case, expert problem conceptualizations could be used as a basis for assessment.

In this direction, this study aimed at (1) exploring the processes underlying complex, ill-structured problem solving of instructional design experts to investigate whether expert instructional designers exhibit recognizable patterns in their conceptualizations of a given instructional design problem; and (2) investigating the utility of annotated causal representations for eliciting problem conceptualizations of experts in a complex, ill-structured problem domain such as instructional design.
The results of this study suggested that annotated causal representations are useful in eliciting problem conceptualizations of individuals and identifying their relative levels of expertise. In addition, expert instructional designers exhibited recognizable patterns in their conceptualizations of the given instructional design problem. Despite these similarities, however, each expert offered different solution approaches for the given problem. This was explained by the differences in the processes underlying well-structured and complex, ill-structured problem solving. Unlike in well-structured problem solving, problem conceptualization and problem solution are not two separate activities in ill-structured problem solving. Rather, they are intimately connected; they complete each other, and develop in parallel.
EXPERT CONCEPTUALIZATIONS OF THE DOMAIN OF INSTRUCTIONAL DESIGN:
AN INVESTIGATIVE STUDY ON THE DEEP ASSESSMENT METHODOLOGY FOR COMPLEX PROBLEM-SOLVING OUTCOMES

By

Deniz Eseryel
B.Sc. Middle East Technical University, 1995
M.Sc. University of Twente, 1999

DISSERTATION
Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Education in Instructional Design, Development, & Evaluation in the Graduate School of Syracuse University

May 2006

Approved

Philip J. D’Moura, Ph.D.

Date April 21, 2006
Table of Contents

CHAPTER 1. STATEMENT OF THE PROBLEM ............................................................. 1
OVERVIEW ........................................................................................................... 1
BACKGROUND ..................................................................................................... 2
  System Dynamics Modeling & Complex Problem Solving .................................... 4
  A Method to Assess Learning Outcomes in Complex Problem Solving ............ 8
PURPOSE OF THE STUDY .................................................................................. 10
  Complex & Ill-Structured Nature of Instructional Design Problem Solving ........ 10
  Specific Research Question ............................................................................. 13
  Significance of the Study ............................................................................... 14

CHAPTER 2. REVIEW OF THE LITERATURE .......................................................... 17
OVERVIEW .......................................................................................................... 17
JUST WHAT IS A PROBLEM? ............................................................................... 17
  Problem Structure ........................................................................................... 21
  Problem Complexity ....................................................................................... 24
  Section Summary ........................................................................................... 25
RESEARCH on PROBLEM SOLVING ................................................................ 27
  Behavioral and Associationist Tradition ........................................................... 27
  Gestalt Tradition ............................................................................................ 28
    Functional fixedness .................................................................................... 28
    Einstellung .................................................................................................. 30
    Guided discovery & transfer of problem-solving skills. ................................. 32
  Information Processing View of Human Problem Solving ............................... 35
    Human problem solver as an information-processing system ....................... 38
    Problem solving as search & understanding processes .................................. 38
  Expert-Novice Comparison Studies in Natural Knowledge Domains ............... 41
    Importance of domain-specific knowledge in human problem solving ........... 43
    Emphasis on ill-structured problem solving .................................................. 47
  Simulation-Based Studies of Complex Problem Solving (CPS) ......................... 68
    Implicit learning in system control ................................................................ 69
    Interplay of the cognitive, motivational, & social components of CPS .......... 72
  Research on Everyday Problem Solving ........................................................... 77
  Dynamic Decision Making (DDM) .................................................................. 79
Naturalistic Decision Making (NDM) ......................................................................................... 80
Section Summary .................................................................................................................... 81
IMPLICATIONS of PROBLEM-SOLVING RESEARCH for INSTRUCTION .................... 86
IMPLICATIONS of PROBLEM-SOLVING RESEARCH for ASSESSMENT ....................... 93
Towards an Assessment Methodology Based on Causal Representations ................... 98
Study one. ............................................................................................................................ 99
Results of study one........................................................................................................ 102
Study two .......................................................................................................................... 104
Results of study two .......................................................................................................... 104
Study three. ......................................................................................................................... 109
Results of study three ....................................................................................................... 112
Study four. .......................................................................................................................... 115
Results of study four .......................................................................................................... 119
Section Summary ................................................................................................................ 127
CHAPTER SUMMARY AND CONCLUDING REMARKS ..................................................... 129

CHAPTER 3. METHODOLOGY ............................................................................................. 135
OVERVIEW .......................................................................................................................... 135
STUDY DESIGN ................................................................................................................... 136
Participants ......................................................................................................................... 136
Materials ............................................................................................................................... 145
Data Collection ................................................................................................................... 148
Data Analysis Plan ............................................................................................................. 149

CHAPTER 4. RESULTS ....................................................................................................... 152
OVERVIEW .......................................................................................................................... 152
Are the representations of expert instructional designers apparently similar? .......... 153
Do expert instructional designers identify similar key factors as important for a given complex instructional design problem? .............................................................. 156
Do expert instructional designers identify similar interrelationships between the key factors for the given ID problem? ................................................................. 166
Do expert instructional designers offer similar solutions for the given instructional design problem? ........................................................................................................... 168
CHAPTER SUMMARY ....................................................................................................... 177

CHAPTER 5. DISCUSSION ................................................................................................. 180
OVERVIEW .......................................................................................................................... 180
SYNTHESIS OF THE FINDINGS ....................................................................................... 183
List of Figures

Figure 1. A causal influence diagram for population growth .............................................6
Figure 2. ISD\textsuperscript{4} Instructional Design Model. .............................................................11
Figure 3. An illustration of the transition of problem conceptualizations of learners ......14
Figure 4. Problem categorization. ..........................................................................................26
Figure 5. An illustration of the candle problem used by Duncker (1945) .........................29
Figure 6. An illustration of the two string problem used by Maier (1931) .....................31
Figure 7. An illustration of the matchstick problem used by Katona (1940) .................33
Figure 8. An illustration of the nine-dot problem used by Maier (1930) and its solution..34
Figure 9. An illustration of missionaries-cannibals problem ..........................................36
Figure 10. A cryptarithmetic problem used by Barlet (1958) .........................................37
Figure 11. Tower of Hanoi problem ...................................................................................37
Figure 12. A simplified schematic diagram of the problem solving process ..................40
Figure 13. An illustration of a simplified schematic diagram of the problem-solving process by Gick (1986) .................................................................................................45
Figure 14. The map of the town of Lohhausen used by Dörner (1987) .......................74
Figure 15. The RPD model illustrated with three cases ......................................................81
Figure 16. Categorization of problem types studied by different traditions of problem solving research .................................................................88
Figure 17. Categorization of problem types and their required performances ............92
Figure 18. An example of concept map used by Novak (1998) .....................................96
Figure 19. Sample causal influence diagram for stress ......................................................98
Figure 20. Problem scenario for the spread of an infection used .................................110
Figure 21. The causal questionnaire form used by Christensen et al. (2000) .............111
Figure 22. Deer population problem scenario used by Christensen et al. (2000) ....113
Figure 23. Yeast generation problem scenario used by Christensen et al. (2000) ......115
Figure 24. The DEEP tool used by Spector and Koszalka (2004) ...............................116
Figure 25. A screenshot of the 'Background Survey' presented by the DEEP tool .......................... 117

Figure 26. Instructions page from the DEEP tool .................................................................... 118

Figure 27. A sample scenario description page from the DEEP tool ......................................... 119

Figure 28. A sample problem space conceptualization page from the DEEP tool ...................... 120

Figure 29. A sample cluster from one of the novices on the medical scenario ...................... 125

Figure 30. A sample cluster from one of the experts on the medical scenario ....................... 125

Figure 31. Instructional design problem scenario presented to participants .......................... 152

Figure 32. A sample representation by Subject#42 .................................................................. 165

Figure 33. Subject#37's annotated representation .................................................................... 170

Figure 34. Subject#41's annotated representation .................................................................... 171

Figure 35. Subject#51's annotated representation .................................................................... 172

Figure 36. Subject#39's assumptions ....................................................................................... 173

Figure 37. Subject#39's annotated representation .................................................................... 174

Figure 38. Subject#42's assumptions ....................................................................................... 175

Figure 39. Subject#42's annotated representation .................................................................... 176

Figure 40. A simplified illustration of ill-structured problem solving processes .................. 190
List of Tables

Table 1. Participant background information ................................................................. 139
Table 2. Participants’ instructional design experience. ................................................. 142
Table 3. Instructional designers who are identified as experts by the subjects .......... 144
Table 4. The most relevant criteria in determining an expert instructional designer according to the subjects .............................................................................................. 145
Table 5. Data analysis framework .................................................................................. 151
Table 6. Surface level analysis results ............................................................................. 154
Table 7. The coding schema used for this study ............................................................ 157
Table 8. Overall summary of the results of semantic analysis on the node level ........... 162
Table 9. Frequency counts of factors identified by each subject ..................................... 164
Table 10. Nodes that were most central in subjects’ representations ............................. 166
Table 11. Summary data ................................................................................................. 167
Table 12. Type of links by subject .................................................................................. 168
Table 13. Overview of surface level analysis .................................................................. 185
Acknowledgements

My working hypothesis as a researcher and as a human being is that we co-create social reality, our perceptions and the world ‘out there’ in conjunction with other persons and events; and in doing so we, too, are created. I believe the intricate, beautiful Turkish folk dances are wonderful metaphors for this process. While virtuosos do take part, the moving quality of that pageant comes from the presence of all of the dancers, the movements of each complementing those of the others.

Therefore, I cannot say I did this all by myself. On the surface, this dissertation appears to be the product of an individual. After all, my name is on the cover. This is misleading, however, because this work is not solely a product of individual’s effort: three categories of people have irrevocably contributed to it and, thus, my debts are three-fold. On one hand, I wholeheartedly wish to thank all those people who assisted me in various ways in actually completing this work. People falling under this category include participants of the dissertation study; my teachers, colleagues, friends, who worked with me, offered support, suggestions, criticism, skepticism, counter arguments, feedback, cooperated with me and practically assisted me in every conceivable way.

First and foremost, I am greatly indebted to my advisor Phil Doughty and to the members of my dissertation committee, Mike Spector, and Jerry Klein. Needless to say that without their commitment, the completion of this work would not have been possible. Despite their workload, they were always available for discussions and were willing to help. It has certainly been a privilege and a very stimulating experience to work under their guidance.

Phil, I thank you for always being there for me. I will never forget your support. Just when I thought there was no way out, you accepted me under your wing. You provided me with materials, intellectual support, and direction but you also furnished me with the necessary freedom that one needs to enjoy in order to find her own path. As soon as you smiled and said, “progress!” or “next!” I knew I was going to be all right. Oh, by the way, I also need to thank you for teaching all of us at IDD&E not to use the word ‘need’ when it is not needed.

Jerry, I thank you for your enthusiastic support, encouragement, and friendship. Our discussions were always a source of stimulation for me. I very much enjoyed working with you during all our collaborative initiatives. I am also indebted to you for stepping up for me when I was having a hard time recruiting one more member for my dissertation committee. Your contribution to this dissertation was certainly indispensable as you helped me recognize the different aspects of the research with which I was involved.

My debts are also huge to another category of people whose thinking has had a profound influence on my own and, consequently, on the ideas and research reported in this dissertation. I have never met or worked with most of these people (in some cases this would have been downright impossible) but most of the ideas expressed in my
dissertation were instantiated through a dialogical interplay with theories and ideas put forward by others decades or even centuries ago. Therefore, the presence of my name on the cover does not tell the whole story. In a way, my name on the cover of this dissertation manifests my contribution but not the contribution of others to my thinking and my understanding. Their contribution to my thinking can be clearly seen in the list of references and, hopefully, should also be conspicuous throughout the text. In this context, I especially thank Mike Spector. He is not only a member of my dissertation committee. Mike’s research and ideas have had profound influence on mine. Mike, I thank you for being the role model that you are.

I also wish to thank: Norbert Seel, Nick Smith, Tiffany Koszalka, Anders Ericsson, David Jonassen, Sanne Dijkstra, and Andy Gibbons for their valuable comments to earlier versions of the research proposal; Jeremy Zhang, Addrie Vischer, Han Vermaat, Richard Petty, and everyone at the Department of Instructional Design, Development, and Evaluation, and the Slutzker Center for International Services for their continuous motivation and encouragement; Dean Christensen, Mary Gick, Gary Klein, Tiffany Koszalka, Mike Spector, Robert Tennyson, Robert Weisberg, American Psychological Association, Lawrence Erlbaum Associates, Columbia University Press, Pearson Education, and the Universal Press Syndicate for granting me permission to reprint some of the figures used in this dissertation; and Petek Askar, who nine years ago encouraged me to pursue a graduate study in this field.

Special thanks are due to Linda Tucker. Linda, none of us at the department could do without you. Certainly, your kindness and support will always be remembered.

Last but most certainly not the least, I wish to thank the people who, in so many ways, have significantly contributed to who I am and where I am today. This group certainly includes my parents Sema & Selcuk Eseryel who had to endure seven long years, separated from me by an ocean, with the only means of telephone and email to share the happiness and worries of their daughter. Mom, Dad, thanks for always being on the other end of the line no matter what time it was that I rang you.

Yeliz: my dearest sister and my best friend…what would I have done without you? You have not only made me feel at home by being with me in Syracuse but you also made the life here more beautiful. I cannot thank you enough for your incredible support during these years.

No words exist that can express my deepest gratitude to Fariba and Firouz Rahmanzadeh, and to their family. They have opened up their heart to me and provided a home away from home. They have significantly contributed to who I am and where I am today. I hope to be deserving. I hope I make them proud!

This dissertation is dedicated to my extended family.

Deniz Eseryel
March 11, 2006
I’ve learned that I still have a lot to learn
Maya Angelou
Reprinted with permission of Universal Press Syndicate. All rights reserved.
CHAPTER 1. STATEMENT OF THE PROBLEM

OVERVIEW

In simple, well-structured problem solving, assessment is straightforward since there is usually a single correct answer to such problems. In the case of complex, ill-structured problems, such as instructional design problems, typically, performance on actual problems, while generally desirable for determining actual level of expertise, is less appropriate since these often require teams of experts and specialists interacting over a period of months to develop an actual solution (Spector & Koszalka, 2004). Furthermore, it is hard to evaluate individual students on the basis of their actual performances since such problems do not have standard ‘correct’ responses and responses are often said-to-be contextual (Funke, 1991; Jonassen, 1997; Sternberg, 1995; Voss, Wolfe, Lawrence, & Engle, 1991). The important but little understood problem that motivated this study was the lack of a reliable assessment method to determine progress in higher-order learning in situations involving complex and ill-structured problems. Without a reliable assessment method, little progress can occur in instructional design research with regard to designing effective learning environments to facilitate acquisition of expertise in domains involving complex, ill-structured problem-solving.

In this direction, this study aimed at exploring the processes underlying complex, ill-structured problem solving of experts. Some argue that differences in performance-outcomes imply domain experts conceptualize ill-structured problems differently. Others argue that experts do conceptualize a given problem similarly but there are other factors that lead to different performance-outcomes of experts. This preliminary study aimed at
further exploration of these issues. The purpose of this exploratory study was two-fold. First, this study aimed at investigating whether expert instructional designers exhibit similarities in their conceptualizations of a given instructional design problem. Second, this study aimed at investigating the utility of the DEEP methodology (cf. Spector & Koszalka, 2004) based on annotated causal representations for eliciting problem conceptualizations of experts in a complex, ill-structured problem domain such as instructional design. The domain of instructional design was a compelling testbed for the proposed study due to the fact that instructional design represents a complex and ill-structured design problem-solving domain. Most instructional design problems have vaguely defined or unclear goals, unstated constraints, multiple solutions or solution paths, no consensual agreement on the appropriate solution, and multiple criteria for evaluating solutions (Ertmer & Quinn, 1998; Goel & Pirolli, 1989; Jonassen et al., 1997; Perez, Johnson, & Emery, 1995; Spector, 2000). In this regard, this study also aimed at contributing to the understanding of how expert instructional designers think about complex, ill-structured instructional design problems. In this direction, the study addressed the concern that current understanding of instructional design was insufficient and perhaps inadequate for making decisions regarding improving instructional design education (Dijkstra & van Merriënboer, 1997; Reigeluth, 1997; Rowland, 1992; Wedman & Tessmer, 1993; Zemke, 1985).

BACKGROUND

Gagné (1985) noted that “the central point of education is to teach people to think, to use their rational powers, [and] to become better problem solvers” (p. 85). Like Gagné, many educators and educational researchers regard problem solving as an important learning
outcome (Knowlton, 2003). Nevertheless, Jonassen (2000a) maintained that instructional
design theory and research had devoted too little attention to the study of problem
solving, especially when it comes to facilitating learning in complex, ill-structured
problem solving. Newell and Simon (1972) provided a comprehensive framework for
successful analysis of human performance when addressing many well-structured
problems, however, recent research (e.g., Dunkle, Schraw, & Bendixen, 1995; Frensch &
Funke, 1995a; Lave, 1988) on situated, everyday, and complex problem solving
provided evidence that the processes used to solve well-structured problems and
complex, ill-structured problems were not similar. Therefore, accounting for complex, ill-
structured problems within the framework of well-structured problem solving offered by
Newell and Simon (1972) still remains a challenge (Jonassen, 1997; Reitman, 1965;

Numerous real-life examples and a vast body of research (see, e.g., Brehmer,
Laplat, & Rasmussen, 1991; Dörner, 1996; Merry, 1995) suggest that people, despite
their expertise, have difficulty in understanding and solving complex problems, even
when granted unrestricted access to all relevant information (Dörner, 1996). Achtenhagen
(2000) contends that complex problem solving is an important issue to address due to the
increasing complexity of entrepreneurial processes and the greater diversity of the
workforce. Spector and his colleagues (2001) point to worsening global environmental
problems, persisting regional and ethnic conflicts, and fluctuating economic conditions
and maintain that we have serious, complex problems to confront if we are to survive in
this planet. That is why, in order to be better equipped to address these challenges for the
future well-being of our species on this planet, an important mission for instructional
design research is to develop effective strategies for designing instruction to support the
development of skills required for complex, ill-structured problem solving (Jonassen,

However, a significant challenge presents itself when identifying factors that
contribute to learning to solve complex problems (Jonassen, 1997; Spector et al, 2001).
Several instructional approaches have been proposed for designing instruction to promote
complex problem-solving skills (see Spector & Anderson, 2000); however, there are no
well-established methods to assess learning outcomes in complex problem solving. As a
consequence, it is difficult to argue that one instructional approach is more effective than
another (Spector et al., 2001).

**System Dynamics Modeling & Complex Problem Solving**

There is some evidence to suggest that system dynamics (SD) can be effectively used to
promote understanding in complex problem solving (Christensen et al., 2000; Davidsen,
1994; Spector & Davidsen, 1997a,b; Sterman, 1988; Sterman, 1994). During the 1950s,
system dynamics originated as an approach to solve complex military problems and later
it was extended to complex management and social problems (Forrester, 1961, 1969,
1970). Forrester (1991), the founder of system dynamics, maintains that complex
problems are very hard to understand and to control due to the dynamic interactions of
problem constituents. Drawing from his engineering background, Forrester (1969)
proposed that in order to solve complex problems more efficiently, one should model
them using feedback loops that also depict cause-and-effect relationships among system
components. Forrester (1969) further argued that by viewing a complex problem
holistically and by accurately modeling the problem from a dynamic systems perspective,
one gains deeper understanding of a complex problem and can make accurate predictions of how the system would react to changes in certain factors. A system dynamics approach to complex problem solving encourages systems thinking; an approach that focuses on how various problem constituents interact with each other to produce behavior (Aronson, 1996). As Sterman (1994) puts it “system thinking is the ability to see the world as a complex and dynamic system in which we understand that you can’t just do one thing and that everything is connected with everything else” (p. 291).

It is this dynamic interrelationship among various problem constituents that makes it harder for humans to solve complex problems. Complex problems typically involve large numbers of variables with a high-degree of connectivity. Changes in one variable may affect a number of other variables, making it very difficult to anticipate all of the variables involved or the relationships between them. Furthermore, not every action has immediate consequences. Some effects may be significantly delayed, such as the effects of word-of-mouth advertising. All of these factors make it very challenging for building conceptualizations of the complex problem situation that could help predict the outcomes of possible actions.

System dynamics provide tools (such as the causal influence diagrams) to represent the dynamic relationships among the constituents that make up a complex problem situation. One commonly used tool is a causal influence diagram (also called a causal loop diagram) (Ford & Sterman, 1998; Laukkanen, 1998; Vennix, Anderson, Richardson, & Rohrbaugh, 1994; Vennix & Gubbels, 1994). A causal influence diagram consists of variables connected by arrows denoting the causal influences among the variables. Figure 1 shows an example causal influence diagram for population growth.
In a causal influence diagram, each node represents a variable, a stock, a flow rate, or a constant. Variables are related by casual links, shown by arrows. In the example in Figure 1, the birth rate is determined by both the population and the fractional birth rate. Each causal link is assigned a polarity, either positive (+) or negative (-) to indicate how the dependent variable changes when the independent variable changes.

A positive link means that if the cause increases in influence, the effect increases and if the cause decreases, the effect decreases. In the example in Figure 1, an increase in the birth rate leads to an increase in population when all else remains the same.

A negative link means that if the cause increases, the effect decreases and if the cause decreases, the effect increases. In the example in Figure 1, an increase in the average lifetime of the population means the annual death rate will be lower than what it would otherwise be, and a decrease in the average lifetime means the death rate will be higher than what it would otherwise be. In causal diagrams, nodes, links and link polarities partially describe the structure of the system. System dynamicists make use of a more detailed model called a stock and flow diagram to depict the deep structure of a

Figure 1. A causal influence diagram for population growth.
complex and dynamic system in a way that can be mathematically modeled and that forms the basis for a simulation. Stock and flow diagrams are intended to depict the entire causal structure of a complex system but are beyond the scope of this study. The notion to be pursued herein is that the simpler causal influence diagrams allow individuals to represent their problem conceptualizations. Furthermore, these diagrams and will form the basis for a meaningful evaluation of relative levels of expertise.

It has been argued that problem solving involves the use of problem conceptualizations in order to predict the outcomes of possible actions (Greeno, 1989; Johnson-Laird, 1983). By activating relevant schemata, problem conceptualizations are constructed, which takes as input some specifications of the actions we intend to carry out and produces an interpretation of “what would happen if we did that” (Rumelhart, Hinton, & Williams, 1986a). In other words, while solving problems, a mental simulation of the problem conceptualization “runs in the mind’s eye” (Seel, 2001, p. 407) envisioning in the imagination the events that would take place if a particular action is to be performed. In a similar fashion, system dynamics modeling could be viewed as a tool to help externalize a person’s problem conceptualizations that are constructed at the time of internal testing tool for alternative solutions. In other words, system dynamics modeling could be viewed as a tool help externalize a person’s conceptualization of problem space. Alessi (2000) argues that system dynamics modeling is useful in facilitating complex problem solving because: (1) SD provides knowledge representation tools (Jonassen, 2000b) such as causal influence diagramming that could externally represent a person’s problem space; (2) by enabling problem-solvers to computer-simulate their model to test their hypothesis SD helps significantly reduce the cognitive
load on the part of the problem solver who may otherwise not be able to ‘run’ his or her
mental model due to limited cognitive capacity (Norman, 1983); and (3) SD forces
problem solvers to be system thinkers and forces them to view the problem holistically by
identifying all the key factors that play important roles in the solution of the problem and
the relationships between these factors.

A Method to Assess Learning Outcomes in Complex Problem Solving

In the case of complex, ill-structured problems, performance-based assessment is usually
not a viable alternative in educational settings. Recognizing the promise of system
dynamics modeling for instructional purposes, Spector and his colleagues (2001, 2004)
proposed an assessment methodology based on causal representations.

The assessment methodology proposed by Spector and colleagues is based on the
view of learning as acquisition of expertise (Ericsson & Smith, 1991a; Sfard, 1998).
When learning is viewed as acquisition of expertise, it makes sense to assess learning in
terms of how learners perform and think in comparison to experts. The underlying
assumption of the DEEP methodology is that simple causal representations will allow
individuals to externalize their problem conceptualizations and form the basis for a
meaningful evaluation of relative levels of expertise.

In the case of complex problem solving, assessment is challenging because
domain experts are likely to exhibit a wide range of performances and many relevant
activities are open-ended. Consequently, in order to be able to utilize the DEEP
methodology in any complex problem-solving domain, it is crucial to establish the
existence of following three conditions (Spector et al., 2001; Spector & Koszalka, 2004):
1. Problem conceptualizations of experts should exhibit recognizable patterns in order to provide a base;

2. Problem conceptualizations of novices should be recognizably different from those of experts so that a comparison over time can be achieved; and

3. A similarity metric should be developed to help compare how problem conceptualizations of novices change over time through a sequence of instructional interventions to resemble (or differ from) problem conceptualizations of experts so that it will be possible to measure the effectiveness of any particular instructional strategy.

Preliminary investigation of the validity of this assessment methodology involved environmental problem-solving (Christensen et al., 2000; Spector et al., 2001). It is then further elaborated as the Dynamic and Enhanced Evaluation of Problem Solving (DEEP) methodology and validated in the domains of engineering, medicine, and biology (Spector & Koszalka, 2004). These studies aimed at determining: (a) whether or not expert patterns of thinking about given complex problem scenarios existed; (b) whether novice patterns were recognizably different; and, (c) whether or not improvements in learning after instruction could be assessed using this methodology. Initial answers to these questions were positive (Spector et al., 2001; Spector & Koszalka, 2004). However, while all of these previous domains of investigation involve a range of different types of problem-solving, there was no evidence that the findings of previous studies would extend to other domains. Thus, in order to make the case for the generalizability of the DEEP assessment methodology, it is important to also investigate the applicability of the
DEEP assessment methodology in other domains that involves ill-structured problem solving.

**PURPOSE OF THE STUDY**

In complex, ill-structured problem solving, performance-based assessment is usually not a viable alternative because experts in such domains exhibit a wide variety of performances. In other words, there is usually no single, best solution that is agreed-upon by experts in the field. One may argue that these differences in performance-outcomes imply domain experts conceptualize ill-structured problems differently. Another alternative explanation may be that experts do conceptualize a given problem similarly but there are other factors that lead to different performance-outcomes of experts. This preliminary study aimed at further exploration of these issues.

The purpose of this exploratory study was two-fold. First, this study aimed at investigating the utility of the DEEP methodology (cf. Spector & Koszalka, 2004) based on annotated causal representations for eliciting problem conceptualizations of experts in a complex, ill-structured problem domain such as instructional design. Instructional design is a compelling testbed for this type of study due to reasons that is discussed in the following section.

Second, this study aimed at investigating whether expert instructional designers exhibit similarities in their conceptualizations of a given instructional design problem.

**Complex & Ill-Structured Nature of Instructional Design Problem Solving**

Instructional design involves complex problem-solving because (1) there are usually too many factors influencing the problem situation and (2) these factors exhibit dynamic
interrelationships that may not always be transparent. Tennyson’s (1995) ISD⁴ model of instructional design (Figure 2) appropriately illustrates both of these points.

In addition, instructional design problems are typically archetypal examples of ill-structured problems. Instructional design problems are generally situated in and emergent from a specific context. In most cases, the designer is constrained by circumstances, one or more aspects of the problem situation may not be well specified, the problem description may not be clear or well-defined, or all the information required to solve the problem may not be provided. Furthermore, in most design problems, there is a variety of solutions, each one of which may work as well as any other.

Figure 2. ISD⁴ Instructional Design Model. (Copyright 1997 Tennyson and Associates. Reprinted with permission.)
Without empirical proof, instructional designers are often required to make judgments about the situation and prescribe solutions based on them. That is where expertise plays an important role, based on years of experience in different contexts and situations, expert instructional designers are able to make links between the problem in-hand and their experiences with similar problems. In other words, even if a given ID problem is ill-structured (i.e., neither the problem nor the means to solve it are clear), expert designers are able to add the necessary information to the problem in order to understand and solve it. Even when a problem is novel, experts may be able to recognize patterns from their previous experiences and generate solutions based on those that worked in the past in similar cases (de Groot, 1965). In other words, experts are said to intuitively know what works or what does not work in certain situations (Klein, 1998). That is what sets experts apart from novices who have the content or theoretical background of instructional design but not the experience of experts. Due to their inexperience, novices are typically not able to make sophisticated judgments or informed decisions about novel problem situations that do not have a textbook-solution (Rowland, 1992).

Despite the ill-structured, open-ended nature of instructional design problems, could it possible that given an instructional design scenario, (a) different experts would identify similar factors as important for the solution of the problem and (b) different experts would foresee similar relationships between those factors? The answers to these questions are very important in providing further insight into developing a reliable assessment methodology for complex, ill-structured problem-solving outcomes.
Specific Research Question

With the purpose of the study just described, the central question of the proposed study is identified as follows:

Do expert instructional designers exhibit recognizable patterns in their conceptualizations of a given instructional design problem?

Based on previous research, it is assumed that problem conceptualizations of novices initially exhibit preconceptions or misconceptions (see, e.g., Vermaat, Terlouw, & Dijkstra, 2003). As an individual’s level of expertise increases, these preconceptions and misconceptions that are initially present in his or her problem conceptualizations are said to be gradually replaced with comprehensive, causal explanations (see, e.g., Seel, Al-Diban, & Blumschein, 2000; Snow, 1990). Thus, in the context of problem-solving, it is possible to describe effective learning process as the one that facilitates transition of problem conceptualizations of learners from the state of preconceptions or misconceptions to the state of comprehensive, causal explanations (Figure 3).

Therefore, the central research question led to the following four questions for this proposed research:

1. Are the representations of expert instructional designers apparently similar? In other words, do they have same number of nodes, one- and two-way links, the number of words per node, number of words per link?
2. Do expert instructional designers identify similar key factors as important for a given complex instructional design problem?

3. Do expert instructional designers identify similar interrelationships between the key factors for the given ID problem?

4. Do expert instructional designers offer similar solutions for the given instructional design problem?

**Significance of the Study**

As mentioned earlier, performance-based assessment of complex, ill-structured problem-solving outcomes is challenging because there is usually no single, best solution agreed-upon by field experts. This situation poses significant challenges in the field of instructional design due to the inability to assess which instructional strategies work best in facilitating acquisition of complex, ill-structured problem-solving outcomes.
The significant contribution of this study is that it provides an in-depth exploration of processes underlying complex, ill-structured problem solving of experts. More specifically, this study addresses whether differences in expert performance are due to differences in their understanding and interpretation of the problem or whether there are other issues that explain the differences in their performance-outcomes. More importantly, despite variances in their performances, do domain experts conceptualize problems similarly, i.e., do they identify similar factors important for the solution of a given ill-structured problem and foresee similar relationships between them? And perhaps more importantly, is it possible to reliably elicit problem conceptualizations of experts? The answers to these questions are instrumental in filling the gap in instructional design research for the purposes of facilitating learning and acquisition of expertise in domains which require complex, ill-structured problem skills.

In addition, there is a concern that current understanding of instructional design is insufficient and perhaps inadequate for making decisions regarding improving instructional design education (Reigeluth, 1997; Rowland, 1992; Wedman & Tessmer, 1993; Zemke, 1985). Instructional design is frequently traced to roots in areas such as systems theory and communications. Representations of ID processes frequently reflect those roots. This study will take a different approach based on four fundamental assumptions:

1. Instructional design is a special case of design, and is likely to be similar in some ways to such fields as graphic design and architecture.
2. Design is a type of problem solving in which the problems are complex and, often, ill-defined.

3. Instructional design involves complex problem-solving that is often ill-structured, i.e. without a standard or approved solution.

4. An important part of defining the construct “instructional design” is understanding expertise in the domain as it exists in the practice of designing, i.e. solving instructional design problems.

In this respect, this study may also contribute to a deeper understanding of instructional design problem solving and provides further elaboration on how instructional design experts approach complex, ill-structured instructional design problems.
CHAPTER 2. REVIEW OF THE LITERATURE

OVERVIEW

The literature is summarized in three major sections. In the first section, definitions for ‘problem’ and ‘problem solving’ that synthesizes much of the literature is offered, then elaborated. In the second section, different research traditions of problem solving are summarized. Finally, in the third section, previous studies on assessment methods in complex problem solving are reviewed.

JUST WHAT IS A PROBLEM?

“When I use a word,” Humpty Dumpty said in a rather scornful tone, “it means just what I choose it to mean- neither more nor less.” (Lewis Carroll, 1935, p. 119)

In informal speech, the term “problem” has two different meanings. We can talk about a problem as a general category, for instance, the problem of deciding the next move in chess. It is not possible to give an answer to this question, because it depends on the position on the chessboard. The term “problem” can also be used in a more specific sense: what move should I make on a chessboard with the black king at e1, while my white king at e3, and a white rook at a8? In this case, a specific answer is possible: move the white rook to a1, checkmate! A problem in the general sense is a set of problems in the specific sense. To avoid confusion, the formal term problem refers to a problem in the general sense, and a specific problem is called an instance. This distinction can roughly
be compared to the terms “task” and “trial” in experimental psychology: a task is a general description of what a participant must do, a trial is a specific instance of a task.

- A problem exists when the goal that is sought is not directly attainable by the performance of a simple act available in the animal’s repertory; the solution calls for either a novel action or a new integration of available actions. (Thorndike, 1898, cited by Sheerer, 1963, p. 18)
- A problem occurs…if an organism follows a goal and does not know how to reach it. Whenever a given state cannot be converted into the desired state directly through the activation of obvious operations, thinking is needed to construct mediating actions. (Duncker, 1935, translated and cited by Frensch & Funke, 1995b, p.6)
- A question for which there is at the moment no answer is a problem. (Skinner, 1966, p.225)
- A person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it. (Newell & Simon, 1972, p. 72)
- A problem is a stimulus situation for which an organism does not have a ready response. (Davis, 1973, p. 13)
- Whenever there is a gap between where you are now and where you want to be, and you do not know how to find a way to cross that gap, you have a problem. (Hayes, 1980, p. i)
- A problem is a “stimulus situation for which an organism does not have a response,”…a problem arises “when the individual cannot immediately and effectively respond to the situation.” (Woods, Crow, Hoffman, & Wright, 1985, p. 1)
- A problem is an unknown. That is, if we have a goal and do not know how to reach that goal, there is an unknown, so we have a problem. …finding the unknown must have some social, cultural, or intellectual value to someone. If no one believes that it is worth finding the unknown, there is no perceived problem. (Jonassen, 2000, p. 65)

These definitions of a problem differ primarily on three dimensions. First, they differ in terms of their semantic content. That is, the focus is on either the absence of a task
relevant *response* or a task-relevant *thought*. Second, the definitions differ in how fuzzy their boundaries are. And finally, the definitions differ in terms of their category size, that is, how many tasks can be classified as problems. Nevertheless, most definitions do appear to share an important attribute, namely, the focus on the *gap* between the capabilities of the problem-solver and the requirements of the task at hand. In other words, a problem is said to exist only if there is a barrier between the state given in the current situation and the goal state in the head of the problem solver. So, problems are not task-specific. A problem is not defined by the features of the task. Rather, a problem exists or do not exist depending on the interaction between task requirements and the problem solver. A certain task may constitute a problem for one solver, but may not for another. On the contrary, task-focused definitions lead that a given task either constitutes or does not constitute a problem for all solvers.

What is, then, problem solving? Again, there is no agreed-upon definition for problem solving. Following are the most-commonly cited definitions:

- A hungry man faces a problem if he cannot emit a response previously reinforced with food; to solve it he must change either himself or the situation until a response occurs. The behavior which brings about the change is called problem solving and the response it promotes, a solution” (Skinner, 1953, p. 64)
- Problem solving may be viewed as a process by which the learner discovers a combination of previously learned rules which can be applied to achieve a solution for a novel situation. Problem solving is not simply a matter of applying previously learned rules, however. It is also a process that yields new learning. The learners are placed in a problem situation, or find themselves in one. They recall previously acquired rules in the attempt to find a “solution.” In carrying out such a thinking process, the learners may try a number of hypotheses and test their applicability. When
they find a particular combination of rules that fit the situation, they have not only “solved the problem” but have also learned something new. One newly learned entity is a “higher-order rule,” which enables individuals to solve other problems of a similar type. The other aspect of new learning may be ways of solving problems in general- in other words, cognitive strategies which can guide the learners’ own thinking behavior (Gagné, 1965, p. 155-156)

- The activity called human problem solving is basically a form of means-end analysis that aims at discovering a process description of the path that leads to a desired goal (Simon, 1969, p.23)
- Problem solving is defined as any goal-directed sequence of cognitive operations. (Anderson, 1980, p. 257)
- What you do, when you don’t know what to do. (Wheatley, 1984, p. 1)
- …problem solving is defined here as a goal-directed sequence of cognitive and affective operations as well as behavioral responses for the purpose of adapting to internal or external demands or challenges. (Heppner & Krauskopf, 1987, p. 375)
- A problem is an unknown. That is, if we have a goal and do not know how to reach that goal, there is an unknown, so we have a problem. …finding the unknown is the process of problem solving. (Jonassen, 2000, p. 65)

As in the case of problem solving, the existing definitions differ primarily on (i) semantic content; (ii) category size, and (iii) how fuzzy their boundaries are. Information processing view of problem solving suggests that problem solving requires the mental representation of the situation, known as the problem space (Newell & Simon, 1972). The process of solving a problem, then, requires some active manipulation of this problem space. The success of the problem solver is highly affected by how well the mental representation of the situation reflects the actual situation. In other words, how well the constructs and the relationships between the constructs of the problem space resemble or fail to resemble to those of the actual situation.
One of the difficulties associated with problem solving is that not all problems are created equal. There are problems which can be solved with a few mental steps and there are problems that require extensive thinking. There are problems that we have never encountered before and there are problems that we are familiar with. There are problems which have clear goals and there are problems which the goal is not that clear to us. Hence, problems can be distinguished on any number of different dimensions. For example, McCarthy (1956), Reitman (1964), and Minsky (1975) distinguish between ill-defined and well-defined problems. Rittel and Webber (1969) added “wicked problems” to this categorization. Mayer and Wittrock (1996) described problems as ill-defined–well-defined and routine–nonroutine. Jonassen (1997) distinguished between well-structured and ill-structured problems and articulated differences in cognitive processing engaged by each. Smith (1991b) distinguished external factors, including domain and complexity, from internal characteristics of the problem solver. Frensch and Funke (1995b) distinguished complex problems from simple problems. There are differences in categorization but there is also an increasing agreement that problems vary in their structure and complexity.

Problem Structure

According to their structure, problems can be defined on a continuum from well-structured to ill-structured problems. Well-structured problems are those that:

- have well-defined problem state (givens) and a goal-state;
- present to the solver all variables of the problem that are required for the solution;
require the application of a limited number of regular and well-structured rules and principles that are organized in predictive and prescriptive ways;

- have knowable, comprehensible solutions where the relationship between decision choices and all problem states is known or probabilistic (Wood, 1983).

Puzzle-problems, textbook math and science problems are typical examples of well-structured problems.

Ill-structured problems, on the other hand, appear ill-defined because one or more of the problem elements are unknown or not known with any degree of confidence (Reitman, 1965; Wood, 1983). They typically possess multiple representations and understandings of the problem. So, identifying an appropriate problem space from among the competing options is perhaps the most important part of ill-structured problem-solving (LeBlanc & Fogler, 1995). Ill-structured problems seldom have a single, best solution; they typically possess multiple solutions, solution paths, or no solution at all (Kitchner, 1983). That is, there is no consensual agreement on the appropriate solution, because opposing or contradictory evidence and opinions exit, and there is not a single, correct solution that can be determined by employing a specific decision-making process (Kitchner, 1983). In other words, ill-structured problems do not typically have a right or wrong solution; rather they typically have several possible solutions, each of which offers advantages and disadvantages to different people and situations in the context of their application. So, there typically are multiple criteria for evaluating solutions. This presents uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized, requires problem-solvers to express personal opinions or beliefs about the problem, and are therefore uniquely human interpersonal activities (Maecham
Ill-structured problems require problem-solvers to make judgments about the problem and to defend them. In other words, ill-structured problems are dialectic in nature, requiring the problem solver to reconcile conflicting conceptualizations of the problem (Churchman, 1971).

Ill-structured problems are said to be domain dependent or context dependent because they require the problem solver to think about the problems as realistic situations rather than to rely on information contained in problem description (Bransford, 1994). However, ill-structured problems have no prototypical cases because case elements are differently important in different contexts and because they interact (Spiro, 1987; Spiro, Coulson, Feltovich, & Anderson, 1988; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987).

A good example for ill-structured problems is design problems, in which the problem solver engages in a reflective conversation with the elements of the problem situation (Schön, 1990). Problems involving political decision-making are also good examples (Voss, Wolfe, Lawrence, & Engle, 1991). Ill-structured problems are typically situated in and emergent from a specific context (Jonassen, 1997). In situated problems, one or more aspects of the problem situation are not well specified, the problem descriptions are not clear or well defined, or the information needed to solve them is not contained in the problem statement (Chi & Glaser, 1985).

While ill-structured problem solving is believed to be a contextually-driven process, learners may also retrieve and apply abstract rules, as with well-structured problems. Recent research (Kosonen & Winne, 1995) has shown that students who are explicitly taught abstract rules about statistics applied those rules across three different
kinds of problems, despite common wisdom that abstract principles do not transfer well, especially in ill-defined problems.

Monitoring ill-structured problem-solving performance is a complex process where learners reflect not only on what they know and have been taught but also on what it means. Yet, they must go beyond what they know to consider what others believe and do develop arguments to support their mental model of the problem space. In ill-structured problem solving, this model is emergent and dynamic, unlike restricted problem schemas that define well-defined problems.

**Problem Complexity**

The level of complexity of a problem is defined by the number of variables affecting the problem state; the degree of connectivity among the variables; the type of functional relationship (linear vs. nonlinear); and the stability properties of the problem over time (i.e., time dependencies in the course of the problem-solving process) (Funke, 1991).

Problem difficulty is a function of problem complexity. For example, problem difficulty has been found to be a function of relational complexity (English, 1998). The idea of problem complexity seems to be intuitively recognizable by even untrained learners (Suedfeld, de Vries, Bluck, & Wallbaum, 1996). Problem complexity necessarily affects learners’ abilities to solve problems. For example, problem complexity has significant effects on search problems (Halgren & Cooke, 1993).

Why do we assume that complex problems are more difficult to solve than simple problems? The primary reason is that complex problems require more cognitive operations than simpler problems (Kluwe, 1995). Therefore, working memory requirements increase at least proportionally. Accommodating a large number of factors
during problem structuring and solution generation places a heavy burden on working memory. However, the serial character of the human-information processing system and its limited short-term memory impose severe constraints (Atwood, Masson, & Polson, 1980; Simon, 1978). The more complex a problem, the more difficult it will be for the problem solver to actively process the components of the problems.

In problem solving literature, there are cases where problem complexity and problem structure overlap. For instance, in European tradition of complex problem solving, complex problems are defined as those that are also intransparant (not all variables affecting the problem are given or directly observable) and have multiple goals (Funke, 1991) in addition to having a large number of interconnected variables. In this definition, complex problems are those that are also ill-structured. Ill-structured problems tend to be more complex, especially those emerging from everyday practice. On the other hand, most well-structured problems such as textbook math and science problems, are simple because they tend to engage a constrained set of variables that behave in a predictable ways. However, a problem could also be simple but ill-structured (e.g., deciding on what to wear for different occasions); or complex but well-structured (e.g., some video games) (Jonassen, 1997).

**Section Summary**

This section acknowledged and summarized various definitions for “problem” and “problem solving.” In both cases, existing definitions of problem and problem solving show differences in terms of their semantic content, category size, and how fuzzy their boundaries are. On the other hand, most definitions of problem emphasize a gap between the capabilities of the problem solver and the requirements of the task at hand. Therefore,
a certain task may constitute a problem for one solver, but may not for another. In other words, problems are not task-specific. Rather, a problem exits or does not exist depending on the interaction between the task requirements and the problem solver.

This section also acknowledged that problems can be distinguished on a number of different dimensions. While there is no universal agreement on what these dimensions are, there is increasing agreement that problems vary in their structure and complexity. Accordingly, problems can be defined on a continuum from well-structured to ill-structured problems as well as on a continuum from simple to complex problems (Figure 4). However, a problem could be simple but ill-structured or complex but well-structured.

For the purposes of this chapter, it is important first to distinguish between different definitions for problem and problem solving. Because, as will be discussed in the next section, researchers subscribing to different traditions of problem solving research have traditionally focused only on those tasks that fit within their definition of

![Figure 4. Problem categorization](image-url)
problem and that, in turn, impacted how researchers, subscribing to that particular tradition went about research on problem solving.

RESEARCH on PROBLEM SOLVING

Existing literature on problem solving research could be examined under eight branches or traditions: (1) behaviorist and associationist tradition; (2) gestalt tradition; (3) information processing view of human problem solving; (4) expert-novice comparison studies in natural knowledge domains; (5) simulation-based studies of complex problem solving (CPS); (6) research on everyday problem solving; (7) dynamic decision making (DDM); (8) naturalistic decision making (NDM).

Behavioral and Associationist Tradition

Behavioral and associationist psychologists (for example, Maltzman, 1955) viewed problem solving as a relationship between a stimulus (input) and a response (output) without speculating about the intervening process. In these studies, a problem was defined as situations where the response required to achieve some goal is less strong than other responses, or where several responses are required and it is unlikely that they all will be performed. In other words, behavioral analysis emphasized the requirement for problem solvers to perform a variety of responses and to raise the probabilities of unusual responses, since (by definition) successful problem solving depends on giving responses that are relatively improbable. Although behavioral and associationistic studies identified conditions that impede or facilitate problem solving, and it was useful to emphasize the importance of flexibility in successful problem solving, these studies rarely provided
enough substantive analysis of the components of any problem-solving performance to permit theoretical development beyond the most general level of abstract concepts (Greeno, 1978).

**Gestalt Tradition**

The experimental study of problem solving can be traced back to the studies conducted by Gestalt psychologists Duncker (1926; 1945), Katona (1940), Köhler, (1927; 1929), Luchins (1942), Maier (1930; 1931), and Wertheimer (1938; 1945; 1959). Gestalt psychologists were mainly interested in further analysis of factors that influenced perception in problem solving. Three major factors identified by Gestalt psychologists were (i) functional fixedness, (ii) Einstellung (i.e., problem set), and (iii) use of the guided discovery method for transfer for problem-solving skill training.

**Functional fixedness.** Gestalt psychologists have concentrated on multi-step tasks in which only a few of the steps to be taken were crucial and difficult. Such problems are called insight problems because the solution follows rapidly once the crucial steps have been taken. An example of such a problem is construction of a wall-mounted candleholder from an odd assortment of materials, including a candle and a box of tacks (Figure 5). The materials are chosen in such a way that the only solution involves using the box as a support for the candle by tacking it to the wall. To find this solution, subjects must change their belief about the box and view it as a construction material. This belief change is the crucial, insightful step. Once it is made, the solution is soon reached. When Duncker (1926) tried this experiment, fifty-seven percent failed. His analysis of subjects’ protocols indicated that the first step taken by successful problem solvers is that of a “comprehended conflict” (p.657). The next step, sometimes taken
after some false steps, and perhaps after hints from the experimenter, is a clear identification of the basic difficulty. The final step is that of a problem solution that addresses the basic difficulty. Such solutions, in his view, are examples of productive thinking and they are therefore refereed as “solutions with functional value” (p.88).

Another problem Duncker (1945) studied, referred to as the X-ray problem, is a situation in which a man cannot be cured of a tumor because the required concentrations of X-rays will kill healthy tissue around the tumor. The key to solving the problem is to note that the rays are too “thick,” i.e., too concentrated (felt difficulty). The solution is to provide “thin” rays from various angles that converge on the tumor. Duncker (1926) argued that a key factor in a successful solution is identifying the basic difficulty. In other words, productive thinking is distinguished by an inventory of the problem situation, and the recognition of a definite lack (Aufgabe) that is supplied by the thinking process (Duncker, 1926, p. 702). According to Duncker (1945), students who are unable to

Figure 5. An illustration of the candle problem used by Duncker (1945). (Copyright 1966 by the American Psychological Association. Adapted with permission.)
perceive the elements of the situation in a new way suffer from “functional fixedness” (p.85).

A similar problem that has been often utilized in the study of functional fixedness is the two-string problem (Maier, 1931). In the two-string problem (Figure 6), the subject is required to tie two hanging strings together although one cannot be reached while the other one is held. Insight comes when the subject realizes that an object (pliers) can be attached to one string and then that string can be swung like a pendulum. This enables the subject to grasp both strings and tie them together.

**Einstellung.** Another perceptual difficulty in problem solving identified by Gestalt psychologists was Einstellung, which can roughly be translated as problem set (Luchins, 1942). Briefly, problem set refers to rigidity in problem solving because the individual perceives that a series of problems are to be solved in the same way.

*Figure 6. An illustration of the two-string problem used by Maier (1931). (Copyright 1995 W. H. Freeman and Company. Reprinted with permission.)*
Luchins (1942) devised the well-known water-jar problems to investigate the effects of problem set. Subjects were given three jars of different capacities and then asked to measure a particular amount of water. The solution to each problem requires pouring certain amounts of water from one jar to another.

In the experiment, problems 2 through 6 are the set-inducing or “E” problems. Problems 7 through 11 are the test problems because they can be solved by the simple A – C method. However, for problems 7, 8, 9, and 11, the more cumbersome strategy used in problems 1 through 6 will also yield a correct solution. Problem 9 is refereed to as the extinction problem because the strategy B – A – 2C will not produce twenty-five units. The subject who fails problem 9 is regarded as demonstrating rigid behavior because he or she solely adheres to a repeated strategy although it is completely inadequate (Luchins & Luchins, 1959, p. 111).

Luchins demonstrated that, in the series of problems, the strategy used for problems 1 through 6 was applied also by the subjects to problems 7 through 11. Of 1,039 subjects, eighty-three percent used the B – A – 2C in problem 7 and 8, and sixty-four percent failed problem 9 (Luchins & Luchins, 1959, p. 110).

In contrast, of 970 subjects who received only problems 7 through 11, less than one percent used B – A – 2C in 7 and 8, and only five percent failed problem 9. This phenomenon was named “Einstellung” (Luchins & Luchins, 1959, p.3) to denote a certain kind of set that immediately predisposes one to a particular type of motor or conscious act.
In one variation of the basic experiment, the solutions of elementary school children to the first six problems were collected prior to the distribution of problems 7 through 11. The children also were told not to use the same method on these problems.

Although the children heeded the warning, most of them failed problems 7 and 8 and others again used the earlier strategy on problems 10 and 11. Some of the children explained that the old method “kept popping up in their minds and they could not help using it” (Luchins & Luchins, 1959, p. 134).

Efforts to answer the question, “what is learned during the problem-solving activity?” revealed a variety of answers. Some subjects learned to generalize a rule, others learned to begin with the middle jar, and others learned to begin with the largest jar. Thus, problem rigidity appears to be not one factor, but many.

**Guided discovery & transfer of problem-solving skills.** Katona (1940) investigated the effects of different ways of demonstrating problem solutions on problem-solving skills. He conducted a series of experiments on matchstick problems in which the task was to change the number of squares formed by the matchstick by moving a minimal number of matches. A typical example is to move three matchsticks to make five squares, illustrated in Figure 7.

One experiment involved teaching two groups of students different approaches to the problem. In one group, the instructor illustrated the solutions to four variations of the same task that were all solved in the same way. In contrast, the method used with the few matches. For example, removing only three matchsticks created a hole in the center of the configuration. This method provided hints to solving other problems by illustrating that major changes could be made by moving only a few matchsticks. That is, the important
structural principle in these problems is that a matchstick may serve as a side in two squares simultaneously. Results comparing the two groups of subjects indicated that the quantity and quality of the solutions to the new problems were greater in the guided discovery group.

The effect of guided discovery in facilitating transfer of problem solving skills has been recently replicated with the nine-dot problem first used by Maier (1930). This problem requires that nine dots arranged in a square be connected by four straight lines, without lifting the pen from the paper and without retracing any lines (Figure 8). This task is very simple in the formal sense that there are only a few possible solutions to try, but it is ridiculously difficult in the psychological sense that the solution rate among college undergraduates who are given a few minutes to think about it is less than five percent (Lung & Dominowski, 1985; MacGregor, Ormerod, & Chronicle, 2001). The
Figure 8. An illustration of the nine-dot problem (left) used by Maier (1930) and its solution (right).

Gestalt psychologists introduced insight problems into cognitive psychology and explained their difficulty in terms of Gestalts, i.e., schemas that are argued to organize perceptual information (Ohlsson, 1984). Consequently, Gestalt psychologists hypothesized that the nine-dot problem is difficult because people are so dominated by the perception of a square that they do not 'see' the possibility of extending lines outside the square formed by the dots (Scheerer, 1963). This hypothesis predicts that telling participants that they can draw lines outside the figure should facilitate the solution.

Burnham and Davis (1969) and Weisberg and Alba (1981) tested this hypothesis, and found that the instruction only worked if combined with other hints that gave away part of the solution, e.g., telling the participants at which point to start or giving them the first line of the solution. A second prediction from the Gestalt hypothesis is that altering the shape of the problem and thus breaking up the square should also help. Both Burnham and Davis (1969) and Weisberg and Alba (1981) found facilitating effects of this
manipulation. A third prediction from the Gestalt hypothesis is that giving people experience in extending lines outside the figure should help. Weisberg and Alba (1981) and Lung and Dominowski (1985) indeed found facilitating effects of such training.

In these early studies, problem solving was conceptualized as a process of cognitive organization (see Duncan, 1959 for a review). Problems were analyzed as situations for which cognitive representations have gaps or inconsistencies, and problem solving finds a way to organize the situation to provide a good structure, including satisfactory achievement of the problem goal. While these studies conducted by Gestalt psychologists provided numerous interesting examples of thinking process that were analyzed insightfully, few general principles emerged that could lead to the development of a solid body of theory of problem solving (Ohlsson, 1984).

**Information Processing View of Human Problem Solving**

Theoretical basis to our current understanding of human problem solving largely came from information-processing theorists. Their approach to problem solving was based on the information processing that accompanied the development of computer programs. As opposed to behaviorist approach, here the emphasis was more on the processes that intervened between input and output, and led to a desired goal from an initial state. In other words, proponents of information processing sought to establish the pattern or form of solution as the problem solver is ‘thinking aloud’ (Ericsson & Simon, 1984; 1993) while he or she proceeds to achieve a desired goal. Therefore, the main focus was to uncover or to codify, if possible, the transformation rules that connect input and output, i.e., system identification.
Selection of problem tasks was also different from the earlier research on problem solving. Information-processing researchers were concerned with multi-step, puzzle-like tasks in which no single step is the key. In these tasks, finding a solution depended on making a number of correct steps. An example of such a task is the Missionaries and Cannibals problem (Greeno, 1974; Jeffries, Polson, Razran, & Atwood, 1977), in which solver tries to transport five missionaries and five cannibals across a river with a boat that can only hold three people (Figure 9). The solution is a sequence of proper moves, correctly applied. The difficulty in the problem lies in deciding which moves to apply, remembering them accurately, and applying them correctly. Thus, the responsibility for the solution is spread over the whole solution process rather than falling on the discovery of one or two key steps. Cryptarithmetic (Barlet, 1958) (Figure 10), Tower of Hanoi problem (Simon & Hayes, 1976; Simon & Kotovsky, 1963) (Figure 11), and logic

Figure 9. An illustration of missionaries-cannibals problem. (Copyright 1975 by the Pearson Education, Inc. Reprinted with permission.)
In DONALD + GERALD = ROBERT,
each letter represents a distinct digit (0,1,…, 9) & D=5.

What digits should be assigned to the letters so that when the letters are replaced by their corresponding digits, the sum above is satisfied?

Figure 10. A cryptarithmetic problem used by Barlet (1958).

problems (Newell & Simon, 1972) were also among those that were highly studied in these tradition. This choice of tasks caused research to focus on how people organize the solution process, how they decide what steps to make and in what circumstances, and how their knowledge of the task domain determines their view of the problem, and their discovery of its solution.

Figure 11. Tower of Hanoi problem used by Simon & Kotovsky (1963).
The culmination of work in this tradition resulted with the theory of human problem solving proposed by Newell & Simon (1972). The core elements of this theory provide the conceptual structure that underlines much of the work on information-processing models of cognition (Bower, 1975). Two assumptions underline this theory. The first is that the human problem solver can be characterized as an information-processing system. The second is that problem solving can be characterized as both a search process and a process of understanding.

**Human problem solver as an information-processing system.** Newell & Simon (1972) describe the human information-processing system, apart from its perceptual mechanisms, as a serial system whose elementary processes are executed in tens to hundreds of milliseconds. The inputs and outputs of these elementary processes are held in a short-term working memory with a capacity of four to seven chunks, or symbols. The system incorporates in long-term memory an almost unlimited amount of information, with an access time of tens of milliseconds to several seconds. It takes several seconds to write a new chunk into long-term memory. This memory system contains declarative information (factual knowledge) and procedural knowledge (knowledge of how to do things). The declarative information is represented as a network of concepts with labeled links describing the relationships between them. The procedural information is represented as sets of condition-action pairs, which specify the actions one can take and the conditions under which they are appropriate.

**Problem solving as search & understanding processes.** In Newell and Simon’s (1972) theory, problem solving is characterized as an interaction between the problem solver and the task environment, i.e., the experimenter’s representation of the
task presented to the subject. As depicted in Figure 12, there are two sets of processes involved in this interaction. The first is a collection of understanding processes that generate a problem space. Newell & Simon (1972) wrote: “Even more difficult than describing the stimulus is finding a neutral and objective way of talking about responses of the subject, including his internal thinking responses, as he goes about dealing with the stimulus situation…We shall find it necessary to describe not only his actual behaviors, but the set of possible behaviors from which these are drawn; and not only his overt behaviors, but also the behaviors he considers in his thinking that don’t correspond to possible overt behaviors. In sum, we need to describe the space in which his problem solving activities take place. We will call it the problem space.” (Newell & Simon, 1972, p.59). In other words, a problem space was defined as the solver’s representation of the task, including his or her understanding of the givens, the goal, the underlying structure of possible solutions, and any problem solving strategies that can be used to solve this task. Each node in a problem space represents a possible state of knowledge on the part of the solver.

The second set of processes involved in the interaction between the problem solver and the task environment is the search processes, which can be characterized as transitions between knowledge states in the problem space. Newell & Simon (1972) assert that search mechanisms are a central component of general problem-solving skills, and that instruction in the use of these search mechanisms would be effective technique for enhancing general problem-solving skills. Newell (1980) calls these general search
Construct a representation of the problem (Problem Space) → Search for a problem solution in the problem space → Implement the solution

Stop: Problem is solved!

Fail

Succeed

strategies “weak methods,” because they trade power for generality. Two of these methods are Generate and Test and Means-Ends Analysis.

Generate and Test is the least structured of the weak methods and can vary in its sophistication depending on the capabilities of the generator. Possible solutions are generated one at a time by a process that proposes candidate solutions. Each solution is then evaluated to see if it is acceptable. Unacceptable solutions are rejected, and the generation process continues. The power of the generate-and-test method is completely dependent on the sophistication of the generator. At one end of the continuum, a generator can simply produce solutions in a trial-and-error fashion (Restle, 1970). At the other end, the generator may be a complex process that enumerates all possible solutions in the order of their likelihood of being successful in the particular task.

Means-Ends Analysis is a problem solving method that guides search by having the solver isolate certain goals to be achieved (ends) and then select the best methods to achieve the specified goals (means). In the classical version of means-ends analysis, as used by a program called the General Problem Solver (GPS) (Ernst & Newell, 1969), the

Figure 12. A simplified schematic diagram of the problem solving process according to Newell & Simon (1972).
problem solver compares his or her current state with the goal state and generates a list
describing the differences between the two states. These differences are then rank ordered
by their importance. The most important difference is selected, and the solver retrieves an
operator that will reduce this difference, while at the same time producing minimal side
effects. If possible, the operator is applied. If the operator cannot be applied in this
situation, a goal of applying this operator is created, and the means-ends process is
applied to the new goal. Means-ends analysis is a powerful and general strategy that has
been used in a variety of artificial intelligence programs and has been shown to be used
by human problem solvers. So much so that Simon (1969) described human problem
solving as, “…a form of means-end analysis that aims at discovering a process
description of the path that leads to the desired goal” (p. 69). Simon (1980) argues that
these search strategies are true general problem-solving mechanisms, that they can be
taught, and that extensive instruction in them, especially means-ends analysis, should be
the core of any instructional program that attempts to teach general problem-solving
skills.

**Expert-Novice Comparison Studies in Natural Knowledge Domains**

The information-processing view of human problem solving contained three implicit
assumptions: (a) the theoretical goal was to understand the cognitive processes of a
person solving a problem; (b) cognitive processes were guided by internal goals; and (c)
perhaps the most importantly, the cognitive processes were essentially the same for all
kinds of problems. Therefore, initially, information-processing theorists mainly focused
on puzzle-like problems, that were easily brought into the psychological laboratory and
that were within the range of computer programming capabilities at that time. Classic
examples include the Tower of Hanoi problem (Simon & Hayes, 1976; Simon & Kotovsky, 1963) and the Missionaries and Cannibals problem (Greeno, 1974; Jeffries, Polson, Razran, & Atwood, 1977). The underlying assumption was that simple tasks, such as the Tower of Hanoi, captured the main properties of a real problem, and that the cognitive processes underlying the subject’s solution attempts on simple problems were representative of the processes involved in solving “real” problems. Thus, simple problems were used for reasons of convenience, and generalizations to more complex problems were thought possible.

Research conducted by de Groot (1965) on expert chess players and Reitman (1964) on music composition posed early challenges to the theory of human problem solving as proposed by Newell and Simon (1972). While de Groot’s (1965) study on expert chess players emphasized the importance of domain-specific knowledge, which was not accounted for in Newell & Simon’s theory of human problem solving, Reitman’s (1964) study on music composition initiated a concern that their theory does not account for how humans solve ill-structured problems. As a result, information-processing psychologists were criticized for focusing on such well-structured, puzzle-like problems and for not developing a coherent body of theory that explain performance in broad classes of problems (Greeno, 1978). Consequently, during the 1980’s research in North America shifted from the study of well-structured, artificial puzzle-like problems to the study of: (a) more semantically rich (but still well-structured) textbook problems, which led to the recognition of the importance of domain-specific knowledge in human problem solving, and (b) ill-structured problem solving, which challenged the basics of information-processing view of human problem solving.
Importance of domain-specific knowledge in human problem solving.

The main impact of de Groot’s (1965) research on expert chess players, which was later extended by Chase and Simon (1973a), was to shift thinking about problem solving from a point of view emphasizing general information processing (Miller, Galanter, & Pribram, 1960; Newell, Shaw, & Simon, 1958) to one emphasizing the preeminence of knowledge. Subsequently, research in problem solving has seen a shift in from the study of well-structured, artificial puzzle-like problems to the study of more semantically rich textbook problems in physics (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Larkin, 1983; Larkin, McDermott, Simon, & Simon, 1980; McCloskey, 1983), geometry (Anderson, Greeno, Kline, & Neves, 1981; Greeno, 1980), and arithmetic (Ashcraft, 1982; Brown & Burton, 1978; Groen & Parkman, 1972; Resnick, 1982; Siegler & Shrager, 1984). These studies showed the importance of domain-specific knowledge in human problem solving and led to a change in the conceptualization of the problem solving process. As discussed in the previous section, the early theory of human problem solving (Newell & Simon, 1972) maintained that humans understand a problem by extracting the given and the goal information. These later studies on domain-specific problems concluded that during the construction of a problem representation, certain features of the problem may activate relevant knowledge in memory (e.g., the presence of certain key words and phrases in an algebra word problem (Hinsley, Hayes, & Simon, 1977; Kintsch & Greeno, 1985). In those cases, a schema (Rumelhart, 1975; Rumelhart & McClelland, 1986b) for that particular type of problem may be activated while constructing a representation of the problem. A schema serves as a vehicle of memory,
allowing organization of an individual’s similar experiences in such a way that the individual can (Marshall, 1995, p. 39):

- easily recognize additional experiences that are also similar, discriminating between these and ones that are dissimilar;
- access a generic framework that contains the essential elements of all of these similar experiences, including verbal and nonverbal components;
- draw inferences, make estimates, create goals, and develop plans using the framework; and
- utilize skills, procedures, or rules as needed when faced with a problem for which this particular framework is relevant.

In other words, schema is a cluster of knowledge related to a problem type. It contains information about the typical problem goal, constraints, and solution procedures useful for that type of problem (Gick & Holyoak, 1983). Gick (1986) synthesized these problem-solving strategies with the earlier work on human problem solving (Greeno, 1977; Newell & Simon, 1972) as represented in Figure 13.

As seen in Figure 13, if schema activation should occur during the construction of a problem representation, then the solver can proceed directly to the third stage of a problem solving, (i.e., the implementation of solution strategies and procedures contained in the schema). For example, in the case solving a geometry problem to prove two triangles are congruent, the activated schema might contain the side-angle-side postulate
Figure 13. An illustration of a simplified schematic diagram of the problem-solving process by Gick (1986) (Copyright 1986 by the American Psychological Association. Reprinted with permission.)

(Anderson, Greeno, Kline, & Neves, 1981). When schema activation occurs during this phase of problem solving, the problem solving process is schema-driven, with little search for solution procedures. Little search is needed because appropriate solution procedures are activated by recognizing the particular problem type. In the absence of appropriate schema activation, the problem solver proceeds to the second step and a search strategy is invoked. The rest of the process is similar to the one described in Figure 12 parallel to the theory of human problem solving proposed by Newell & Simon (1972).

Furthermore, Chi, Feltovich, and Glaser (1981) have shown that whereas novices’ schemata for physics problems are based on superficial similarity, experts’ schemata are based on solution principles. For example, novices sort problems together if they contain an inclined plane, even when instructions emphasize sorting on the basis of solution procedures. In contrast, experts group problems together that require the same principles (e.g., conservation of energy), even if the problems contain different physical features, such as an inclined plane versus a pulley. Chi et al. (1981) concluded that the schemata of novice physics problem solvers are based on object categories, such as ‘falling bodies.’
Experts, on the other hand, possess schemata organized around the law of physics. The experts’ schemata also contain much procedural knowledge about solutions and their applicability. Compared to experts, novices’ schemata for physics problems contain less information about effective solution procedures.

Efficient categorization by experts on the basis of solution procedures has been observed in other problem domains as well. For example, Chase and Simon (1973a) determined that the long-term memories of chess experts contain many patterns associated with effective chess actions and strategies. Hinsley et al. (1977) demonstrated that college students who are familiar with algebra word problems classified them quickly into categories based in different solution procedures (e.g., distance, rate, and time, or the calculation of different legs of a triangle). Adelson (1981; 1984) found that expert computer programmers had abstract, conceptually based representation of programs. In contrast, novices’ representations were syntactically organized (e.g., based on common control words).

Differences in the schemata of experts and novices affect the strategies they use in problem solving. Larkin, McDemott, Simon, & Simon (1980) and Simon & Simon (1978) found that experts use a strategy described as working forward, whereas novices employ a working backwards strategy. In the working forward strategy, experts work forward from the given information to the problem goal by choosing equations containing the given and calculating unknowns until the solution to the goal of the problem is found. In addition, experts often do not mention the particular equation being used, but instead report the result of the equation (Simon & Simon, 1978). Experts also describe the actual physical situations verbally. Novices, on the other hand, describe the problem only in
terms of equations. They choose an equation that contains the goal and set subgoals of finding further unknowns in that equation. This subgoal then results in the generation of further equations to solve for new unknowns.

strategies required by each domain (Sternberg, 1985). Second, these studies suggested that experts possess schemata relevant to problems in their domain of expertise (Voss & Post, 1988).

Secondly, these studies acknowledged the differences in the underlying cognitive processes between ill-structured and well-structured problem solving (Reitman, 1964; Voss & Post, 1988). In particular, studies conducted in design problem solving contributed to the study of ill-structured problem solving in rigorous terms. As a result of his study on music composition, Reitman (1964) argued that there is a lack of information in each of the three components of design problems. The start state is incompletely specified, the goal state is specified to an even lesser extent, and the transformation function from the start to goal states is completely unspecified. In other words, many degrees of freedom exist in a design problem statement, which impedes the creation of a problem space. Therefore, Reitman (1964) concluded that ill-structured problem solving does not fit well with information-processing theory of problem solving. As a result of intensive studies on design problem solving, Gedenryd (1998) agrees with Reitman and maintains that design problem solving does not fit well into information-processing theory of problem solving as described by Newell and Simon (1972) because in a design problem solving, the problem is not a given: “…in reality, producing the problem is a work that the designer must do. And it is not a minor issue; it is on the contrary the most difficult part of the work.” (p. 70). This issue is illustrated in a study conducted by Parnas and Clements (1986) on software design process. One of the subjects noted out this point (Parnas & Clements, 1986, p. 253, italics added):
Who writes the requirements document? Ideally, the requirements document would be written by the users or their representatives. In fact, users are rarely equipped to write such a document. Instead software developers must produce a draft document and get it reviewed and, eventually, approved by the user representatives…. Determining the detailed requirements may well be the most difficult part of the software design process because there are usually no well-organized sources of information.

Therefore, in design problem solving, the first step is not the creation of a problem space as identified in the information-processing theory of problem solving (Newell & Simon, 1972) but it is “problem structuring” (Newell & Simon, 1972, p.59), which is the process of finding the missing information and using it to construct the problem space. As opposed to well-structured problem-solving, design problem solving requires extensive problem structuring. Schön (1983) acknowledges this when he says, “as a design problem does not present itself in a well-defined structure, a designer has to impose such a structure on it before it can be effectively solved” (p.74). In his view design involves problem solving, and most importantly, problem setting: “the designer must make sense of an uncertain situation that initially makes no sense.” (Schön, 1983, p. 74). This leads to other important characteristics of design problem solving that separates it from well-structured problem solving: the specification of constraints. There are multiple sources for constraints. Constraints may originate strictly from the requirements specification and are laid down before the designer begins his or her work. An example of this situation is the legally imposed restrictions, such as building regulations, as evident in the protocol of one of the subjects in Lawson’s (1980) study:
Design legislation today may cover anything from the safety of electric goods to the honesty of advertising or the energy consumption of buildings…. The architecture today must satisfy the fire officer, the building inspector, and the town planner and in addition, depending on the nature of the particular project, the housing corporation, health inspectors, Home Office inspectors, the water authority, the Post Office, factory inspectors, and so the list goes on. (p.67-68)

On the other hand, in the design literature, there are abundant of examples of ways in which constraints are not the fixed restrictions given in advance as standard accounts portray them. For example, the customary incompleteness of requirements specifications means that constraints typically are not given. Guindon (1990b) provides a number of examples out of her protocols where the designer adds requirements that are not given in the instructions. She argues that the incomplete nature of specifications makes requirements elaboration an important task, because constraints that the designer adds herself are often essential to a good solution:

By simulating a Lift scenario, the designer realizes that a user may press a floor button to go in one direction, but once inside the lift, may press a lift button to go in another direction. This test case was not mentioned in the problem statement, yet it is critical for the design of a good control algorithm. (p.288)

Interestingly, in design problems, adding constraints to the problem does not always mean making the problem more difficult. Due to the fact that specifications encountered in practice typically are incomplete, adding constraints is crucial to yielding requirements that capture the desired functionality: “The ill-structuredness of problems in the early stages of design will require structuring- inferences of new goals and evaluation criteria”
(Guindon, 1990b, p. 297). Even more surprisingly, design researchers found that designers frequently impose constraints that are neither necessary nor objectively valid. They often apply them for practical (but still very good) reasons, and not from a strict necessity that is inherent in the problem. In one case, one of Guindon’s (1990b) subjects says:

You would rather not have a single point of failure because if it goes down all the elevators go down. So, I'll start off thinking about a distributed control system… (p.289)

Guindon (1990b) comments:

The designer recognizes from past knowledge with similar systems that ‘no single point of failure’ would be a highly desirable requirement. However, other designers might have considered low cost or high speed to be more desirable than no single point of failure. (p.289)

In this case, the designer’s professional experience suggests a distributed control solution, and as becomes evident later on, he also already knows how to implement it. Being able to apply a technique he is familiar with is probably a major reason for him to impose this particular constraint. This helps him to draw upon personal knowledge to structure his design problem, rather than as a constraint that will only make his task more complicated. Still having a distributed control system could just as well have been a requirement from a client. This example also shows that constraints often may be seen as belonging to the solution, as much as being part of the problem; once again, being helpful rather than problematic, quite contrary to the traditional view. Accordingly, constraints
do not necessarily make the designer’s job harder. Guindon (1990b) sees them as being mainly helpful:

… inferred and added requirements mainly serve two purposes: (1) they lessen the incompleteness and ambiguity inherent in the specification of the requirements and (2) they decrease the range of possible design solutions by acting as simplifying assumptions. In particular, these inferences contribute to problem structuring. Moreover, they effectively guide the search of a solution by pruning a large set of possibilities.

(p.290)

While legislated constraints are completely rigid and designer-imposed constraints are completely flexible, constraints that are imposed by clients and users represent a middle ground, being somewhat flexible. A client is guaranteed to have a number of wishes and demands on the product he or she is paying for. Still, if the designer finds that a requirement or a combination of them necessarily leads to a bad solution, she has the option of negotiating the requirement with the client. This is also an important part in problem restructuring.

A third difference between well-structured and ill-structured problem solving is that in ill-structured problems, the problem and its solution are intimately connected and they develop in parallel. This is evident especially in design problem solving, where problem structuring is an important aspect of solving the problem. This aspect of ill-structured problem-solving is well-illustrated in a study conducted by Nardi and colleagues (Nardi & Miller, 1991; Nardi & Zarmer, 1993) on developing computer spreadsheet models. The first example Nardi and Zarmer (1993) provided was of an accountant who learned to develop such models himself, instead of having the company’s
programmers do it for him, as had been originally intended. The main reason why he did so lies in the close coupling between problem setting and problem solving. He found it impossible to describe to a programmer just what it was that he wanted. Instead, when he built the models himself, he could use the spreadsheets to develop his own understanding of what he wanted by working on the problem. That is, he wasn’t able to formulate a problem statement without working on a solution to it. The following interaction demonstrates the iterative nature of the problem solving process (Nardi & Zarmer, 1993, p. 13):

Jeremy: We had to have rather large complex spreadsheets [for the business plans] where you had lots of variables. And I found it is easier to develop that myself than to go to somebody and say here’s what I want, here’s what I want, here’s what I want. And that’s what really got me going on [spreadsheets]…

Interviewer: Why was it easier for you to do this yourself than to specify it for a programmer?

Jeremy: I think it was easier because I felt that I was learning as I went, as I was developing the spreadsheets, I was learning about all the variables that I needed to think about. It was [as] much a prop for myself as [a way of]…Getting the outcome…And there were a lot of false endings, I should say, not false starts. I’d get to the end and think, “I’m done,” and I’d look at it and I’d say, “No, I’m not, because I’ve forgotten one thing or the other.”

This above episode illustrates several aspects of ill-structured problem solving. First of all, the accountant states that he did not have a clear picture of what the problem was, even to himself, and much less one that he could give to the programmer. It seems paradoxical, but in the beginning he appeared to have a clearer picture of the solution he
wanted than of the problem. This goes counter to the information-processing theory of problem solving, but it makes sense in the way that he describes it. He couldn’t make use of a programmer because he could not separate the phases for problem setting from a problem solution.

Instead he needed to develop a solution to understand what he wanted and spreadsheets enabled him to do this. That was why he liked them. And when he describes his work on the spreadsheets as a “prop” (Nardi & Zarmer, 1993, p.13) for himself, he is referring directly to the second, inquiring function of this work, in that it also serves as a prop for his own thinking (about the problem), i.e. the inquiry, “as much as a way of getting outcome” (Nardi & Zarmer, 1993, p.13). This last phrase is also a clear reference to the first, ordinary purpose of his work, that of producing the spreadsheet model itself.

Lastly, he describes the dialectical structure of this work, which seamlessly shifts back and forth between problem and solution. It is clear that understanding the problem helps in solving it, but here the reverse is also obvious: a solution is not the end of the process, but only a false ending, as new solutions repeatedly serve to make him understand new aspects of the problem. Thus, problem and solution both develop in parallel, each as a prop for the other.

In the study we found that spreadsheet users are very aware of the fact that initial problem formulations are likely to be fuzzy, incomplete and badly structured. They like spreadsheet software because it helps them to work through these difficulties. (Nardi & Zarmer, 1993, p. 13):
Similarly, in a study of architects Eastman (1970) showed how designers explored the problem through a series of attempts to solutions and found no meaningful division between analysis and synthesis, but rather a simultaneous learning about the nature of the problem and the range of possible solutions. The designers discovered much more about the problem as they critically evaluated their own solutions. This is a well-known phenomenon in design work.

In the second example, another accountant describes how she creates spreadsheets for an executive in her firm and how the spreadsheets worked as props for her boss. Her story seems to be taken right out of a “Dilbert” cartoon:

Oh, this [spreadsheet] is what I gave to the CFO at first just comparing Q2 [Quarter 2] year-to-date budget to Q2 year-to-date actuals. And he said, “Well, for the board meeting I want [some other things].” Every time you do this he wants it differently. So I can’t anticipate it. I just give him what I think [he wants] and then he says, “Ah, no, well, I want to have projected Q3 and projected Q4, and then total projected, and then the whole year’s plan on there.” (Nardi & Zarmer, 1993, p.14).

By merely seeing the model, the chief financial officer can better describe what he wants. Again, the early versions mainly serve to inquire into what he wants; hard work on these is probably wasted (“Every time you do this he wants it differently.”). They should merely set in motion the process which will ensure the final quality. Progress is incremental, with new problems and solutions alternating as the successive frames in a comic strip, the untiring accountant walking to the chief’s office and back again. It is also evident that the task of problem setting spans the whole process, the CFO not knowing
what he wants till it is on his desk. This example also demonstrates what the accountant in the previous example gained, by doing both parts of the work himself.

In summary, information-processing view of human problem solving does not work for ill-structured problem solving because the duty that has been assigned to the analysis phase cannot be performed by analysis alone, as exemplified by above examples from design problem solving: it needs to be performed together with the other activities of the design process: understanding the problem, working on solutions, and evaluating the solutions. Rittel (1984) refers to this point about ill-structured problem solving when he provided the following response to the question of what was learned from the failure of systematic design methods:

…that the design process is not considered to be a sequence of activities that are pretty well-defined and that are carried through one after the other like “understand the problem, collect information, analyze information, synthesize, decide,” and so on; and another being the insight that you cannot understand the problem without having a concept of the solution in mind; and that you cannot gather information meaningfully unless you have understood the problem but that you cannot understand the problem without information about it…(p.8)

As a result of these rather similar findings of studies on problem solving in different design domains, a number of researchers developed an interest on deriving a generic model of the design problem-solving process (Adelson & Soloway, 1985; Carroll, Thomas, & Malhorta, 1979; Goel & Pirolli, 1989; Guindon, 1990a; Guindon & Curtis, 1988; Perez, Johnson, & Emery, 1995; Perez & Neiderman, 1992). For instance, Goel and his colleagues (Goel, 1991, 1995; Goel & Pirolli, 1989, 1992) conducted a
series of studies in an attempt to articulate the differences between the design and nondesign problem solving. They have analyzed a total of twelve protocols involving design problem solving in three different domains: architecture, instructional design, and mechanical engineering and compared them with six nondesign protocols gathered from published sources, involving a mathematics problem from Schoenfeld (1985), and a cryptarithmetic and the Moore-Anderson task from Newell & Simon (1972). The analysis of these protocols suggested that there are significant differences in the problem space of design and nondesign problems. For instance, they found that in design tasks, problems structuring and problem solving stages are significantly different. In design situations, problem solving process appears to entail three stages: preliminary design, refinement, and detailed design. These three stages differ in their characteristics. In contrast, in nondesign problem solving, the problem solving was comprised of cycles of the same basic activity of searching for a solution, and if the current activity is not leading to solution, the person goes back and starts down another path. In design problem solving, designers will occasionally stop and explicitly try to change the problem situation so it more closely fits their expertise, knowledge, and the client’s expectations. Goel and Pirolli (1992) called it “reversing the direction of the transformation function” (p. 418). Such a sequence does not and could not occur in nondesign problem solving. Furthermore, in design problem solving, the solution is decomposed into leaky modules, an interim design ideas or solutions are generated, they are retained, massaged, and incrementally developed until they reach their final form. This incremental development process does not occur in nondesign problems.
Another study that attempted to derive a generic model of design problem solving processes comes from Greeno, Korpi, Jackson, and Michalchik (1990a,b). They observed eight students in the Stanford Teacher Education Program (STEP), four of whom had recently graduated and four were new to the program. In this study, a simulation of a fictitious vehicle called VST2000 is provided to the participants, who were then asked to design instruction about it. A design model derived from Greeno’s (1980) earlier study on problem solving in the domain of geometry guided the analysis of the think-aloud verbal protocols. The analysis of these verbal protocols characterized the design process as consisting of three subproblems: (1) determine the materials to be used in the design, the arrangement of these materials, and the details of their implementation; (2) decide the types of knowledge used in the design, the domain of design, and the object of design; (3) use of interacting subprocesses such as formulating the problem, including general goals and constraints, adding components, and so on. Further analysis confirmed the findings on design problem solving in other domains. In summary, they found that the designers spent most of their activity determining the content of instruction and determining the nature of instructional transactions. Also, designers spent most of their time on trying to introduce new material into their design. A considerable amount of time was also spent by recapping, reflecting, evaluating, monitoring, and justifying. Some time was also devoted to putting new information into the problem space. The designers spent almost all of their activity putting information into the design and reflecting upon information that they had put there. There was very little reversal in the activity of these designers. These findings are parallel to the ones reported by Goel and Pirolli (1989; 1992). Furthermore, a prototypical pattern of subproblems was observed in most of the
designers. At the beginning of the problem, they spent a short time clarifying the task that was presented. The main part of the protocol was characterized by a strong emphasis on determining the content and with small segments of determining the sequence. Designers sometimes specific some instructional transactions or less often instructional resources while proposing the content. Also, the designers sometimes commented on their progress on the design. Late in the main design task, the designers often switched to instructional transaction, and sometimes, instructional resource as the dominant subproblem, but continued to propose content and sequence. Toward the end of the transcripts, when participants were asked to review a structured sequence of topics, the designers usually followed a pattern that was consistent with this sequence.

Perez and his colleagues also recognized the importance of deriving a generic model of design problem solving process. However, they argued that neither in Goel’s (1991) study nor in Greeno and colleagues (1990a,b), a formal coding procedure and inter-rater reliability had been established, therefore, these studies might have only reflected the subjective judgments of the researchers. So, Perez and his colleagues (Perez & Emery, 1995; Perez, Johnson, & Emery, 1995; Perez & Neiderman, 1992) set up a two-phase study to develop a generic, cognitive model of the design process. In the first phase, four expert training designers were interviewed using a structured interview (Yaghmai & Maxin, 1984) designed to elicit how they designed training materials. The operational definition for expertise included: (1) nomination by peers; (2) years of experience; (3) awards from professional organizations; and (4) hands-on experience. The structured interview focused on nine general aspects of training design: (1) description of materials; (2) content; (3) audience characteristics; (4) goals of the
developer; (5) learner motivation; (6) features of the material; (7) training context; (8) development process; (9) general/miscellaneous. There were approximately five questions for each aspect and each interview lasted about four and a half hours. The second series of interviews pertained to a successful design project and a difficult design project. The experts were asked to provide examples and materials for each type and elaborate on them. Tapes from these interviews were transcribed verbatim. These transcripts were then coded by using a coding scheme adapted from Greeno et al. (1990b). Two coders were trained in the use of this coding scheme and then independently coded the transcripts. Following the coding, inter-rater reliability was established by using Kappa coefficient (Cohen, 1960), which showed that the estimate of agreement between the two coders across all categories of the coding scheme was near the excellent level of reliability. At a top level, the design process as depicted by experts reflected the systems approach to training (analysis, design, development, and evaluation), but, at a more detailed level, experts varied with respect to their implementation of and how they described the design process. Perez and Neiderman (1992) explain it as follows: “…they vary with respect to the framework used in guiding design decisions. For examples, GTD 1 almost exclusively used a human development framework in deciding the sequence of instruction; whereas GTD 2 relied exclusively on a task decomposition method. While others, SMED 1 and SMED 2, are guided by the content structure or process they are teaching” (p.273).

Perez and Neiderman (1992) also concluded that the generic designers were more acutely aware of the design process and appeared to be very comfortable in describing their declarative knowledge (i.e., facts, concepts, and principles), formal rules (i.e., rules
regarding how to use these facts), procedural knowledge (i.e., skills), meta rules (i.e., rules for applying formal and procedural rules), heuristics (i.e., rules of thumb), and relations among these various facets were used to come up with a design solution.

Whereas the subject-matter-expert designers were not as explicit about their rationale for their design solutions. They interpreted that this difference is due to the fact that the subject matter experts’ rationale and procedures are embedded within the structure of the content.

Perez and Neiderman (1992) also found, as Greeno et al. (1990b), that the design process consisted of at least three subproblems: (1) Determine the materials to be used in the design, the arrangement of these materials, and the details of their implementation; (2) Types of knowledge used in the design, knowing the domain of design and the objects of the thing to be taught; & (3) Use of interacting subprocesses, as formulating the problem, including general goals and constraints, adding components to the design, and elaborating and modifying components that have been included in the design. However, in their study, experts did not engage in a linear sequence of short generate-evaluate cycles. Rather, they used a strategy similar to that described by Goel and Pirolli (1989): the designer begins by focusing on one component of the problem at a time and generates an initial design. They then focus on this proposed design solution, evaluate it as an interim design solution, and either accept, reject, or modify it. They may not only apply the solution to that component but also extend it to other components of the design task, and then evaluate it as a design solution to the whole design task, and either accept, reject, or modify it.
Perez and Neiderman (1992) also found that the initial design solution is evaluated by the designer within three different contexts: (1) as an interim solution for a specific component of the design task; (2) as a working model of the final design; and (3) as a final design solution for the design task. The results of their study differ significantly from both Greeno (1990b) and Goel and Pirolli (1989) in that the designers in Perez and colleagues (1995) reported that they spent a large portion of the design process concerned with motivation factors.

Five training design experts and three novices participated in the second phase of this study (Perez et al., 1995). Novices were upper-level graduate students with coursework in ID or masters degrees with less than two years of work experience in ID. They selected novice instructional designers so that they would have the content and theoretical background but not the experience that experts have (Chase & Simon, 1973a). The content for the think-aloud procedure consisted of designing an instruction for troubleshooting a simulated diesel engine. Time limit was two and a half hours. Subjects were both video and audio taped. Two pairs of coders were first trained and then were given practice trials in applying the coding scheme. The protocols from Phase I were used to demonstrate how to apply the different categories of the coding scheme and also how to segment the protocols into meaningful fragments. The coders were not allowed to code or fragment the verbal transcripts until they agreed with each other on a test protocol during training. The coding scheme consisted of the following two levels: knowledge source and design phase. Each fragment was assigned a combined or composite code for the two levels. The fragments from the practice protocols enabled the raters to become comfortable with using the coding scheme.
Reliability between raters was established using Kendall’s tau (Winkler & Hayes, 1975). The tau statistic for the composite code was .445 (p.< .001) for the first pair of raters and .558 (p.<.001) for the second pair of raters. The qualitative analysis of the think-aloud protocols was performed in two steps. First, one author and two research assistants examined the verbal segments in search of the overall pattern and examined the coding events related to these patterns. Second, Perez and his colleagues (1995) examined the protocols by asking questions related to the designers’ knowledge sources. A number of differences were observed between experts and novices. Experts developed solutions breadth first, whereas novices developed their solutions depth first (also seen in Anderson, 1982 with computer programmers). Experts expand a full level of a design tree (Anderson, 1985) branch before going down to expand the next level, whereas novices went almost directly to the lowest levels of the problem. Thus, experts selected a basic design strategy before working out all the details of the design. They systematically applied this plan to each successive phase of instruction. Experts integrated, reiterated, and cycled through the design process. Novices exhibited a straightforward, step-by-step approach, “first I must to this, and finally this”; whereas experts did not focus on one area independent of the others.

Experts were also more reflective in their selection and use of a design strategy. They devoted more effort in the initial analysis and planning phase before selecting an ID strategy. Novices almost immediately selected a design strategy and applied it to the whole design problem. Experts were immediately concerned with determining the learners’ characteristics, goals, and objectives. Experts broadened the planning phase by including the identification of tasks to be taught and the knowledge, skills, and abilities
necessary for task performance. Then they determined the client’s requirements, needs and constraints. In contrast, novices immediately verbalized several design solutions based on only having considered the background materials for the course. Novices then proceeded to consider the learners’ characteristics— which lead to the generation of several design strategies. As the novices progressed through the training design process, the number of verbalizations associated with actual design diminished and reflected the novices attempts to determine how the selected design strategy impacted upon the goals and objectives. Both experts and novices used forward-chaining solution paths.

In summary, experts spent considerably more time exploring the problem than novices. They interpreted the design problem while novices identified the problem. Experts and novices retrieved and used different types of knowledge in arriving at their design solutions. Experts’ representations of the design problem are substantially different. Experts considered a wide range of factors in combination with one another; whereas novices considered fewer factors and one factor at a time. Experts employed different control mechanisms than novices. Experts tended to use fewer learner-control strategies than novice designers (Perez et al., 1995). Perhaps, another important conclusion of this study was the importance of strategic knowledge in the application of domain specific knowledge. Perez et al. (1995) stated that they observed an absence of the use of a basic plan centering around general principles of instructional design by the novices even though they all had recently completed graduate courses in instructional design. The authors concluded that the novices were not able to translate this theoretical knowledge into practice because they lack the strategic knowledge that is thought to come with experience, which would have enabled them to implement their theoretical
knowledge. The experts, on the other hand, not only used learning principles but also design principles in their solutions.

The expert’s model of the instructional design process developed by Perez et al. (1995) resemble the generic model of design described by Goel and Pirolli (1989) earlier. However, there are also differences. One such difference was that the novices in Perez et al. (1995) had a more global approach to instructional design overall even though each phase was elaborated extensively. Moreover, these elaborations were at only the content level; whereas, the expert elaboration took place at three levels. Experts broke down the design process into three levels that include content, instructional transaction, and presentation (in this order). For the content level, the expert began by selecting the problem space and the goal of the design. At the second level, the expert was concerned with interactions created by the presentation of the instructional materials, and the students’ reactions. Lastly, the expert addressed the presentation and the media used to deliver instruction. Throughout the design process, the expert would complete the elaboration of each level and then would review them with regard to how they would be impacted by the characteristics of the students. Whereas, the novices’ analysis was always at one level, “depth-first, top-down, progressive refinement” (van Lehn, 1989, p. 562). Furthermore, the novices’ elaborations were very specific and are thought to be tied to the availability of a limited number of heuristics. There are fewer experiences to draw upon so novices are unable to see alternatives; they simply select the first available option.

Perez et al. (1995) observed with the experts that the process of selecting an instructional design strategy often included reflection on past design problems and
solutions, and drawing comparisons between those and the present problem. Experts appeared to have a separable approach to the design process, breaking it into manageable parts and systematically integrating them. As a result of their study, Perez et al. (1995) characterized the expert design strategy process as integrating, reiterating, and cycling though the design process: “The expert design process is not a deterministic linear activity but rather an iterative activity that requires creativity as well as logic. Novices exhibit a straightforward approach to the design process” (p. 341-342).

In a similar study of instructional design expertise, Rowland (1991) found a similar pattern of differences between experts and novices in the design process. Rowland (1991) used a think-aloud method that asked experts and novices to design instruction to teach service technicians basic physics. Rowland’s (1991) study differs in many important respects from Perez et al.’s (1995) study. For example, Rowland’s design task involved the domain of basic laws of physics as opposed to the teaching of troubleshooting of a diesel engine using a simulator. Selection criteria was also different. Perez et al. (1995) defined experts as having at least ten years of experience as opposed to six years of experience. Novices in Perez et al.’s (1995) study had taken at least two graduate courses in instructional design, curriculum development, or instructional technology and had no more than two years of practical experience. Irrespective of these important differences, Perez et al. (1995) and Rowland (1991; 1992) found similar patterns of difference between expert and novices. These were:

- Experts spent considerably longer time exploring the problem than novices.
- Experts interpreted the problem while novices identified the problem.
- Experts and novices retrieved and used different types of knowledge.

- Experts constructed problem representations that were substantially different from those constructed by novices.

- Experts considered a wide range of factors in combination with one another.

  Novices considered few factors and one factor at a time.

- Experts employed different control mechanisms than novices.

Overall the four expert training designers in Perez et al.'s (1995) and Rowland's (1991) study show similar characteristics to experts studied in other domains (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Farr, 1988; Dreyfus & Dreyfus, 1986; Ericsson, 2002; Ericsson & Smith, 1991):

1. Experts excel mainly in their own domain; their expertise does not transfer to other domains.

2. Experts perceive large meaningful patterns in their domain. This perceptual ability is not reflective of superior perceptual abilities, but rather, it reflects an organization of the knowledge base.

3. Experts are faster than novices at performing the skills of their domain and they quickly solve problems with little errors. The explanation for this speed is that experts have acquired skills through many hours of practice making many of the skills automatic and thus freeing up memory capacity for the processing of other tasks.
4. Experts have superior short-term and long-term memory. This is due to the automaticity of many of the skills which enable the experts to have greater resources for storage.

5. Experts see and represent a problem in their domain at a deeper (more principled) level than novices. Novices tend to represent problems at a superficial level.

6. Experts use domain principles to organize categories, whereas, novices organized categories around literal objects stated in the problem description.

7. Experts spend a great deal of time analyzing a problem qualitatively. At the beginning of a problem-solving episode, experts typically attempt to understand a problem completely before initiating any action, whereas novices begin immediately to apply equations and solve the unknown.

8. Experts analyze the problem qualitatively by building a mental representation of the problem from which they can infer relations that can be used to define the situation, and then they add constraints to further define the problem.

9. In spite of all these differences between experts and novices, an expert with low content knowledge and little experience in a particular context behave similar to novices.

**Simulation-Based Studies of Complex Problem Solving (CPS)**

Researchers’ realization that problem-solving processes differ across knowledge domains and across levels of expertise and that, consequently, findings obtained with simple laboratory tasks cannot necessarily be generalized to problem-solving situations outside the laboratory, has during the past two decades, led to an emphasis on real world problem
solving (Frensch & Funke, 1995b). However, this emphasis has been expressed quite differently by different research groups. As outlined in the previous section, while one cohort of researchers concentrated on studying expert-novice differences in problem solving in separate, natural knowledge domains another cohort of researchers focused on novel, relatively complex, semantically rich problems that are constructed to be similar to real life problems and that have been performed via computer-simulated scenarios (i.e., microworlds) (see Funke, 1991 for an overview).

Two principal approaches are observed in simulation-based studies of complex problem solving (CPS) (Frensch & Funke, 1995b). One approach was largely initiated by Broadbent (1977) in England; the second approach was by Dörner in 1987 in Germany (for an overview in English, see Dörner & Wearing, 1995). In both approaches, problems utilized for experiments did not require any specific content expertise; they could be administered to anyone of at least roughly average intelligence. However, these two approaches differ somewhat in their theoretical goals and methodology. The key difference between the two approaches is that in the former, one is able to specify a precise rule via a mathematical formula that would optimize problem solving, whereas in the latter, the problems are so complex that it is questionable whether anyone could ever devise any mathematical or even computer simulation that would clearly optimize performance.

*Implicit learning in system control.* The tradition initiated by Broadbent has mainly been interested in studying implicit learning, that is the ability to acquire new knowledge even when apparently unaware of it, or unable to express it. These studies emphasize the distinction between cognitive problem-solving processes that operate
under awareness versus outside awareness, and typically employ mathematically well-defined computerized systems.

One of the most well-known studies in this tradition is the *SUGAR FACTORY* (Berry & Broadbent, 1984). The *SUGAR FACTORY* uses a simple computer-simulated scenario in which the participants were asked to manage a small sugar-production factory in order to reach and maintain a given target production level. Their goal is to reach and maintain the production of sugar (P) at a specified target level by modifying the amount of workers (W) allocated to the production. The size of the workforce (W) can be varied in 12 discreet steps, yielding a level of production (P). Unbeknown to participants, P and W are related to by the following formula:

$$P(t) = 2 * W(t) - P(t-1) + \varepsilon$$

where P(t) is the quantity of sugar produced at trial t, just after the allocation of W(t) workers, P(t–1) represent the amount of sugar produced in the previous trial, and \(\varepsilon\) is a random variable that can assume with equal probability one of the values in the set \([-1, 0, +1]\). The value for both W and P ranges from 1 to 12; if the resulting values of P are less than 1 then they are simply set to 1, and values exceeding 12 are set to 12. For a more realistic interpretation, values of W are multiplied by 100 (hundreds of workers), and values of P by 1,000 (tons of sugar). Finally, a random factor of \(\varepsilon (+1000, 0, -1000)\) is added to the final result of the equation to make the task more difficult and to prevent the participants from learning the rule.
With their *SUGAR FACTORY* system, Berry and Broadbent (1984) were one of the first researchers to explore the concept of implicit learning in process control, and they reported negative correlations between task performance and the ability to answer specific questions about a system’s behavior (Berry & Broadbent, 1984; Broadbent, 1977). In a series of studies, Berry and Broadbent (1984; 1987) found evidence that, despite low explicit task knowledge (as measured by a questionnaire), subjects were able to control small systems with good performance. In a later study, Dienes and Fahey (1995; 1998) developed two models of the *SUGAR FACTORY* task using either rules or instances and found that the former model reproduced human behavior more closely than the latter. In addition, they found that subjects that displayed the best control performance of the system also exhibited the lowest amount of system knowledge, as determined by a post-task test.

Another well-known study of this tradition includes the *TRANSPORTATION* (Broadbent, 1977). In this system, subjects have to control the busload (L) and vacant parking spaces (VS) in a fictitious city parking lot by manipulating the time intervals between bus arrivals (T) and the amount charged for use of the lot (F). The formulas are:

\[
L(t+1) = 200*T(t) + 80* F(t)
\]

\[
VS(t+1) = 4.5*F(t) – 2*T(t)
\]

Broadbent (1977) reported a disassociation between the verbal statements of the subjects and their actual ability to control the system. Using the *TRANSPORTATION* system, a series of studies conducted by Sanderson (1989) also demonstrated
disassociation as well as association effects between task performance and verbalizable knowledge depending on amount of practice, kind of display, and cover story. Interestingly, Sanderson’s results contradict the common thesis that, with growing practice, verbal task knowledge decreases (e.g., Anderson, 1983).

In the last few years the system control research has stagnated and two other competing implicit learning paradigms (with much less external validity, but maybe better suited to demonstrate learning without awareness) have prospered at its expense. These paradigms are artificial grammar learning and serial reaction time. However, the body of research on system control remains very interesting. The most common effects to be explained are related to how people improve their control of the system, but cannot verbalize that knowledge. The theorization and computational modeling in this branch of CPS are extremely rich. Models are based on exemplar learning, rule learning, and both (e.g., Dienes & Fahey, 1995; Gibson, Fichman, & Plaut, 1997; Lebiere, Wallach, & Taatgen, 1998).

**Interplay of the cognitive, motivational, & social components of CPS.** Mainly practiced in Germany, this tradition of complex problem solving uses by far the most complex tasks. Initiated by Dörner (see Dörner & Scholkopf, 1991; Dörner & Wearing, 1995), this CPS tradition is the most radical departure of the mainstream problem solving tradition. The main focus of this line of research is the interplay of the cognitive, motivational, and social components of problem solving, which can be classified around the following three topics (Funke, 1991): (a) the role of personal factors (cognitive abilities, emotional and motivational factors, and personality characteristics), (b) the role of situational determinants of complex problem solving (the
transparency of the situation and the concrete test demands with which a subject has to cope.), and (c) the role of system characteristics (the formal aspects of the system, i.e., the number of variables, their connectivity, the resulting stability of the system, the degree of time delays, etc., and the aspects with regard to content, such as the semantic embedding of the system in question but also with the relation between the actually implemented structure and the structure which is assumed by the subject because of previous knowledge).

One of the earliest studies published in this tradition is the TANALAND system (Dörner & Reither, 1978). The ecosystem of an African landscape with various flora and fauna as well as human groups, the ‘Tupis’ and ‘Moros’, who live by cattle and sheep farming, is simulated. The fifty or more system variables are connected through a complicated process of positive and negative feedback. Subjects are to assume the role of a technical agronomy advisor to improve the living conditions of the native population. The system is very difficult to handle. As Dörner and Reither (1978) showed, almost no subject was able to succeed in this task. The observed failures mirrored deficits of a more general nature. It appeared that the subjects did not possess enough cognitive ability to be able to cope with complex systems. Dörner and Reither (1978) maintained that linear thinking failed to help people solve problems in such complex, dynamic systems that featured high-degrees of connectivity and opaqueness. For such systems, Dörner and Reither (1978) proposed thinking in the form of causal networks.

TANALAND was later modified and expanded into a system called LOHHAUSEN (Dörner, 1987), which simulates a small, mid-European town (Figure 14). The town had approximately 3,500 residents and lived mainly from a municipal industrial enterprise, a
manufacturing plant producing watches. In addition, there was a city administration, doctor’s practices, retail stores and shops, a bank, schools, kindergartens, etc. Subjects were able to influence production and sales policies of the city factory, to vary rates of taxation, to create employment positions for school and kindergarten teachers, to establish and lease doctors’ practices, to urge on housing construction, to provide for leisure time arrangements, etc. This computer simulation contained more than two-thousand variables. Dörner, Kreuzig, Reither, and Stäudel’s (Dörner, Kreuzig, Reither, & Stäudel, 1983 in Funke, 1991) comprehensive monograph introduced the five

Figure 14. The map of the town of Lohhausen used by Dörner (1987). (Copyright 1987 John, Wiley, & Sons, Inc. Reprinted with permission.)
years of work on this unique study with the following sentences (as cited in Funke, 1991):

The following report states the results of a relatively long-term psychological experiment. We tried to find out something about the conditions and forms of actions in ambiguous and complex situations. For this we systematically observed 48 subjects over a relatively long period and processed the manifold results of these observations. (p.202)

Subjects of the LOHHAUSEN study assumed the role of mayor of the town, and were instructed to take care of the future prosperity of the town over the short and long term, that is, over a simulated ten-year period. A variety of problems were presented to these individuals, such as how best to raise revenue to build roads. Testing was done in eight two-hour sittings. Approximately 100,000 data points per subject resulted, from which the authors hoped to successfully separate the important from the trivial, and accidental from meaningful information.

The analysis of the findings—with a few exceptions, such as case studies of selected experimental subjects—was based upon aggregated data. The authors first agglomerated the objective and subjective measures of problem-solving quality to a single general quality criterion, which made it possible to split the total sample into two extreme groups (N=12) of good and poor problem solvers. Results comparing the two groups showed that different variables in the LOHHAUSEN system (such as earnings of the industry, funds of the town, stocks of the bank, production and trade data, number of inhabitants, and rate of employment) developed more detrimentally when worked on by the poor problem solvers than by the good problem solvers. Even the ‘good problem
solvers’ were not what their designation suggested, however. System experts (the experimenters) achieved even higher values on some of the variables.

The behavioral effects were less interesting than the connected thought, planning, and decision processes: Besides formal characteristics (e.g., the frequency and consistency of decisions) and content biases (e.g., financial situation of the watch factory) of the experiments’ gross protocol, there were interesting references in the think-aloud protocols that the subjects were encouraged to produce. Subjects’ problem-solving quality and their test intelligence were found not to be correlated. Neither Raven’s Advanced Progressive Matrices (APM) nor Catell’s Culture Fair Intelligence Test (CFT) correlated substantially with the solution quality. Rather, what correlated significantly with problem-solving performance was the experimenters’ spontaneous judgment that a subject makes an intelligent impression (Dörner et al., 1983).

Further findings of the LOHHAUSEN study were concerned with personality characteristics and their relation to solution quality. The construct of self-confidence has to be given a special mention in this context; it had a strong positive relation to complex problem solving and was introduced to set off the total failure of intelligence tests. Also, prior knowledge was not a significant predictor of success.

The condensed theory of this comprehensive study contains a list of elementary information processing methods for dealing with complex problems such as component and dependence analysis as well as sub- and super-ordination processes. The construction and pursuit of partial objectives by a subject is subsumed under an intention management model. Based upon the emotional embedding of cognitive processes (Dörner et al., 1983), the intellectual emergency reaction—a quick and general reaction of the cognitive system
to unspecified danger situations—can be brought into connection with the actual competence of the actor. Self-confidence can be used as an indicator for heuristic competence, which refers to the ability “to be able to create adequate ways of dealing even with unknown situations” (Dörner et al., 1983, p. 436; cf. Stäudel, 1987). Central to the theory is the concept of control: Control competence guarantees action in uncertainty, and loss of control leads to the negative emotional consequences, which override problem-solving thought.

LOHHAUSEN not only stands for a new field of research in cognitive psychology; it is also an appeal against the prevalent analytical procedure in scientific endeavor. The examination of highly complicated cognitive system of mankind—following Dörner—cannot be pursued using strictly experimental means due to the isolation of a few chosen variables in a laboratory says little about the normal interplay of processes that are interactively embedded within other variables. The demand for the exact description of the observed phenomena, goes hand in hand with the search for an overlapping conceptual framework concerning the complete workings of the psychic system.

**Research on Everyday Problem Solving**

Another tradition to problem solving is conducted under the general rubric of everyday problem solving, which is founded as a reaction to problem solving research in well-structured, laboratory tasks (Eysenck, 1984; Riegel, 1973). As Meacham & Emont (1989) put it:
… in laboratory research the temporal point of problem solution is generally quite clear. Not only is the problem structured so that there is only one correct solution, which can be quickly confirmed upon its discovery, but the researcher knows the solution in advance and can confirm for the participant that this is the correct solution. In contrast, for everyday problems there are often many alternative solutions, all workable but involving different combinations of costs and benefits. Once particular solution has been decided upon, confirmation that this is the correct or best solution may take years, if such confirmation is possible. Consider, for example, that many possible solutions and the associated uncertainties in choice of an identity, career, or spouse (p. 12).

This branch of problem solving research is interested in questions such as: How do mature adults adaptively solve problems? What kinds of problems do they typically encounter? What special forms might their logical thought take? How do younger persons compensate for the lack of experience that the mature person has in abundance? Researchers in this problem solving tradition test variables such as problem context (physical or emotional), intuition, motivation, and intention. These questions broadened the parameters of the traditional research on problem solving. The efforts in this tradition is scattered in a number of different literatures including, psychological, educational, gerontological, and marketing.

While early information processing theory of problem solving held that “in general, the processes used to solve ill-structured problems are the same as those used to solve well-structured problems” (Simon, 1978, p. 287), research in situated and everyday problem solving (Lave, 1988; Sinnott, 1989) makes clear distinctions between convergent problem-solving thinking and the thinking required to solve everyday problems. Some preliminary research (Dunkle, Schraw, & Bendixen, 1995) has concluded that
performance in solving well-structured problems is independent of performance on ill-structured problems, with ill-structured problems engaging a different set of epistemic belief. More research is needed to substantiate this finding, yet there is evidence to suggest that well-structured and ill-structured problem solving engage different skills.

**Dynamic Decision Making (DDM)**

The dynamic decision making (DDM) tradition (e.g., Brehmer, 1992; Busemeyer, 2002; e.g., Sterman, 1994) is centered in simulations with economical environments like stock purchases or inventory control (Sterman, 1989) and is fairly well integrated with standard decision theory. DDM also tends to display a high level of formalization. The multistage betting paradigm explained, for example, in Rapoport (1975), is an extension of the standard single-stage betting paradigm. The research methodology has inherited the normative models approach: the decision maker’s actions are compared to a five-variable mathematical model that is supposed to be optimal. Systematic discrepancies between the optimal model and the decision maker’s behavior are included in the psychological model. Unfortunately, contrary to what is an extended practice in decision theory, formulating and computing an optimal strategy is problematic in complex tasks, and is possible only in the simplest dynamic decision making situations (Slovic, Fischhoff, & Lichtenstein, 1977). Some authors, like Toda (Slovic et al., 1977) have focused mainly on decision problems for which analytical solutions can be obtained. Most of the work in the area has been done in discrete dynamic decision tasks that change only when the participant introduces a new set of inputs. Variables like time pressure have been successfully integrated in models like Busemeyer and Townsend’s (1993) decision field theory.
**Naturalistic Decision Making (NDM)**

Naturalistic decision making (NDM) branch of decision making (e.g., Salas & Klein, 2001; Zsambok & Klein, 1997), inaugurated by Klein and associates has been centered in field research. Examples of studies include interviewing firefighters after putting out a fire or a surgeon after she has decided in real time what to do with a patient.

Based on their observations of experts during real-life problem solving tasks, Klein and his colleagues have developed the Recognition-Primed Decision Making (RPD) model (Klein, 1997, 1998; Klein, Orasanu, Calderwood, & Zsambok, 1993). Figure 15 illustrates the application of RPD model to three problem scenarios from simpler to more complex. RPD model is based on the idea that in real-life tasks domain experts use the current goal and the current state of the environment to retrieve from memory actions that have worked under similar circumstances in the past, which indeed is parallel to the findings of CPS research in other traditions discussed earlier. This tradition does not use computer-simulated environments or microworlds. Klein and his colleagues (1993) have criticized mainstream theories of problem solving and decision making as being inapplicable to everyday settings. This is a very fragmented field, where each researcher works on a particular real-world task, and the generalizability of the results is questionable (no taxonomy of NDM tasks has ever been developed). Theoretical developments in NDM are sparse, and computational modeling is almost nonexistent. The main theoretical contributions have been achieved when some researchers successfully adapted to NDM existing concepts and models as research vehicles. For example, the classical model of memory and categorization MINERVA II (Hinzman, 1988) has been used to implement Klein’s recognition-primed decision-
making paradigm (Warwick, McLlwaine, & Hutton, 2002; Warwick, McLlwaine, Hutton, & McDemott, 2001).

**Section Summary**

This section presented a review of existing research on problem solving. Eight different research traditions were identified: (1) behaviorist and associationist tradition; (2) gestalt tradition; (3) information processing view of human problem solving; (4) expert-novice comparison studies in natural knowledge domains; (5) simulation-based studies of
complex problem solving (CPS); (6) research on everyday problem solving; (7) dynamic decision making (DDM); (8) naturalistic decision making (NDM).

Existing research traditions differed in (a) task selection and (b) research focus. For instance, researchers that belonged to behaviorist and associationist traditions focused on simple, puzzle-like tasks, which can be solved with one correct step. Behaviorist researchers viewed problem solving as a relationship between a stimulus and a response without speculating about the intervening process.

Gestalt psychologists focused on puzzle-like, insight problems, in which the solution follows rapidly once the crucial step has been taken. Gestalt psychologists were mainly interested in further analysis of factors such as functional fixedness and Einstellung that influenced perception in problem solving.

Earlier information processing theorists also focused on well-structured, puzzle-like tasks, which do not require domain knowledge, however, as opposed to the tasks studied by Behaviorist or Gestalt researchers, the tasks they studied contained multi-steps, where no single step was the key. In these tasks, finding a solution depended on making a number of correct steps. As opposed to behaviorist approach, information processing theorists were more concerned with the processes that intervened between stimulus and response. Two assumptions underline their theory: (1) the human problem solver can be characterized as an information-processing system, and (2) problem solving can be characterized by two separable sets of processes involved in problem solving: (a) a collection of understanding processes, in which the solver extract the given and the goal information and generate a problem space, e.g., an internal problem representation, and (b) the processes of searching for a solution in the problem space.
Research conducted by Rietman (1964) on music composition and de Groot (1965) on expert chess players posed early challenges to the information-processing theory human problem solving. These and other studies focused on problems in natural knowledge domains and mostly compared problem solving approaches of domain experts and novices. The culmination of these studies demonstrated two very important findings. First, the information-processing theory of problem solving was not sufficient in explaining well-structured problem-solving in natural knowledge domains. For instance, Hinsley, Hayes, & Simon (1977) argued that in domain-specific problem solving, a schema for that particular type of problem may be activated while constructing a representation of the problem. If schema activation should occur then the solver can directly proceed to implementing the solution skipping the ‘search’ stage. Therefore, these studies also indicated that problem solving in different domains is different due to domain-specific strategies required by each domain. Furthermore, these studies suggested that experts possess schemata relevant to problems in their domains of expertise whereas novices typically do not possess such schemata.

Secondly, studies with domain-specific problems acknowledged the differences in the underlying cognitive processes between ill-structured and well-structured problem solving. Research with ill-structured problem solving demonstrated that it does not fit well into information-processing theory of problem solving because in ill-structured problem solving, such as design problem solving, the problem is typically not a ‘given’. Therefore, in ill-structured problem solving, the first step is not the creation of problem space as identified in the information-processing theory but it is problem structuring,
which is the process of finding the missing information and using it to construct the problem space.

This leads to other important characteristics of ill-structured problem solving that separates it from well-structured problem solving: the specification of constraints. There may be multiple sources for constraints including legally imposed restrictions, constraints imposed by problem-solver, clients, environment, and so on.

A third difference between well-structured and ill-structured problem solving is that in ill-structured problems, the problem and its solution are intimately connected and they develop in parallel.

Especially studies conducted with design problems further elaborated the difference between ill-structured and well-structured problem solving. In a few studies conducted to derive a generic model of design problem solving (see, e.g., Greeno et al, 1990b; Goel & Pirolli, 1989; Perez and Neiderman, 1992) researchers argued that in design situations, problem solving process appears to entail three stages: preliminary design, refinement, and detailed design. These three stages differ in their characteristics. In contrast, in well-structured problem solving, the problem solving was comprised of cycles of the same basic activity of searching for a solution, and if the current activity is not leading to solution, the person goes back and starts down another path. In design problem solving, designers will occasionally stop and explicitly try to change the problem situation so it more closely fits their expertise, knowledge, and the client’s expectations. Goel and Pirolli (1990a; 1990b) called it “reversing the direction of the transformation function” (p. 418). Such a sequence does not and could not occur in well-structured problem solving. Furthermore, in design problem solving, the solution is
decomposed into leaky modules, an interim design ideas or solutions are generated, they
are retained, massaged, and incrementally developed until they reach their final form.
This incremental development process does not occur in well-structured problems.

Furthermore, as a result of these studies, many important differences were
observed between experts and novices. However, perhaps the most important distinction
was related to strategic knowledge: novices were not able to translate their theoretical
knowledge into practice because they lack the strategic knowledge that is thought to
come with years of experience. Therefore, while solving problems, novices tended to
identify the problem on a superficial level by only using the givens while experts spent
considerably more time exploring and their problem representations include their own
interpretations of the problem with many elements that were not mentioned in the
problem scenario.

The remaining four problem-solving research traditions, i.e., everyday problem
solving, dynamic and naturalistic decision making, and simulation-based studies
reviewed in this section concentrated on complex problem solving with varying research
focus. Some of these traditions used well-defined complex problems while others used
ill-structured complex problems. Except the simulation-based studies, which studied
highly complex problems, some with 2000 variables, all other three traditions researched
real-life problems. Naturalistic decision making tradition solely observed complex
problem-solving in real-life settings. Some of the interesting findings about complex
problem solving include:
Humans, in general, do not possess enough cognitive ability to be able to solve or formulate an optimal strategy for highly complex problems (Dörner, 1984; Slovic, Fischoff, & Lichtenstein, 1977)

solvers who have displayed linear thinking failed to solve complex problems that feature high-degrees of connectivity and opaqueness. For such systems, Dörner and Reither (1978) proposed thinking in the form of causal networks.

Subjects’ problem solving quality and their test intelligence were not found to be correlated (Dörner et al., 1983) however, there was a strong positive correlation between self-confidence and task performance.

In real-life complex problem-solving situations, experts use the current goal and the current state of the environment to retrieve from memory actions that have worked under similar circumstances in the past (Klein et al., 1993).

Unfortunately, collective results of different traditions of complex, ill-structured problem solving do not yield a comprehensive view due to the fragmented nature of available studies.

**IMPLICATIONS of PROBLEM-SOLVING RESEARCH FOR INSTRUCTION**

The implications of the findings of existing problem-solving research traditions involve inconsistencies, ambiguities, and variance for designing instruction that facilitates acquisition of problem-solving skills, and subsequently, for assessing improvements in learner’s problem-solving capabilities. A close look at the selection of problem tasks utilized in each paradigm and goals of the research in different traditions helps explain this variance. For instance, researchers who subscribed behaviorist, gestalt, and
information-processing theories utilized simpler, well-structured, puzzle-like problems. The extension of information-processing theory, which found itself in the form of mostly expert-novice studies in natural knowledge domains also utilized more well-structured problem tasks. However instead of puzzle-like, knowledge-lean tasks, they concentrated on knowledge-rich tasks such as math or science problems. On the other hand, problem-solving researchers following other traditions such as everyday problem solving, and dynamic and naturalistic decision making mainly study tasks can be classified somewhere between well- and ill-structured end of the continuum while others, especially the ones used by Dörner and his colleagues, are towards the ill-structured end (Figure 16).

These differences in the selection of problem tasks help explain why results suggested by any one tradition do not, by themselves, provide a comprehensive view on designing instruction for facilitating acquisition of problem solving skills. For instance, Gestalt theorists raised issues related to meaning, understanding, and insight, which are distinctly human characteristics (Wertheimer, 1945). Therefore, they argued that problem solving instruction should address these issues rather than the steps undertaken after understanding and reorganization have occurred. In other words, situations or problems include some elements that are structurally central while others are peripheral. Of major importance in learning to solve problems is to grasp the structurally central elements and differentiate them from the peripheral or unimportant features (Cox, 1997; Wertheimer, 1945). The difficulty in applying the Gestalt perspective in the classroom is the lack of a
set of clearly defined principles for learning. Gestalt researchers developed general suggestions for problem solving instruction. First, embed the problem in concrete situations. For instance, “finding the area of a rectangle may be embedded in the situation in which two farmers wish to exchange two plots of land” (Wertheimer, 1945, p.272). In other words, the teacher should provide reasonable problem situations that the student attempts to address. Then cooperative help should be provided as required.
Second, Gestalt researchers suggest that assistance provided during problem solving should not be that of copying or repeating procedures. Instead, the teacher should provide guided discovery in the form of cues or hints to help learners reorganize their view of the problem (referred to as functional fixedness). The goal is for students to discover a solution with functional value; that is, a solution that addresses the basic difficulty posed by the problem. The test of the occurrence of real learning is to determine if the individual can solve a related problem or task (the principle referred to as transfer) (1980). If the student has only memorized some steps, he or she will not be able to recognize the similarities of the two situations and will be unable to solve the problem.

Third, Gestalt researchers suggest that instruction should not present students with sets of trite problems that can be solved by learning a series of rote steps. This approach leads to the difficulty referred to as Einstellung (Luchins, 1942).

On the other hand, information-processing theorists came up with more comprehensive principles for designing instruction to facilitate problem solving skills. Based on the information-processing theory of problem solving, Simon (1980) argued that extensive instruction in general search strategies, especially means-ends analysis, should be the core of any instructional program that attempts to teach problem-solving skills. Following information-processing theory of problem solving, a number of instructional programs, such as the ‘Productive Thinking Program’ (Covington, Crutchfield, Davies, & Olton, 1974); the ‘Cognitive Research Trust (CoRT) Thinking Lessons’ (de Bono, 1973), ‘Patterns of Problem Solving’ (Rubinstein, 1975), and ‘How to Solve Problems’ (Wickelgren, 1973) sought to teach replicable, general, domain-independent problem solving skills with the expectation that these general problem-
solving skills would transfer to all kind of problems. In their analysis of these programs, Polson & Jeffries (1985) conclude that students experienced difficulty in fluently generating alternative solutions and representations, and the methods did not transfer to solving complex, ill-structured problems.

Problem-solving researchers focusing on expert-novice studies in natural knowledge domains attribute this difficulty to the nature of complex, ill-structured problems and maintain that complex problems cannot be solely solved by the use of general search processes even though almost any complex problem can be cast as a search problem (Anderson, Greeno, Kline, & Neves, 1981; van Merriënboer, 1997). This is mainly due to limited capacity of human cognition that restricts individuals’ ability to deal with such huge problem spaces (Jonassen, Beissner, & Yacci, 1993; Scandura, 1973). Therefore, the problem solver must have both powerful search strategies and relevant domain in order to limit the search to fruitful lines of attack.

The findings of studies in other problem solving research traditions, such as naturalistic decision making, also emphasize the importance of solver’s ability to relate the specifics of the given complex problem situation to retrieve from memory actions that have worked under similar circumstances in the past.

In sum, existing literature on problem solving reviewed in this chapter suggests that: (1) there are significant differences in the structure of simple problems and complex problems, (2) there are also significant differences in the structure of well-structured problems and ill-structured problems, (3) problem solving processes vary with respect to the type of problem and the context in which they are encountered, and therefore, (4) an instructional strategy that shows effectiveness for a specific problem type/context is not
necessarily effective in another, which implies that, (5) instructional strategies that work for simple, well-structured problems do not necessarily work for complex, ill-structured problems and (6) instructional strategies that work in one problem-solving domain do not necessarily work in another.

The problem categorization schema in Figure 17 adapted from Dijkstra and van Merriënboer (1997) illustrates this point very well. Dijkstra and van Merriënboer (1997) distinguished these kinds of problems: (a) categorization or description; (b) interpretation; and (c) design. Knowledge that supports categorization problem-solving are concepts, conceptual networks, and descriptive theories; knowledge that support interpretation problem solving are principles, causal networks, explanatory theories; and knowledge that supports design problem solving are plans, procedures, prescriptive theories. Dijkstra and van Merriënboer (1997) further distinguish three levels of performances for each of the three categories of problems: (a) remember, recognize, and imagine; (b) apply, use, and predict; and (c) construct, create, and invent and provide examples on how each level of performances fit into different problem categories (Figure 17).

Dijkstra and van Merriënboer maintained that these different categories of problems usually appear together. Therefore, knowledge that is required for one category of problem solving is often indirectly required for the other type of problem-solving activity. Furthermore, they state solving these problems result in: (a) conceptual knowledge how to categorize objects and which relationship between objects exist; (b) hypotheses and theories why and how objects change; and (c) design rules for sketching and developing artifacts or new objects. The three types of problems and the information
Figure 17. Categorization of problem types according to Dijkstra and van Merriënboer (1997) and their required performances

and problem solving procedures that are the result of solving the problems can be used as a framework for the descriptions of knowledge and skills, for assessment of these and for the design of instruction. The problem situations can be used for clarifying the goals of education and for guiding students’ activities within the subjects.
Dijkstra and van Merriënboer maintain that this framework could be used in: (1) for the design of appropriate learning environments, the type of problem to be solved as well as the required level of performance yields guidelines for the selection of instructional strategies or methods; and (2) as a meta-model to characterize existing ID theories and models. Dijkstra and van Merriënboer (1997) add:

Then it becomes clear that most ID models developed so far concentrate on lower levels of performance (i.e., the teaching of concepts, principles, or plans), or in a lesser degree, on middle levels of performance (i.e., the teaching of conceptual or causal networks and procedures). With regard to procedures, most models further concentrate on algorithmic instead of heuristic procedures. Up to present, ID models to support construction of theories are almost absent (p. 41-42).

Dijkstra and van Merriënboer contend that “exploration and systematic empirical research are the kinds of activities that are badly needed to further develop and validate such ID theories” (p.42) that can address higher-order, complex, problem-solving outcomes. Therefore, a valid and reliable assessment methodology for complex problem-solving outcomes turns out to be the crucial piece of the puzzle of which instructional strategies work well under what conditions for complex, ill-structured problems. What do we know about the requirements of a reliable assessment methodology for complex problem solving outcomes? This is discussed in the following section.

**IMPLICATIONS of PROBLEM-SOLVING RESEARCH for ASSESSMENT**

As discussed in the previous section, existing research on problem solving suggests that domain knowledge is essential for solving complex, ill-structured problems. Traditionally, domain knowledge is assessed by asking learners to recall what they know using a form of standardized test. However, research on complex, ill-structured problem solving also suggests that there are important cognitive activities or skills that are
required in order to be able to solve complex, ill-structured problems. Of these, the two most important kinds are structural knowledge and causal reasoning that do not lend themselves for assessment by standardized tests (Jonassen, 2004; Scandura, 1977; Seel, 1999).

Structural knowledge is the knowledge of how concepts within a domain are interrelated (Jonassen, Beissner, & Yacci, 1993). In other words, structural knowledge refers to the integration and organization of concepts in an individual’s memory. Scandura (1977) maintains that structural knowledge enables learners to form the complex interconnections required to make predictions and inferences necessary for solving problems. Jonassen & Wang (1993) suggest that structural knowledge of a content area, that is, the knowledge of the structural inter-relationship of knowledge elements is necessary in order to flexibly use that knowledge. Indeed, a number of research studies have shown that structural knowledge is important in problem solving (Chi & Glaser, 1985). For instance, Robertson (1990) used think-aloud protocols to assess structural knowledge of students and found that the extent to which those think-aloud protocols contained relevant structural knowledge was a strong predictor of how well learners would solve transfer problems in physics on a written exam. In fact, structural knowledge was a much stronger predictor than either aptitude (as measured by standardized test scores) or performance on a set of similar problems. Therefore, Robertson (1990) concluded that cognitive structures that connect the formula and important concepts in the knowledge base are important to understanding physics principles and it seems it is more important than aptitude.
As seen on the study conducted by Robertson (1990) and others that have been reviewed in this chapter earlier, providing solver a problem scenario and asking him or her to think-aloud while solving the problem has proved to be a valid and reliable method to assess structural knowledge (Ericsson & Simon, 1984, 1993) and is a very common assessment method in research settings. However, think-aloud methodology is labor-intensive and takes considerable time to conduct. Therefore, it is not a very cost-effective method in educational settings for assessment purposes. Instead, semantic networking tools such as concept mapping has been suggested (Novak, 1998) for the purposes of assessing structural knowledge of students. Figure 18 presents an example concept map adapted from Novak (1998).

Concept mapping has been widely studied in a number of different domains and validated as an assessment tool (Battle, Fives, Moore, & Dryer, 2003; Herl, O'Neil, Chung, & Schacter, 1999; Liu, 1994; Liu & Hickey, 1996; McClure, Sonak, & Suen, 1999; Ruiz-Primo & Shavelson, 1997; Taricani & Clariana, 2006; Wilson, 1993). Furthermore, concept mapping has been studied and utilized as an instructional tool as well as an instructional strategy (Jonassen, 1993a; 1993b, Ross & Munby, 1991; Schmid & Telaro, 1990; Smith & Dwyer, 1995; Willerman & Mac Harg, 1991; Zwaneveld & Vuist, 1995), as a tool for collaborative problem solving and decision-making (Chung, O'Neil, Herl, & Dennis, 1997; Hughes & Hay, 2001; Roth & Roychoudhury, 1993; Roth & Roychoudhury, 1994), and as a research and evaluation tool (Markham, Mintzes, & Jones, 1994; Wallace & Mintzes, 1990).

Causal reasoning is the other important cognitive component skill that is argued to be a very important for solving complex, ill-structured problems. Causal reasoning, like
structural knowledge, requires the attributions of one set of concepts to another.

However, with causal reasoning, the attributions are causal. That is, one concept causes a change in state of another concept. Research on complex problem solving suggest that causal reasoning is perhaps the most important cognitive skill for complex, ill-structured problem solving (Dörner, 1987) because such problems usually involve changes in states brought on by causal factors. Causal reasoning is especially important when it comes to solving ill-structured problems. Ill-structured problems are difficult to solve because the behavior of the system in which the problem occurs is not predictable. Forrester (1961) maintain that solving ill-structured problems often requires a different perspective, namely the systems perspective. According to Jonassen (2004) there are two
important ideas in systems theory that must be represented by problem-solvers in order to be able to solve complex, ill-structured problems (p. 77):

…[First,] usually, causality is not a one-way process. Hunger causes eating although that is partially true, what causes cessation of eating, or does the organism continue to eat until it bursts? Most systems in which problems occur can also be seen as closed-loop systems, in which the components of those systems are interdependent and controlled by feedback. The perception of hunger causes eating, which occurs until the perception ceases (feedback), which causes a cessation of the eating behavior until the perception occurs again (another form of feedback). Something that is initially an effect can become a cause.

[Second,] most real-world systems are dynamic; they change over time. In well-structured problems, the entities do not change, but in complex, ill-structured problems such as everyday problems, the entities in the problem are constantly changing. They may be affected by each other or by external forces. Hunger states, for example, change not only with the volume of eating but also may depend on the levels of exercise or the kinds of the food available.

The results of Dörner and colleagues’ (1983) LOHOUUSAN study substantiate these statements. Jonassen (2000a) also argues that in order to assess causal reasoning, students should be presented by new, authentic, unencountered scenario-based questions that require them to make predictions about what will happen or draw an inference about what did happen. One of the semantic networking tools that is appropriate for representing the dynamic nature of complex, ill-structured problems is causal influence diagrams, which show the causal relationships and circular feedback in systems (Seel, 1999). A causal influence diagram illustrates the interdependence of system parts, specifically the conditions under which system components are interdependent and the effects of that interdependence. For instance, Figure 19 describes the causal relationships in a family where a husband who is stressed at work drinks more alcohol, which in turn, causes more stress. Alcohol also causes a reduction in his health, and as his health crumbles, his work productivity decreases, which causes more stress at work, and so on.
In order to build causal influence diagrams, one must determine the choices that are available in a system and the trade-offs that result from those choices. Articulating the various causes that affect a problem is necessary to being able to solve it.

These properties of causal influence diagramming make it an ideal candidate for an assessment tool for measuring progress of learning in a student’s understanding of a complex problem domain. The following section provides a review of four studies that investigated causal representations as an assessment tool for higher order, complex problem-solving outcomes.

**Towards an Assessment Methodology Based on Causal Representations**

Two instructional design research groups investigated causal representations as an assessment tool for complex problem-solving tasks in a variety of domains. Although both groups had different focus and approaches, the findings of their research efforts
were complementary. This section is intended to provide an overview and synthesis of the four studies conducted in this regard.

**Study one.** Ifenthaler and Seel (2005) conducted two studies in order to assess the learning-dependent progression of mental models. They developed an assessment methodology based on simple causal diagrams and a stochastic model (cf. Bartholomew, 1967) to assess similarities or dissimilarities of learners' models on the basis of transition probabilities.

For the purposes of these studies, a computer-based multimedia learning environment was designed with declarative and heuristic modules. The curriculum mode contained scientific information about the prevailing content. Here, the learners could navigate through different topics. However, there were no models available within this module that can affect learners’ ability to construct of their own mental models. In this learning environment, there were four supplementary modules (Ifenthaler & Seel, 2005, p. 320):

1. "Wissen.de" (p.320), which includes various text documents, audio recordings, and pictures to complement the information in the curriculum mode.
2. Model-Building-Kit (MoBuKi), which provides students with information about models, model-building, and analogical reasoning as well as examples of successfully applied analogies on a meta-level. In other words, MoBuKi offers heuristics for problem solving which can be transferred to various content. 
3. A module for presentation of the problem and the learning task, where the students were requested to solve a complex problem. The task the students were provided with was to construct two models - one model which explains the stated problem (explanation model) and a second model with relations and functions similar to the explanation model, which was called an analogy model.

4. The toolbox "MS PowerPoint" (p.320) module, which allowed students to externalize their mental models on the problem they were trying to solve.

In both studies, two factors of the model-centered discovery learning were varied: (a) individual vs. collaborative learning, and (b) self-guided vs. scaffolding-based learning.

Fifty-two (21 male and 31 female) secondary school students (9th grade) took part in the first study. Average age was 15 years. These students used the learning environment as part of their geology course. The subjects were randomly divided into two groups of 26 each. The first group of students worked individually while the other worked as collaborative teams.

Student models are stored at pre-defined stages of students' learning process, a preconception (a priori) model, and after each day of the class for seven days and an after model at the end of day 8, e.g., the take-home model. For this last model, the students were only given 15 minutes but were not given the model of the preceding day nor were they allowed to use the computer-based multimedia learning environment, except for the toolbox MS PowerPoint. Accordingly, students had to construct their own model on a blank piece of slide within limited time.
The models produced by the individual learners (13 self-guided, 13 scaffolding-based) were selected in order to measure their learning-dependent progression. Two external groups of "model-raters" were asked to assess student models to determine whether there were similarities or differences in the structures of the models. The first group consisted of 31 language students with different nationalities and native languages with an average age of 22. This first group assessed the explanation models. The second group consisted of 21 first-year instructional design students with an average age of 21. This second evaluation group assessed analogy models.

The explanation and analogy models were put into chorological order from day one to day eight as a MS PowerPoint slide show. Two video projectors were used to project models next to each other in chronological order from one day to the next. Accordingly, model raters were able to compare similarities or dissimilarities from different stages of the students' learning process. The model-raters were provided with a questionnaire on which they had to mark "+" if the projected model had a similar structure and "-" if it had a different structure. Each slide show consisted of seven model comparisons. The first comparison consisted of the learner's preconception model constructed before they worked with the multimedia learning environment and the first day learning model, constructed after the first day of working with the multimedia learning environment. Comparisons of 2 to 6 consisted of the models constructed during the subsequent days working with the learning environment (3, 4, 5, 7, 8). At this phase, the learners were allowed to continue each new day with their last stored model from the preceding day. The last comparison consisted of the last model constructed while working in the learning environment and the so-called take-home-model (8th) which the
learners constructed on the last day without using the learning environment or the preceding models.

Model-raters were instructed only to compare the surface (structure) of the models. Accordingly, the quality of relations and semantic meanings within the models had to be ignored by the model-raters (Ifenthaler & Seel, 2005).

**Results of study one.** Both groups of model-raters compared the same set of 26 slide shows on two different days in order to test the reliability of our instrument. The coefficient of internal consistency calculated for the first evaluation group using Cronbach's coefficient alpha was .84 (n=5642). For the second evaluation group, the coefficient of internal consistency calculated using Cronbach's coefficient alpha was .86 (n=3822). These findings provide evidence that our instrument can measure similarities or differences of models reliably. The collected data of all model-raters provide a basis for a first application of the measurement of change in mental models.

Probabilities of change from one model to the following one was calculated for both the explanation models and the analogy models.

*Explanation Models*: The probability of change between the preconception model and the first learning-day model was very high (p=.99). Between the last learning-day model and the take-home model there was also a high probability of change (p=.80). Between the first and the last learning day, the probability of change decreased at an average of 16.9% per day.

The probabilities of change of all students were partitioned into two groups based on the experimental variation (scaffolding-based vs. self-guided learning) and entered into a one-way ANOVA. The analysis revealed that a significant effect for the
comparison of the models between the measuring point 6 and 7 (F=11.45, p<0.05). The probability of change in the scaffolding-based learning group, p=.439 is significantly higher than that in the self-guided learning group. However, a one-way ANOVA showed no further significant differences between the two learning groups on the preceding and following measuring points.

Analogy Models: The results for the analogy models revealed a slightly different picture. The average probability of change between the preconception model and the first learning-day model was expectedly high (p=.80). However, unlike the results of the explanation models, there was no continuous decrease in the probability of change between the first and the last learning day models. Interestingly, the students changed their mental models with a higher probability from measuring point 4 to 5 (p=.65) than on the preceding or following measuring points. Ifenthaler and Seel (2005) explained this result as follows: "...many students stopped constructing their analogy model by the second or third measuring point because they were more focused on the construction of their explanation model. Therefore, only after they were satisfied with the explanation model they constructed did the students start to work on their analogy model” (p.333).

As in explanation models, the probability of change from the last-learning-day model to the take-home model was high (p=.86) in the analogy models constructed by the students.

Furthermore, in accordance with the experimental variation, the probabilities of change of all students were split into two groups (scaffolding-based vs. self-guided learning) and entered into a one-way ANOVA. The results showed no significant
differences between the experimental variations of model-centered discovery learning in Study 1 (Ifenthaler & Seel, 2005).

**Study two.** The second study conducted by Ifenthaler and Seel (2005) was a replication of the first study in a different subject-domain. 79 secondary school students (40 male and 39 female) of a geophysics course participated in the second study. The average age of the students were 14.24 (SD=1.253). Of these 79 students, 33 of them took part as individual learners and 46 students worked collaboratively. The models produced by the individual learners (16 self-guided, 17 scaffolding-based) were selected in order to measure their learning-dependent progression. Again, model-raters were asked to assess the models with regard to similarities and differences in the structure. As in the first study, students' task was to construct two models (explanation and analogy).

In this second study, an external evaluation group was also used to assess the student models. The group of model-raters who had to assess the explanation and analogy models consisted of 23, third-semester instructional design students. Since the assessment instrument was found to be highly reliable in the first study, the model-raters assessed the student models only once.

**Results of study two.** Study two contained only seven points of measurement due to organizational constraints as opposed to nine in the previous study. To describe the trajectory of the learners' externalized mental models, transition probabilities for the explanation and analogy models were calculated.

*Explanation Models.* Again, in the second study, a high probability of change between the preconception model and the first learning-day model (p=.87). Also, a high probability of change between the last learning-day model and the take-home-model
In addition, a continuous decrease was observed in the probability of change between the five models constructed by the students while working with the multimedia learning environment.

All students were partitioned into two groups (scaffolding-based vs. self-guided learning) based on the experimental variation and computed a corresponding one-way ANOVA. A significant effect between the scaffolding-based learners and the self-guided learners between the measuring point 3 and 4 (ANOVA, F=4.62, p<.05). At this measuring point, the probability of change in scaffolding-based group (p=.552) was significantly higher than in the self-organized group (p=.271). However, one-way ANOVA showed no further significant differences between the two learning groups (scaffolding-based vs. self-guided) on the preceding and following measuring points.

**Analogy Models.** The results of analogy models of the second study revealed a different picture than the first study. The average probability of change between the preconception model and the first-day-learning model was rather low (p=.28). Ifenthaler and Seel (2005) attributed this result to the difficulty of the problem used in the second study compared to the one in first study. Furthermore, they argued that students of geophysics course were more likely to have less prior knowledge about geophysics than students of geology would have concerning geology. Thus, Ifenthaler and Seel (2005) argued that the students focused on constructing their explanation models but did not start their analogy model. A detailed analysis of students' models, where they found empty analogy slides, confirmed their assumptions.

For the rest of the measuring points, a higher probability of change was calculated (p=.51). After a decrease in the probability of change for the following three measures, a
high probability of change was computed between the last-learning-day model and the take-home model (p=.58).

Furthermore, in accordance with the experimental variation, the probabilities of change of all students were split in two groups (scaffolding-based vs. self-guided learning) and entered into a one-way ANOVA. The results again showed a significant difference between measuring points 3 and 4 (ANOVA, F=4.87, p<.05), where the probability of change in the scaffolding-based group (p=.591) was higher than in the self-guided group (p=.288).

In summary, as far as the explanation models were concerned, in both studies, there was a high probability of change between the preconception model and the first-learning-day model. In both studies, the students had worked at least two hours with the multimedia learning environment before constructing the first-day-learning model. Therefore, the investigators argued that this high probability of change was expected since the students acquired new knowledge concerning the phenomenon in question.

Contrary to this result, on average, there was a decrease in the probability of change from the first-day-learning explanation model to the last-day-learning explanation model. Ifenthaler and Seel (2005) attributed this to the fact that a learner's model was not easy to change or modify if there was a predominant subjective plausibility about her or his mental model. Furthermore, they stated that the students always started a new learning-day with their learning-day model from the previous day. With regard to mental model theory, this was a weak point in their study since mental models are subjective ad-hoc constructions which individuals use in order to solve complex problems (Rumelhart
& McClelland, 1986b; Seel, 2001). Accordingly, the learners should have constructed a new model on each learning day.

Ifenthaler and Seel (2005) attributed the difference in the probability of change between the experimental variation of the model-centered discovery learning to the fact that in the first study all students received feedback on their 6th learning-models before they constructed 7th learning-day model. The feedback for the students in the self-guided learning group was rather simple. Unlike the self-guided learning group, the students in the scaffolding-based group received detailed feedback on their models. Therefore, the scaffolding method may be regarded as an effective instructional strategy. These findings correspond to findings from Seel and Schenk (2003).

As for the analogy models, for the first study, the high probability of change between the preconception model and the first-day-learning model was similar to the results for the explanation models. Accordingly, the analogy models in study 1 reflected the structures of the explanation models at this stage of the learning process. The decrease in the probability of change from learning day one to the following day was also comparable to the explanation models. However, the results of analogy models of the second study revealed a different picture than the first study. The average probability of change between the preconception model and the first-day-learning model was rather low (p=.28). Ifenthaler and Seel (2005) attributed to the more difficult nature of the problem in the second study.

The results of these two studies with explanation and analogy models demonstrated that the assessment methodology based on causal representations can be considered a suitable method of measuring change in mental models of students
throughout their learning, i.e., assessing the learning-dependent progression of mental models. Only by measuring each learner's progress in learning over time is it possible to effectively change the instruction at the right time of the learning process.

Furthermore, results of these two studies suggested that the assessment instrument based on causal representations was highly reliable. Ifenthaler and Seel (2005) pointed out to the fact that the model-raters had no difficulty in assessing similarities or differences between the models presented. Furthermore, they stated that the model-raters were highly motivated while assessing students' mental models.

Ifenthaler and Seel (2005) also argued that MS PowerPoint is a very economical tool for the purposes of their assessment methodology because the students' models that had already been constructed with MS PowerPoint could be easily transported into slide shows. Also, in their study, students were already familiar and comfortable with using MS PowerPoint.

As for their further research plans, Ifenthaler and Seel (2005) stated that they planned to extend the measurement of change with regard to the quality of relations and semantic meanings within the models and the underlying stochastic model. Accordingly, three layers of the measurement of change is being planned: (1) the surface structure of mental models, (2) the deep structure or quality of relations, and (3) the semantic structure or quality of semantic meanings within the mental models.

Ifenthaler and Seel (2005) conclude that their measurement instrument based on causal representation as it had been developed so far was a first step toward an answer to the unsolved problem of how the learning-dependent progression of mental models can be assessed.
**Study three.** Following two studies represent the efforts of another team of instructional design researchers investigating the utility of causal influence diagrams as an assessment methodology for complex problem solving. However, their approach were slightly different from the two studies discussed above.

Christensen, Spector, and Sioutine, and McCormack’s (2000) general hypothesis was that within the context of a complex, ill-structured problem situation, experts would construct similar causal influence diagrams and that these diagrams would be noticeably different from those constructed by less experienced persons. As a consequence, Christensen and colleagues (2000) argued that, the level of fit between a learner’s causal loop diagram and that of an expert’s would be a reasonable predictor of level of expertise in that problem domain. Their methodology was partly quantitative and partly qualitative in nature. Christensen and colleagues (2000) maintained that a measure of fit between a learner’s causal influence diagram and an expert’s could be derived based on similarities in the set of key concepts identified for a particular problem domain, and the types and directions of links.

In other words, in order for this assessment methodology to work, it was necessary to determine whether or not experts make similar assumptions, identify similar key factors, and produce recognizably similar causal influence representations. One can then use such patterns as a benchmark to assess how far learners are from those expert responses and see how their representations change after instruction and experience. Two studies were conducted to test this assessment methodology.

In the first pilot study, three different problems were selected to determine whether this assessment methodology works. The problems selected were: (1) the spread
of an infection; (2) yeast reproduction; and, (3) a deer population problem (Christensen et al., 2000). In each domain, three to five experts were asked to produce causal influence diagrams on paper representing the concepts, factors, and causal relationships thought to be associated with a short problem description. Once convinced that there would be a recognizable pattern of responses from experts, the problems were then presented to students.

The pilot study included a problem scenario (Figure 20) and a questionnaire (Figure 21). The problem scenarios were developed by the research team based on a review of prior research in these three problem domains.

Subject experts were asked to identify and describe key concepts and variables as well as relationships and effects, just as the experts were asked to do. The tool was then tested with students using the same problem scenarios presented to the expert panels. None of the students had previous experience with system dynamics or system thinking.

---

**Read the passage below:**

The total population of Tech, a town in Brazil, consists of two sub-populations, the susceptible population and the infectious population. The susceptible (non – infected) population is drained by infection spreading in the population at a particular rate. At the same time, the infectious population is increased by the infection spreading at the current rate. The infection rate (the rate at which the infection is spreading) changes over time. It depends on the rate of contacts between members of the infectious population and members of the uninfected population, called red contacts, leading to the transmission of decrease. The rate of red contacts is determined by the rate of contacts between members of the infectious population and any other member of the population as well as the probability that the person contacted is actually non-infected. This probability is closely related to the density of susceptible in the population in total. The rate of contacts between members of the infectious population and any other member of the population is determined by the size of the infectious population and the rate at which each of them meet with other members of the population.

*Figure 20. Problem scenario for the spread of an infection used by Christensen and his colleagues (2000). (Copyright 2000 Christensen, Spector, Sioutine, & McCormack. Reprinted with permission.)*
a. List the variables or concepts you think are related to the deer population behaviour over the period of time. (Please note that you can list as many variables that you can think of that may have caused the observed behaviour. Use the back of the sheet if you need more space)

**Example:** Suppose you identify a concept P and you assume that P has some effect on the observed behaviour. Then on the “What is the name of the concept” column you will write “P”. On the “Explain the meaning of the concept” column you will write “Age of Deer” if that’s the meaning of “P”.

<table>
<thead>
<tr>
<th>What is the name of the concept?</th>
<th>Explain the meaning of the concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Age of Deer</td>
</tr>
</tbody>
</table>

b. From the concepts you have listed above indicate the relationship between each of them.

**Example:** Let us assume you have identified two concepts above as “P” and “Q”. We shall also assume that you think that “P” has a **positive** influence on “Q” i.e. An **increase** in “P” leads to an **increase** in “Q”. Below you will write underneath concept 1: “P” and underneath concept 2: “Q” and on the second column you will write a positive sign indicating the effect of “P” on “Q”. Had it been a negative effect i.e. when there is an increase in P this leads to a decrease in Q, you will write a negative sign instead of a positive sign. Now go on a fill the blank spaces.

<table>
<thead>
<tr>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Effect of Concept 1 on Concept 2 : Positive(+) or Negative(-). Note: (Not Both)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Q</td>
<td>+</td>
</tr>
</tbody>
</table>

*Figure 21.* The causal questionnaire form used by Christensen and his colleagues (2000). (Copyright 2000 Christensen, Spector, Sioutine, & McCormack. Reprinted with permission.)

Questionnaires were distributed on the first day of an Instructional Technology Strategy course at the University of Bergen in Norway, randomly giving students one of the three problem scenarios. As with the experts, students were asked to: (1) list the concepts and variables related to the described problem; (2) indicate relationships between concepts; and, (3) draw out a diagram of relationships. Students then had an opportunity to gain some expertise in the subject and in causal thinking through learning exercises. At the end of the second day, students were asked to complete the questionnaires again with a different problem than they had been given on the previous day.
Results of study three. This pilot study was aimed at determining: whether or not expert patterns of thinking and about typical problem scenarios in complex domains existed; whether novice patterns were recognizably different; and whether or not improvements in learning after instruction might be assessed using this methodology (Christensen et al., 2000). The basic answer to these three critical questions was positive. Patterns were found among the experts, student (novice) responses were different from expert patterns, and improvements after instruction could be assessed for this group.

In addition, the pilot study revealed a method to assess relative complexity. Christensen and colleagues (2000) suggested that the level of complexity of a problem can be described by:

1. the number of concepts and variables;
2. the number of interrelationships or links between concepts;
3. the signs of polarity (or direction of change in independent) variables or links;
4. the number of feedback loops and delays.

This is an important aid to designers, especially those who accept some form of elaboration theory or graduated complexity.

The deer population problem (Figure 22) was not described completely and, as a consequence, few learners mentioned concepts related to the predator population. Also, many learners mentioned variables not mentioned in the problem scenario that are only of marginal relevance to the particular problem (e.g., pollution, acid rain, etc.). This is probably due to a lack of general awareness and sensitivity in the subject population to
Read the story below:
Prior to 1907, the deer herd on the Kaibab Plateau, which consists of some 727,000 acres and is on the north side of the Grand Canyon in Arizona, numbered about 4,000. In 1907, a law was passed banning all hunting of deer from the area. By 1918 the deer population increased tenfold, and by 1924 the herd had reached 100,000. Then it started to decrease and by 1936 to 1940 it was around 10,000.

Graphical representation of the deer population over time (years)

Figure 22. Deer population problem scenario used by Christensen and his colleagues (2000). (Copyright 2000 Christensen, Spector, Sioutine, & McCormack. Reprinted with permission.)

environmental issues. However, the method did discover that experts require a much less complete problem scenario or description. In addition, the study demonstrated that this method can be used to identify when learners are focusing on distracters. Also, some learners used a description of the state of a concept (less food) when a more general concept (food supply) would have been appropriate. This is information that can aid both designers (provide complete problem descriptions) and course facilitators (use these concept maps to diagnose student misunderstanding as well as assess understanding).

The spread of infection problem in Figure 20 was more easily interpreted and most participants identified nearly all of the relevant concepts related to the populations. However, not all were able to identify the effect of density and connectivity on the infection rate. Christensen et al. (2000) reported that some students confused rates of
infection with rates of contacts. A more descriptive label for rate of contact would have been frequency of contact. In some cases, learners did not see that the total population was not changing and some did not understand how population density was defined. None of the students represented the probability of infection if there is contact with an uninfected person, although all of the experts used this concept in their causal representations. While this appears to be a trivial difference with little consequence in this problem, it becomes relevant over time and when one wants to develop more general dynamic models that take into account that over time some uninfected people become infected.

In the yeast regeneration problem (Figure 23), learners seemed to identify most of the relevant concepts and many were able to identify the relevant relationships and effects, in comparison with the expert panel. However, novices tended to introduce concepts not included in the problem description (e.g., temperature). While one way of representing this problem situation includes temperature, since there was no mention of it in the problem description, those who introduced the concept did not have a way to relate it to the rest of the model. Experts merely assumed that temperature was relatively constant throughout. Also, students had trouble with the concept of budding.

The overall results demonstrate that the degree of similarity found with experts did not appear with novices and that there were noticeable differences between novice representations in comparison with those of experts. Moreover, simple causal maps were effective in showing how subjects perceive a dynamic problem. Novices tended to use too few concepts and look for concepts outside the problem description that were often irrelevant. Spector and Davidsen (1997a) concluded that beside an assessment
Yeast is a yellowish sediment that develops in sugar solutions such as fruit juices. It consists largely of simple cells of a minute fungus and is useful particularly as an agent for fermentation in the making of bread, alcoholic beverages such as wine and bear, and other foods. During fermentation, yeast lives by breaking sugar molecules into alcohol and carbon dioxide. In fact, alcohol is one of the oldest methods known for preserving juice and food. Yeast cells reproduce by budding, as shown in Figure 1.0.

During the process of budding, small bud forms on the membrane of a mature cell. As the bud grows, it breaks away from its “mother” and forms a new plant. When put in a favourable sugar environment, yeast cells keep budding and tend to continue to develop until the sugar on which they feed reaches a critical point. At this point, available sugar is low and the yeast’s growth medium has been filled with alcohol and carbon dioxide. Since yeast cannot survive in a medium of alcohol and carbon dioxide, individual yeast cells eventually die.

Figure 23. Yeast generation problem scenario used by Christensen and his colleagues (2000). (Copyright 2000 Christensen, Spector, Sioutine, & McCormack. Reprinted with permission.)

methodology, this technique could also be used to aid instructional designers and also to assist facilitators in diagnosing student misconceptions.

**Study four.** Funded by the National Science Foundation (NSF), the second study, namely the “Enhanced Evaluation of Learning in Complex Domains” project (NSF EREC 03-542) sought to build upon the pilot study to develop a methodology to reliably determine improvement in higher order learning situations involving complex and ill-structured problems (Spector & Koszalka, 2004). This study aimed at validating a Dynamic Evaluation of Enhanced Problem-solving (DEEP) methodology as a learning assessment tool in a variety of educational contexts (biology, engineering, and medicine).

The Project was conducted through a one-year effort and involved a total of sixteen experts and forty-nine novices in three different problem domains: medical (6/14), engineering (5/18), and biology (5/17) (Spector & Koszalka, 2004, p. 8). Experts
were selected among college faculty with over five years of working experience in their specialization. Medical domain novices were graduate medical school students with no clinical experience. Engineering and biology novices were upper-level undergraduate students. All participants were affiliated with either Syracuse University or the State University of New York (SUNY) Upstate Medical University. Participants were paid a nominal fee for their participation.

Data collection was carried out via the DEEP Problem Conceptualization Tool (Figure 24), a Web-based software that was developed and pilot tested to assist data collection efforts. The DEEP conceptualization tool first asked the participants to register with their name, create username and password for themselves and answer the questions in the background survey.

*Figure 24. The DEEP tool used by Spector and Koszalka (2004). (Copyright 2004 Spector & Koszalka. Reprinted with permission.*)*
Following registration, participants were administered a background survey (Figure 25), which included questions to collect basic demographic information about the participants. The background survey also included questions aimed at identifying participants’ perception of their expertise in the specialized domain, their inclination to engage in deliberate practice and learning to improve their performance as well as the length of their work experience. In addition, two questions were asked to determine their relative comfort in working with paper-based versus computer-based materials and reading text versus viewing diagrams.

Figure 25. A screenshot of the ‘Background Survey’ presented by the DEEP tool (Copyright 2004 Spector & Koszalka. Reprinted with permission.)
Following the survey, the DEEP Tool presented participants with an instructions page that included the purpose of the study and a description of the steps to complete the task (Figure 26). Participants were then presented with two problem scenarios (Figure 27) in their domain of specialization. These two scenarios were of different difficulty levels (during the post-interview, respondents in all domains stated that they found the second scenario simpler than the first). For each scenario, respondents used the DEEP Tool to record the concepts, issues, factors, and/or variables that they considered relevant to developing a solution for the problem scenario, provided detailed explanations for each.

Figure 26. Instructions page from the DEEP tool (Copyright 2004 Spector & Koszalka. Reprinted with permission.)
item they mentioned, and drew a diagram showing the relationships among them (Figure 28). Lastly, they recorded their assumptions, information, and other considerations that they believed were relevant to developing an acceptable solution for the scenario.

**Results of study four.** In order to establish that the DEEP methodology is both reliable and robust, this study focused on (Spector & Koszalka, 2004):

1. determining whether experts exhibit recognizable patterns of responses (problem conceptualizations) to complex problem scenarios in three quite different problem-solving domains; and,
2. developing measures of similarity between problem-solving patterns that can show change or progress over time and towards expertise.

Originally, the DEEP methodology was planned to involve three levels of analysis (surface level, structural level, and semantic level). During the analysis process, the structural and semantic levels were merged since it was found that at a practical level, structural analysis depended on the ability to say that nodes in different responses
represent the same or similar thing, which required semantic analysis (Spector & Koszalka, 2004).

Level one analysis, i.e., surface analysis, involved the number of nodes and links identified as relevant to the problems, the density of annotations of those nodes and links, and the general appearance of the representation. Responses were analyzed in terms of number of nodes, one-way links, two-way links, words per annotated node or link, and the first several nodes identified. Results of level one analysis showed that patterns between novices and experts sometimes changed depending on the problem scenario. For example, engineering experts provided denser elaboration for links than novices in response to scenario one, but the reverse was true with regard to scenario two. Spector and Koszalka (2004) concluded that this anomaly might just be a result of having a small pool of expert respondents; it should nevertheless be explored in future studies. Another interesting finding was that novices sometimes provided denser elaborations for nodes and links than experts. On average, expert medical practitioners provided denser elaborations (more words per node and link) than novices, but this pattern did not occur in the engineering and biology domains (Spector & Koszalka, 2004).

Structural analysis involved similarities and differences in responses in terms of the relationships among the various nodes. This analysis depended on the ability to say that nodes in different responses represent the same or similar thing, which required semantic analysis. Structural analysis, therefore, involved comparing two representations with regard to the number and percentage of the same or similar nodes and links. The following were the key steps in the process (Spector & Koszalka, p. 27):
- Identify key protocols to look for in each response based on the domain expert’s comments and responses to problem scenarios;
- Code five expert and three novice responses using those protocols;
- Domain experts review the initial coding to determine consistency and whether or not changes to the protocols are required;
- Complete the coding of responses using the modified protocol;
- Formulate similarity measures and comparative assessments based on the coded responses.

A subset of the protocols was coded by both the domain expert and two research assistants until the domain expert, research assistants, and principal investigators had strong confidence that variations in coding or coding bias were not a significant concern. Initial reliability ratings were 65% for biology, 78% for engineering and 90% for medicine (Spector & Koszalka, 2004). Two research assistants, then, coded all the protocols independent of each other.

Level one analysis resulted in variances with respect to different domains as well as different scenarios. In both scenarios, in the biology domain the experts’ representation had more nodes and links while the novices, on average, used more words to describe their nodes and links. However, in the engineering domain, in the first scenario, novice representation, on average, had more links and more words per node while expert representations had more words for links only. The average number of nodes were similar in both expert and novice representations. In scenario two, the engineering experts’ representations had more nodes and links than those of novices, similar to the biology
domain. In the medical domain, the situation was completely reversed, as expert representations in the first scenario show less nodes and links than those of novices’ while experts use more words, on average, per node and per link. In scenario two, expert and novice representations contained, on average, the same number of nodes, links, and number of words per link while experts utilized, on average, more words per node than novices (Spector & Koszalka, 2004).

In level two & three analysis, in the biology domain, as compared to the novices, experts had a much higher percentage of cause and effect links and a much lower percentage of correlation links in both scenarios. In both scenarios, the highest percentage of links made by experts involved correlations; for novices, it was correlations in scenario one and examples in scenario two.

In the engineering domain, there were differences in the types of links made by experts and novices. In the first scenario, the highest percentage of links made by experts involved correlations but the second scenario involved more examples. For novices, the highest percentage of links in scenario one was correlations, in scenario two, there were no correlation-links and the highest number of links was from examples. In scenario one, the experts had lower numbers of links than novices on every link type except for example- links which both parties had none. In scenario two, the percentage of example-links was similar for experts and novices where the percentage of cause-effect links was much higher for novices than experts and the percentage of mathematical links much higher for experts than novices (Spector & Koszalka, 2004).

In the medical domain, the types of links made by experts and novices also showed differences. The highest percentage of links made by both experts and novices in
scenario one were cause and effect. In scenario two, experts had almost an equal number of cause and effect and process links whereas novices had an approximately equal numbers of cause and effect and correlation links. The percentage of process links was much higher for experts than novices in both scenarios. Novices had a higher percentage of links that were correlations as compared to the experts in both scenarios (Spector & Koszalka, 2004).

In all three domains, it was possible to identify factors around which links tended to cluster in responses. These factors showed differences in expert and novice responses. For instance, in the medical domain, in scenario one, ‘tests,’ ‘differential diagnosis,’ ‘diagnosis,’ were the three most dense nodes across expert responses while across novice responses, the three most dense nodes were ‘history of present illness,’ ‘hypothesis testing,’ and ‘chief complaint.’

Figure 29 is representative of maps drawn by one of the domain novices showing clustering in the medical domain scenario. Highlighted nodes indicate (because of the density of the node) the central issues for the problem conceptualization identified by the respondent. Figure 30 was drawn by one of the experts for the same scenario in the medical domain.

Overall, the results of this study showed parallels to prior research in expert-novice differences in problem solving in that there were a variety of differences among the experts and novices within each of the domains studied. For example, the number of nodes and links varied among novices and experts and within domain scenarios. Patterns also emerged across the domains that support the hypothesis that experts conceptualize complex problems in recognizably similar ways and that these conceptualizations are
Figure 29. A sample cluster from one of the novices on the medical scenario. (Copyright 2004 Spector & Koszalka. Reprinted with permission.)

Figure 30. A sample cluster from one of the experts on the medical scenario. (Copyright 2004 Spector & Koszalka. Reprinted with permission.)
distinct from those of novices. These patterns included similarities and differences among
the representative nodes, levels of descriptions of nodes and links, and types of
relationships shown in the conceptualizations (Spector & Koszalka, 2004).

Furthermore, on average, the experts in all three domains tended to identify more
concepts (nodes) in their representation than novices in their domain. Experts’ nodes
tended to include both information specifically from the scenario and non-stated
information deemed important to the problem. Novices on the other hand tended to
include mostly information that was stated in the scenario, for example summarizing the
given information. Spector and Koszalka (2004) attribute this to the fact that experts may
be better able to make inferences from problem situations based on experience level and
deeper domain and application knowledge than less knowledgeable and less experienced
novices.

In many cases experts tended to use denser descriptions of nodes and links than
novices to describe their representations. This is attributed to the fact that experts had
deeper knowledge of the key factors conceptualized in the scenarios and how these
factors related to each other (Anderson, 1982; Ericsson & Smith, 1991; Milrad, Spector,
& Davidsen, 2002; Sfard, 1998). Thus, experts were better able to explain the scenario
illustrating a deep foundational knowledge of their domain.

Finally, experts, on average, showed more causal relationships that narrowly
clustered among key concepts central to their problem representation. Novices tended to
have wider clusters, potentially indicating uncertainty about key areas of focus in
problem scenarios. Spector and Koszalka (2004) attributed this to the stronger abilities of
experts to identify key aspects of problem scenarios within their domain and a richer knowledge of connections among central concepts in domain-related problem scenarios.

**Section Summary**

This section presented four studies that investigated the utility of causal representation as an assessment tool for complex problem-solving outcomes.

Ifenthaler and Seel (2005) developed a stochastic model to assess similarities or dissimilarities of learners’ causal representations on the basis of transition probabilities. Their proposed assessment methodology involved three layers of analysis: (1) the surface structure of the causal representations; (2) the deep structure or quality of relations; and (3) the semantic structure or quality of semantic meaning within the causal representations.

Initial investigations of Ifenthaler and Seel (2005) involved analysis of the surface structure. Two important findings were reported by Ifenthaler and Seel (2005). First, the two studies they conducted demonstrated that their assessment methodology based on causal representations can be considered as a suitable methodology for measuring change in mental models of students throughout their learning. In other words, Ifenthaler and Seel (2005) showed that simple causal diagrams allowed individuals to represent their conceptualizations of the problem space.

Secondly, the studies by Ifenthaler and Seel (2005) demonstrated that their assessment instrument based on causal representations was highly reliable. Model-raters in their study did not report any difficulties in evaluating visual similarity of any two given causal representations.
The DEEP methodology investigated in two studies by Christensen et al. (2000) and by Spector and Koszalka (2004) also involved assessment of learners’ causal representations in three levels: (1) surface, (2) structural, and (3) semantic. However, there are differences between the two methodologies in terms of how they go about assessing surface level similarity of representations. The DEEP methodology takes into account the aspects of representations that can be counted such as the number of nodes, links, average word accounts etc while the methodology proposed by Ifenthaler & Seel (2005) ask the model-raters look at the models and pass a judgment on whether or not any two representations are similar. Nevertheless, studies with both methodologies demonstrated that causal representations can be used to externalize problem spaces of solvers’. Furthermore, these studies demonstrated that causal representations enable assessment of the changes in problem conceptualizations of learners.

The DEEP methodology, is based on the view that learning can be viewed as the progressive development of expertise (see Sfard, 1998). Moreover, the DEEP methodology is based on the notion that experts exhibit recognizable patterns in their conceptualizations of complex problems and novice responses are recognizably different from those of experts (Spector, Christensen, Siotine, & McCormack, 2001). Therefore, three questions were raised in order for the DEEP methodology to be a reliable and robust assessment methodology (Spector et al., 2001; Spector & Koszalka, 2004):

1. Do domain experts exhibit recognizable patterns of responses (problem conceptualizations) to a given complex problem scenario?
2. Are novice responses to a given complex problem scenario recognizably different than those of experts?

3. Is it possible to develop measures of similarity between problem-solving patterns that can show change or progress over time and towards expertise?

Initial answers to these questions were positive in the three domains studied by Spector and Koszalka (2004). Based on their findings, Spector and Koszalka (2004) maintained that the DEEP methodology represents a major step forward in developing a robust and reliable methodology for ascertaining progress of learning and relative level of expertise in complex domains for which standard solutions often do not exist. However, Spector & Koszalka (2004) also emphasized that the method is still in its infancy and that especially due to the domain-dependence of complex, ill-structured problems, more studies are required in different domains.

**CHAPTER SUMMARY AND CONCLUDING REMARKS**

As stated in the first chapter, the motivation behind the proposed dissertation study was the lack of a robust assessment methodology to reliably assess progress of learning in domains requiring complex, ill-structured problem solving.

In this direction, this literature review included four major sections. The first section was intended to frame later discussions in the chapter and presented various definitions of problem and problem solving identified in the literature. Furthermore, a classification schema was proposed for different types of problems.
In the second section, eight different traditions of problem-solving research were discussed. Variances in the results of different problem-solving traditions were explained by the differences in the types of problems utilized in different traditions. In sum, the review of literature on problem solving confirmed that the processes involved in complex, ill-structured problem solving are different than those involved in simple, well-structured problems. Furthermore, it was also suggested that complex, ill-structured problem solving is domain-specific.

The third section discussed the implications of research reviewed in the second section for problem-solving instruction. Differences were observed between the instructional recommendations of different traditions of problem-solving research. This was attributed to the impossibility to generalize the results of research conducted with one type of problems to the other. In addition, the review of problem-solving literature confirmed the necessity for methods to assess complex, ill-structured problem-solving performance (see, e.g., Baker & Schacter, 1996; Herl, O'Neil, Chung, & Schacter, 1999), which require cognitive complexity (see, e.g., Allison, Morfitt, & Damaerschalk, 1996; Andrews & Halford, 2002; Granello, 2001; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987; Suzuki & Harnisch, 1995) and higher-order problem-solving skills (see, e.g., Dabbagh, Jonassen, Yueh, & Samouilova, 2000; Funke, 1991; Jacobson, 2000; Jonassen, 2003; Jonassen & Hernandez-Serrano, 2002).

Typically, performance on actual problems, while generally desirable for determining actual level of expertise, is less appropriate for complex problem solving situations since these often require teams of experts and specialists interacting over a period of months to develop an actual solution (Spector & Koszalka, 2004). Furthermore,
it is hard to evaluate individual students on the basis of actual performances since such problems do not have standard ‘correct’ responses; responses are often contextual and one often should build proper argumentation to defend his or her response to complex, ill-structured problems (Funke, 1991; Jonassen, 1997; Sternberg, 1995; Voss, Wolfe, Lawrence, & Engle, 1991). Think about the standard solution for the question of how to build and sustain world peace!

The fourth section discussed the implications of problem-solving research reviewed in the second section for assessment of problem-solving skills. One methodology that was used in various studies to assess problem solver’s structural knowledge about the complex problem domain was the think-aloud methodology (Ericsson & Simon, 1984; 1993). The think-aloud methodology basically involves providing a solver a problem scenario and asking him or her to think-aloud while solving the problem. Think-aloud methodology has been shown as a valid and reliable method to assess a solver’s problem space in various studies (see, e.g., Battle, Fives, Moore, & Dryer, 2003; Herl, O’Neil, Chung, & Schacter, 1999; Liu, 1994; Liu & Hichey, 1996; McClure, Sonak, & Suen, 1999; Ruiz-Primo & Shavelson, 1997; Taricani & Clariana, 2006; Wilson, 1993). The think-aloud method is extensively used in research settings and it serves very well the purpose of examining a small number of individuals in order to investigate a particular hypothesis with regard to human problem solving. However, the analysis of think-aloud protocols takes considerable time. It could take days and weeks to they could have any sense of the solver’s problem space and the decision points he or she came across during the solution of the problem. Then, the process has to be replicated with a number of individuals before it is possible to have a representation of a continuum
of different expertise levels. Think-aloud protocol analysis can be likened to grounded theory in that it is a qualitative study which involves many levels of analysis, and it takes a long time before there can be any conclusion. Therefore, the think-aloud methodology is a basic research methodology and is robust in the sense of where an individual is in that continuum of expertise but it is not appropriate to scale up as a robust assessment tool for educational and workplace settings.

In the literature, it was not possible to find an assessment methodology for complex, ill-structured problem-solving outcomes that was established as valid, reliable and robust for educational and workplace settings. However, simple causal representations were identified as a promising tool to support assessment of complex, ill-structured problem-solving outcomes. The remaining of the fourth section reviewed studies aimed at investigating the utility of causal representations for assessment purposes. Despite the differences in the particular assessment methodology utilized in these studies, they all proposed analysis of causal representation in three levels: (1) surface, (2) structural, (3) semantic meaning. Furthermore, they all emphasized that assessment of learning in complex problem-solving domains should involve learning-dependent progression.

The studies reviewed in the fourth section utilized problem demonstrated that methods involving causal representations to elicit solvers’ conceptualizations of problem space are very promising for assessing complex problem-solving outcomes. At the time of this review, the DEEP methodology by Spector & Koszalka (2004) was the one that was more fully developed. Findings of the studies with the DEEP methodology suggest that the DEEP methodology can be used to predict performance and the relative level of
expertise in some complex domains. In addition, the first level analysis of the DEEP methodology could be automated so the methodology has the potential to scale up for use in educational and performance settings involving many individuals. However, the DEEP methodology still requires further testing in a variety of different domains involving complex, ill-structured problems. For instance, in the second study (Spector & Koszalka, 2004), problem conceptualizations of experts showed similarities and they were noticeably different from novice responses. Nevertheless, there were also noticeable variances among experts, which could not be sufficiently explored as it was not the focus but it was suggested for a future study.

Another interesting finding was that as the perceived difficulty of the problem increased, the patterns between expert and novice responses changed. For instance, in all three domains that were studied, scenario two was identified as the easier problem scenario of the two by both experts and novices in post-interviews. In the biology domain, regardless of the perceived difficulty of the problem scenario, expert conceptualizations were denser than those of novices. However, in the engineering domain, the density of expert and novice representations was almost equal for the more difficult scenario one; but for scenario two, expert representations were denser. In the opposite fashion, in the medical domain, novice representations were denser in the more difficult scenario one but the density of expert and novice representations, on average were similar for the easier scenario two. These results suggest variability in expert characteristics (a) in different domains; and (b) with problems presenting different levels of difficulty. As Spector and Koszalka (2004) suggested, one reason for this variability could be the small number of experts used in the study while another could be the fact
that a convenience sample was used for the study, where all participants were from the Syracuse area involved with either Syracuse University or Upstate Medical University.

In light of this literature review, the following chapter presents details of the methodology for the proposed study that aims at further investigation of the utility of the DEEP methodology in another domain, i.e., in the domain of instructional design, which mostly involves highly ill-structured, complex problem solving.
CHAPTER 3. METHODOLOGY

OVERVIEW

As indicated in the first chapter, the purpose of the study was to explore processes underlying ill-structured problem solving and problem conceptualizations of experts and whether there are recognizable patterns among them to be used as a basis for assessment in complex, ill-structured problem solving outcomes. Therefore, qualitative research methodology was employed in order to uncover the processes underlying ill-structured problem-solving in instructional design and to explore possible expert patterns.

In this direction, the main challenge was the elicitation of problem conceptualizations of experts. As identified during the literature review, the DEEP methodology (cf. Spector & Koszalka, 2004) based on annotated causal representations showed promise in preliminary studies with complex problem domains. However, it was not tested with ill-structured problems and the methodology was still in its infancy. Therefore, another goal of this study was to extend the DEEP methodology and to investigate whether it could be used in highly ill-structured problem solving domains such as instructional design.

The remainder of this chapter discusses the design of this study. The first section details how participants were selected for the purposes of this study. This is followed by a detailed description of the materials used in the study. The third section presents how data were collected. The fourth and the final section of this chapter presents an overview of the data analysis plan.
STUDY DESIGN

Participants

In accordance with the goal of the study, purposeful, homogeneous sampling strategy was used to select subjects for this study. In homogeneous sampling, “the researcher purposefully samples individuals or sites based on membership in a subgroup that has defining characteristics” (Creswell, 2005, p.305). The purpose of this study was to investigate whether expert instructional designers exhibit recognizable patterns in their problem conceptualizations of a given complex instructional design problem scenario. Therefore, the study called for recruiting expert instructional designers. As discussed in the second chapter, the following criteria were used in previous studies to identify instructional design experts, which were also adopted for this study:

- graduate degree in the field of instructional design, curriculum design, instructional technology or a related field (Goel, 1991; Goel & Pirolli, 1989; Perez & Emery, 1995; Perez et al., 1995; Perez & Neiderman, 1992);
- a minimum of ten years of hands-on instructional design experience (Chase & Simon, 1973b; Chi et al., 1988; Ericsson, 2002; Goel & Pirolli, 1989; Perez et al., 1995; Simon, 1981); and
- recognition by peers which can be manifested by active participation in professional conferences and so on (Perez & Emery, 1995; Perez et al., 1995; Perez & Neiderman, 1992).
In order to recruit subjects for this study, a data collection session was announced with the details of the study in one of the major professional conferences on instructional design. Eleven instructional designers participated in this session. A background survey was administered to all of the session participants in order to help identify which participants satisfied above criteria to be considered expert instructional designers for the purposes of this study. In addition, the background survey was also used to obtain further information about the participants and their professional experience. The survey was divided into three sections (see Appendix 4). The first section was for basic demographic information such as age, gender, highest educational degree attained, and degree specialization.

The second section dealt specifically with participants’ instructional design experience. Questions in this section included items such as years of experience in instructional design, title of current position, instructional design activities regularly performed in their current position, participants’ self-assessment of their expertise level, and the criteria that they believe to be most relevant in determining whether someone is an expert instructional designer.

The third section of the survey sought to identify subject’s preferences for working with information. This section is adapted from Fleming’s (2001) VARK questionnaire (used with permission), which has been validated in a number of studies (Fleming, 2001). The results of this section were used to determine whether subjects’ preferred mode of receiving and providing information has an effect on their ability to construct causal representations.
Responses of two participants who did not have a minimum of ten years of hands-on experience in instructional design and a graduate degree in instructional design, instructional technology, or curriculum development were excluded from this study since these participants did not fulfill the above-mentioned criteria to be considered an expert in the field of instructional design. Furthermore, three participants dropped out early in the data collection. One of them stated that he did not believe he could complete the process. The other two stated that they had to leave due to time constraints.

Data presented in this dissertation belongs to the remaining six participants who fulfilled the criteria to be considered as expert instructional designers for the purposes of this study. Since this study is an investigative, qualitative study, smaller number of subjects was considered necessary in order to provide an in-depth understanding (Bogdan & Biklen, 1998; Patton, 1990) of the similarities and differences between the problem conceptualizations of expert instructional designers. As argued by Creswell (2005), “the overall ability of a researcher to provide an in-depth picture diminishes with the addition of each new individual or site” (p. 305). The importance of this principle was also evident in similar studies on instructional design expertise, in which the number of subjects varied from one (e.g., Goel, 1991; 1995) to a maximum of four (e.g., Perez et al., 1995) as reviewed in the second chapter. Table 1 presents demographic information of these six expert instructional designers collected via the background survey. Table 1 displays
Table 1. Participant background information

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Subject #</th>
<th>Subject #</th>
<th>Subject #</th>
<th>Subject #</th>
<th>Subject #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37</td>
<td>39</td>
<td>41</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>Avg. (years) / Frequency</td>
<td>Avg. (years) / Frequency</td>
<td>Avg. (years) / Frequency</td>
<td>Avg. (years) / Frequency</td>
<td>Avg. (years) / Frequency</td>
<td>Avg. (years) / Frequency</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>19 ~ 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 ~ 39</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>40 ~ 49</td>
<td></td>
<td></td>
<td>42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 ~ 59</td>
<td>50</td>
<td>55</td>
<td>57</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>60 ~ 69</td>
<td>69</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>70 ~</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest Degree Attained</td>
<td>Associates</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bachelor’s</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Master’s</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Doctorate (Ed.D/Ph.D)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Area of Specialization</td>
<td>Instructional Design &amp; Development</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Instructional/Educational technology</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Educational psychology, learning</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evaluation and/or Assessment</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adult education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Online learning</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Training and development</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Position</td>
<td>Instructional designer</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instructional/educational technologist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Training designer/developer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instructional media specialist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance engineer/human performance technologists</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instructional delivery specialist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Professor of IDT</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Graduate of IDT</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructional Preference [* indicates the strongest]</td>
<td>Multimodal</td>
<td>3</td>
<td>6*</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Kinesthetic</td>
<td>4</td>
<td>4</td>
<td>5*</td>
<td>6*</td>
</tr>
<tr>
<td></td>
<td>Aural</td>
<td>5*</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Read/Write</td>
<td>5*</td>
<td>5*</td>
<td>6*</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>4</td>
<td>4</td>
<td>5*</td>
<td>6*</td>
</tr>
</tbody>
</table>
individual results while also displaying frequency and percentage information for the entire sample.

Individual results are reported since they are useful while elaborating on individual representations of the participants. Among all participants, 67% were male and 33% female. The average age of the participants was 50.5 years (min. 30 yr; max. 69 yrs). All participants held graduate degrees (5 with Ph.D. and 1 with master’s) with specializations in instructional design & development (n=5; 83.33%), instructional technology (n=4; 66.67%), educational psychology (n=2; 33.33%), evaluation/assessment (n=2; 33.33%), online learning (n=1; 16.67%), and training & development (n=4; 66.67%). At the time of data collection, titles of participants’ then-current positions included; instructional designer (n=1; 16.67%); professor of instructional design and/or technology (n=2; 33.33%); doctoral candidate (n=1; 16.67%); and director of instructional technology (n=2; 33.33%).

Since this study called for participants to represent problem components and their relationships visually, the last section of the background survey aimed at identifying participants’ preferred mode of working with information. The VARK questionnaire (Fleming, 2001) was used for this purpose. The instrument has been validated in a number of studies (Fleming, 2001). The scoring of each participant’s VARK questionnaire was carried out by the automated scoring help at Fleming’s (2004) website.

Results of this section (Table 1) provided insight into participants’ preferred mode of taking-in and giving-out information. Five out of six participants reported having multiple preferences; one had a strong kinesthetic preference. Four out of six participants (i.e., Subjects #37, #41, #42, & #51) did not report a strong visual preference. This might
suggest possible difficulty for these participants in visually representing the relationships between the important factors of a given instructional design problem scenario.

Table 2 presents the results of a background survey seeking information on participants’ instructional design experience. All of the participants had a minimum of ten years of hands-on experience thereby meeting the ‘10-year threshold’ to be considered as experts in the field for the purposes of this study. Average hands-on instructional design experience was 20.5 years with the most experienced participant having 37 years of experience practicing instructional design. A number of participants also had relatively limited) experience with teaching courses related to instructional design

The background survey also asked participants to identify the ID activities they regularly perform in their current position. The results are displayed in Table 2. Among them, task analysis was the least performed (n=2; 33%) while determining solution alternatives & approaches (n=6; 100%) and selecting instructional strategies (n=6; 100%) were the two-most commonly performed activities. Overall, the results of this section of the background survey suggest that, on average, participants of this study regularly carry out, in their current position, all the activities associated with instructional design although the frequency with which they perform each activity might differ across activities.

In addition, the background survey also asked participants if they had taught graduate level courses related to instructional design. As presented by Table 2, only Subject#39 had experience teaching a variety of courses while the others had taught one to three courses each. ‘Multimedia design and/or development’ was the most commonly
Table 2. Participants' instructional design experience.

<table>
<thead>
<tr>
<th>Years of Experience Full-time Equivalent Experience in:</th>
<th>Subject#37</th>
<th>Subject#39</th>
<th>Subject#41</th>
<th>Subject#42</th>
<th>Subject#45</th>
<th>Subject#51</th>
<th>Avg. (years)</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-on Instructional Design</td>
<td>37</td>
<td>20</td>
<td>15</td>
<td>30</td>
<td>11</td>
<td>10</td>
<td>20.5</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Teaching ID-related courses</td>
<td>15</td>
<td>9</td>
<td>2</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>5.3</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Conducting research in ID</td>
<td>10</td>
<td>18</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1 ½</td>
<td>5.75</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities Regularly Performed in Current Position</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct needs assessment</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Determine solution alternatives and approaches</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>6</td>
</tr>
<tr>
<td>Propose solutions</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Write learning objectives</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Conduct task analysis</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Identify types of learning outcomes</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Assess learner's entry level skills</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Assess learner characteristics</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Develop test items</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Select instructional strategies</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>6</td>
</tr>
<tr>
<td>Select media formats</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Conduct formative evaluations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Conduct summative evaluation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Manage instructional/training projects</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Courses Taught</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional analysis</td>
<td>0</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Needs assessment</td>
<td></td>
<td></td>
<td>1</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Human performance technology</td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Instructional design</td>
<td></td>
<td></td>
<td>2</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Instructional systems development</td>
<td></td>
<td></td>
<td>1</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Educational/instructional technology</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Multimedia design/development</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>4</td>
</tr>
<tr>
<td>Advanced multimedia design/development</td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Distance education</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Educational simulations/games</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Message design</td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Program evaluation</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Evaluation methods and techniques</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Tests and measurement</td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Project management</td>
<td></td>
<td></td>
<td>2</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Principles of learning and instruction</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Theories of adult learning</td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Instructional research methods</td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Curriculum planning</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
taught course (n=4; 67%) followed by ‘educational/instructional technology’ and ‘principles of learning and instruction’ (n=3; 50%).

In the background survey, only one participant (Subject#45) assessed level of expertise as low; all the others responded either high or very high. Subject#37 assessed his level of expertise both as high and very high. The following two items in Table 2 addressed participants’ own definition of expertise. Two questions were asked in this regard. The first one asked participants to indicate people they consider to be expert instructional designer(s). The responses included a number of important (recognizable) names in the field of instructional design who either have published either a theory or a model of instructional design. Also included were several professors of ID (Table 3).

In order to understand participants’ own definitions of expertise, participants were asked to indicate the criteria they believed are most relevant in determining whether someone is an expert instructional designer. Responses included criteria such as educational background, recognition by peers and professional organizations, as well as years of experience. These criteria are found to be very similar to those mentioned in the

<table>
<thead>
<tr>
<th>Self-Assessment of Instructional Design Expertise</th>
<th>Subject#37</th>
<th>Subject#39</th>
<th>Subject#41</th>
<th>Subject#42</th>
<th>Subject#45</th>
<th>Avg. (years)</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>1</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>4</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>2</td>
<td>33%</td>
</tr>
</tbody>
</table>
Table 3. Instructional designers who are identified as experts by the subjects.

| Subject#37 | Robert Gagné  |
|           | Briggs       |
|           | Smith Ragan  |
|           | Walter Dick  |
|           | Lou Carey    |

| Subject#39 | Wilhelmina Savenye |
|            | Liz Strand      |
|            | Deloris Caralick |

| Subject#41 | Anyone with the criteria below (see Table 4; Subject#41) |

| Subject#42 | Robert Gagné |

| Subject#45 | (no response) |

| Subject#51 | Rex Allen |
|            | Janette Hill |

literature (Chase & Simon, 1973b; Chi et al., 1988; Ericsson, 2002; Goel & Pirolli, 1989; Perez et al., 1995; Simon, 1981) (Table 4). Additional criteria mentioned by the participants were related to professional performance. For instance, Subject#39 argued that in order for someone to be considered as expert, an instructional product he or she developed must function effectively and stand the test of time. Subject#41 stated that in order to be considered an expert in the field, a person must be able to design products in a number of different contexts for different populations; furthermore, he or she should be flexible to be able to change his or her design methodology to meet the needs of a particular situation (Table 4). These arguments reflect the challenges and discourse in the field in defining instructional design expertise (Ertmer & Stepich, 2005; Hardré et al., 2005; LeMaistre, 1998; Perez et al., 1995; Rowland, 1992).
Table 4. The most relevant criteria in determining an expert instructional designer according to the subjects.

| Subject#37 | - Educational background  
| - Performance  
| - Research conducted  
| - Publications  
| - Recognized by peers  
| - Recognized by professional organizations |
| Subject#39 | - Instructional products functioning effectively in the field which stand the test of time |
| Subject#41 | - How long have then been doing instructional design?  
| - Variety of projects-contexts/population- ability to work with  
| - Ability to develop solutions for a variety of situations and content areas  
| - Flexibility- not tied to a particular approach, able to change methodologies to meet the needs of a particular situation |
| Subject#42 | - Depth of knowledge in learning and instruction  
| - Applied theory to real problems |
| Subject#45 | - Experience  
| - Training  
| - Practice  
| - Success |
| Subject#51 | - Ability to correctly assess needs & skills and create effective instruction that motivates people to change |

Materials

The participants of this study were provided with a data package, which contained the following:

- a cover page (Appendix 1);
- letter of informed consent (Appendix 2);
- participant information sheet (Appendix 3);
- the background survey discussed in the previous section (Appendix 4);
- directions for the problem solving activity (Appendix 5)
- a worked example including a sample problem scenario and a sample solution for that scenario (Appendix 6)
- instructional design problem scenario (Appendix 7)
- paper-based worksheets for participants to record their responses (Appendix 8)
- a copy of the notification from the Institutional Review Board (Appendix 9);
- small sticky notepads, pencils, and erasers.

The worked example was aimed at supporting the data collection effort by clarifying participants’ questions on the procedures involved in the study. In order not to bias the outcome towards there being a pattern among respondents, two measures were taken; First, the problem scenario in the worked example addressed a quite different ID problem than the scenario utilized in the experimental task. The problem scenario in the worked example focused on needs assessment while the problem scenario provided to participants in the experimental task involved managing limited resources of an instructional design project.

Second, in order not to affect the responses of the subjects, the problem scenario and its response in the worked example were not fully elaborated. Rather, they were used to illustrate the steps involved in the task that the participants were about to take.

The instructional design problem scenario (Appendix 7) was developed by an expert instructional designer to be representative of real-life instructional design problem situations but also generic enough to be recognized by experts who work in different contexts. In addition, the problem scenario was developed in a way that ID experts could associate with their earlier experiences. Therefore, the scenario description was brief,
leaving an open door for the experts to adapt it to their earlier experiences and recommend solutions that work according to their previous experiences with similar situations.

The materials used in this study were pilot tested (see Eseryel, 2002) and revised prior to this study. Subjects for this pilot study included three faculty members of instructional design, eleven students of a first year course on instructional design, and eight students of an advanced level course in instructional design. In general, the background survey proved to be a useful tool in determining subject’s relative levels of expertise in instructional design. Furthermore, the causal representations of faculty members were more comprehensive than the ones belonging to the students in the advanced level instructional design course. The representations of the students in the first year ID course could at best be described as ‘chaotic.’

Following the data collection, informal interviews were conducted with the subjects about their experiences with the data collection tools. In general, participants agreed that the data collection methodology was clear for them as they had no trouble in understanding what was being asked of them. Participants also unanimously reported that the instructional design scenario was clear and easy to understand. They stated that the scenario mimicked real-life instructional design cases, as it was something that could have easily occurred regularly in any real-life instructional design context. As for their experiences with the causal representations, first-year ID students reported an overwhelming feeling of confusion. They reportedly had problems while trying to represent their problem conceptualization by using the causal representations even though they thought they understood the problem very well. In addition, some of these students
reported that they were not used to represent their thinking in graphics. As one of the students put it they were “simply not visual!” These students were also not familiar with any of the concept mapping methodologies prior to this study. The other two groups of participants did not report such negative experiences with the causal representations (Eseryel, 2002).

After the pilot testing, the background survey was revised to include VARK questionnaire adopted from Fleming (2001) to help assess participants’ learning preferences. Apart from these changes in the background survey, pilot study results suggested that the instruments used in this study were effective in supporting data collection and analysis efforts.

Data Collection

After the administration of the background survey, participants were first provided with a worked example (Appendix 2) explaining the task they were about to undertake. This part took about 10-15 minutes.

Then, participants were provided with the instructional design problem scenario that is available in Appendix 3, small sticky pads, pencils, erasers, and a worksheet (Appendix 4) to record their answers. They were asked to:

1. individually reflect on the problem scenario and provide their assumptions and contextual remarks;
2. create a representation of the given problem scenario, identifying key factors and the relationships between key factors. Participants were encouraged to write down each factor that they thought was a key factor for the problem on a
small sticky-pad, and to move those around until they were convinced of the final form that they wanted their representation to take, then draw the relationships between the factors as one- or two-way arrows between sticky-pads, and identify the direction of the relationship as direct (+) or inverse (-); 3. assign a number to each node (factor) and a letter to each link (relationship) in their representation and provide more details on a separate page by further elaborating on their meanings and details; and 4. provide recommendations for the solution of the given problem scenario based on their analysis.

An informal interview with the experts followed the data collection to learn about their experiences during the task. These interviews were intended to capture subjects’ overall experiences during the data collection procedures.

Data Analysis Plan

The goal of this study was to investigate whether expert instructional designers exhibit recognizable patterns in their problem conceptualizations of a given complex instructional design problem scenario. As stated in the first chapter, this central research question led to the following four specific questions:

1. Are the representations of expert instructional designers visually similar?
2. Do expert instructional designers identify similar key factors as important for a given complex instructional design problem?
3. Do expert instructional designers identify similar interrelationships between the key factors for the given ID problem?

4. Do expert instructional designers offer similar solutions for the given instructional design problem?

Table 5 presents the data analysis framework that was utilized to answer above subquestions. Expert representations were compared on three different levels of analysis according to the DEEP methodology (Spector & Koszalka, 2004): (1) surface level; (2) structural level; and (3) semantic level.

*Surface level* is the most superficial level of analysis. It is simply concerned with how expert representations compare visually. In the DEEP methodology, surface analysis involves counting the number of nodes, one-way links, two-way links, words per annotated node, and words per annotated link (Spector & Koszalka, 2004). In other words, surface level analysis involved elements of the representations that can be easily counted, and automated.

*Structural analysis* involved the identification of similarities and differences in expert responses in terms of the relationships among various nodes. Structural analysis called for expert representations to be examined in order to reveal how the nodes in each representation were interconnected, i.e., the structural patterns of expert representations.

*Semantic analysis* involved protocol analysis of participants’ annotated representations of the given instructional design problem scenario, their assumptions and their recommendations for a solution. Semantic analysis was conducted according to the protocol analysis guidelines developed by Ericsson & Simon (1984; 1993).
Table 5. Data analysis framework

<table>
<thead>
<tr>
<th>Subquestion</th>
<th>Variable</th>
<th>Analysis Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the representations of expert instructional designers visually similar?</td>
<td>- # of nodes&lt;br&gt;- # of one-way links&lt;br&gt;- # of two-way links&lt;br&gt;- # of words per node&lt;br&gt;- # of words per link&lt;br&gt;- density of the representations</td>
<td>- Surface</td>
</tr>
<tr>
<td>Do expert instructional designers identify similar key factors as important for a given complex instructional design problem?</td>
<td>- Annotations of nodes</td>
<td>- Semantic</td>
</tr>
<tr>
<td>Do expert instructional designers identify similar interrelationships between the key factors for the given ID problem?</td>
<td>- Annotations of links</td>
<td>- Semantic &amp; Structural</td>
</tr>
<tr>
<td>Do expert instructional designers offer similar solutions for the given instructional design problem?</td>
<td>- Expert recommendations for solution (text)</td>
<td>- Semantic</td>
</tr>
</tbody>
</table>

The following chapter presents the results of the data analysis which was carried out according to the framework presented in Table 5.
CHAPTER 4. RESULTS

OVERVIEW

Subjects’ responses to the given instructional design scenario (Figure 31) were analyzed according to the analysis framework in Table 5 (see the previous chapter). For each subject, protocols included the following data; (1) subject’s assumptions and contextual remarks, (2) representation of the problem depicting its key factors and the relationships among these key factors; (3) annotations for each node in the subject’s representation; (4) annotations for each link in the subject’s representation; and (5) subject’s recommendations for possible solution approaches for the given instructional design.
problem. For illustrative purposes, Appendix 10 includes the data protocol filled out by the Subject#42.

All data protocols gathered from expert instructional designers were analyzed to answer the central research question of the study, i.e., whether the expert instructional designers exhibit recognizable patterns in their problem conceptualizations of the given instructional design problem. The data analysis framework presented in the previous chapter (Table 5) guided this analysis. For illustrative purposes, Appendix 11 includes the analysis of the data collected from Subject#42.

This chapter is divided into five sections. The first four sections present data analysis results pertaining to each of the research subquestions. The chapter concludes with a summary section.

**Are the representations of expert instructional designers apparently similar?**

In order to address the first research subquestion, a surface level analysis was conducted as suggested by the DEEP methodology. Surface level analysis included counting the number of nodes, links, words per node name, words per node, and words per link (Spector & Koszalka, 2004). The goal of surface level analysis was to observe whether there were any obvious patterns among expert representations. As reviewed in the second chapter, Seel and his colleagues (Ifenthaler & Seel, 2005; Seel, 2001) used a visual similarity test to make this determination. The DEEP methodology took a slightly different approach because the interest was in developing means to automate the process in the future for assessing the relative level of expertise based on the analysis of problem
conceptualizations. In the DEEP methodology, therefore, the surface level analysis included the analysis of all items that were easily counted manually and automatically rather than using the visual similarity test developed by Seel and his colleagues (Ifenthaler & Seel, 2005).

Some interesting findings reflected in Table 6 hint at the possible existence of expert patterns. The majority of expert representations had 10 +/- 2 nodes. The representation of Subject#39 had the highest number of nodes (n=12) while Subject#41’s had the lowest (n=7).

The densities of the expert representations were all in the vicinity of 0.13. The least dense representation belonged to the expert with the smallest number of years of hands-on instructional design experience. Number of nodes and links were similar in all representations.

On average, subjects used 4.69 words per node name and 10.43 words per link. Two experts, Subjects#39 and #42 included two-way links in their representations.

Table 6. Surface level analysis results

<table>
<thead>
<tr>
<th>Subject</th>
<th>#Nodes</th>
<th>#1-way Links</th>
<th>#2-way Links</th>
<th>Avg. words/ node</th>
<th>Avg. Words/ Node Name</th>
<th>Avg. Words/ Link</th>
<th>Density of the Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>#37</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>6.75</td>
<td>8.43</td>
<td>0.13</td>
</tr>
<tr>
<td>#42</td>
<td>10</td>
<td>10</td>
<td>3</td>
<td>12.1</td>
<td>3</td>
<td>14.1</td>
<td>0.14</td>
</tr>
<tr>
<td>#39</td>
<td>12</td>
<td>14</td>
<td>4</td>
<td>16.25</td>
<td>5.83</td>
<td>11.67</td>
<td>0.14</td>
</tr>
<tr>
<td>#41</td>
<td>7</td>
<td>6</td>
<td>0</td>
<td>15.86</td>
<td>6.86</td>
<td>13.67</td>
<td>0.14</td>
</tr>
<tr>
<td>#45</td>
<td>10</td>
<td>12</td>
<td>0</td>
<td>4.7</td>
<td>2.4</td>
<td>5.42</td>
<td>0.13</td>
</tr>
<tr>
<td>#51</td>
<td>10</td>
<td>9</td>
<td>0</td>
<td>7.6</td>
<td>3.4</td>
<td>10.11</td>
<td>0.10</td>
</tr>
<tr>
<td>Average</td>
<td>9.5</td>
<td>9.6</td>
<td>1.16</td>
<td>8.82</td>
<td>4.69</td>
<td>10.43</td>
<td>0.13</td>
</tr>
</tbody>
</table>
Representations of these two experts also had higher numbers of nodes and one-way links. Interestingly, the representation of Subject#37, who has the largest number of hands-on instructional design experience had lower number of nodes and links than Subjects#42, #39, #45, and #51.

Further analysis revealed that, in his background survey, Subject#37 responded that managing instructional design projects is not one of the tasks he frequently performs in his current job. Unlike Subject#37, the Subjects#39, #41, #42, and #51 indicated that they actively managed instructional design projects. Indeed, Subject#39 stated that he worked as a manager of instructional design at the time of the study. In addition, Subjects#39 and #51 indicated that they taught a graduate-level course on project management of instructional design. Surface level analysis results suggested that the number of nodes and links in an individual’s representation as well as the density of the representation could be instrumental in determining relative levels of instructional design expertise of different individuals.

The analysis their VARK surveys revealed that Subjects#37, # 41, #42, and #51 are not particularly strong in visual cues. According to Fleming (2001), this means that they do not prefer the depiction of information in charts, graphs, flow charts, and the symbolic arrows, circles, hierarchies and other devices for the purposes of receiving or providing information. On one hand, these results could be interpreted as one of the combined effects that could explain the lower numbers of nodes and links the representations of Subject#37 and #41. However, the densities of all the representations were about the same. Surface level analysis, by itself, was not sufficient to arrive at any conclusive conclusions in this regard.
Do expert instructional designers identify similar key factors as important for a given complex instructional design problem?

In order to address the second question, whether or not expert instructional designers identified similar key factors as important for the given complex instructional design problem, semantic analysis was employed as suggested by Spector & Koszalka (2004).

Semantic analysis of expert protocols included the analysis of the annotated nodes in participants’ representations of the given ID problem scenario. This analysis was conducted according to the protocol analysis guidelines developed by Ericsson & Simon (1984; 1993). The coding scheme originally developed by Greeno and colleagues (Greeno et al., 1990a, 1990b) for instructional design problem solving was used for the purposes of this study. This coding scheme was further developed and validated by Goel & Pirolli (1989), Goel (1991) and Perez & colleagues (Perez & Emery, 1995; Perez et al., 1995; Perez & Neiderman, 1992) in their studies on instructional design expertise. For the purposes of this study, the most recent version by Perez and his colleagues (1995) was adapted based on general methods and guidelines suggested by Ericsson & Simon (1984, 1993). Table 7 presents the coding schema used in this study. The codes in italics show what was added to the original coding schema during the iterative adaptation process.

In order to ensure coding reliability, a research assistant was hired to code the protocols in addition to the investigator. The assistant was trained in order to minimize errors and increase inter-rater reliability. During training, the investigator first explained the original coding schema developed by Perez and his colleagues (1995). Then, the research assistant was given as much time as she required to reflect and check her
Table 7. The coding schema used for this study.

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0. ANALYSIS:</td>
<td></td>
</tr>
<tr>
<td>1.1 Instructional goals</td>
<td>Determine goals and objectives</td>
</tr>
<tr>
<td>1.2 Task analysis</td>
<td>Conduct task analysis; Identify knowledge, skills, abilities necessary; Identify background within course required to perform task; Determine tasks to be taught; Identify expert performance</td>
</tr>
<tr>
<td>1.3 Learner characteristics</td>
<td>Determine learner characteristics, such as age, prior education, motivation, preferences for certain training media; determine current levels of performance, expectations of the course; etc.</td>
</tr>
<tr>
<td>2.0 DESIGN:</td>
<td></td>
</tr>
<tr>
<td>2.1 Instructional unit design</td>
<td>Determine the instructional units (i.e., modules) and content for each unit</td>
</tr>
<tr>
<td>2.2 Scope / Sequencing</td>
<td>Determine the size, scope, sequencing, timing, duration of instructional units</td>
</tr>
<tr>
<td>2.3 Instructional strategies</td>
<td>Determine the instructional strategies for each instructional unit; i.e., ways in which student will interact with the materials (collaboration, open discussion, analogy, lecture, etc.)</td>
</tr>
<tr>
<td>2.4 Materials / facilities</td>
<td>Determine the materials (computers, books, or manuals) or facilities (i.e., labs) required for each instructional unit</td>
</tr>
<tr>
<td>2.5 Content relevant non-design issues</td>
<td>Issues that are relevant to the content only—excludes the design related issues. This code will be used when the subject explicitly talks about content-related details</td>
</tr>
<tr>
<td>3.0 DEVELOPMENT:</td>
<td></td>
</tr>
<tr>
<td>3.1 Instructional unit development</td>
<td>Develop instructional units: an instructional unit could be a module, lesson, etc.</td>
</tr>
<tr>
<td>3.2 Instructional media</td>
<td>Develop instructional media (printed or electronic) such as books, CD-ROM, etc.</td>
</tr>
<tr>
<td>3.3 Formative evaluation</td>
<td>Develop formative evaluation (pilot testing, field testing) plan</td>
</tr>
<tr>
<td>3.4 Summative evaluation</td>
<td>Develop summative evaluation plan</td>
</tr>
<tr>
<td>3.5 Assessment instrument</td>
<td>Develop assessment instruments to support formative or summative evaluation</td>
</tr>
<tr>
<td>4.0 EVALUATION:</td>
<td></td>
</tr>
<tr>
<td>4.1 Formative evaluation</td>
<td>Conduct formative evaluation, also referred to as pilot testing, internal testing, and field testing</td>
</tr>
<tr>
<td>4.2 Summative evaluation</td>
<td>Conduct summative evaluation, also referred to as external testing</td>
</tr>
<tr>
<td>4.3 Revision</td>
<td>Revision of instructional modules, materials etc.</td>
</tr>
<tr>
<td>Code</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5.0 PROJECT MANAGEMENT/MONITORING:</td>
<td></td>
</tr>
<tr>
<td>5.1 Production process</td>
<td>Determine processes for production, who will do what, in which order</td>
</tr>
<tr>
<td>5.2 Progress monitoring</td>
<td>Monitoring processes related to whole or parts of the project</td>
</tr>
<tr>
<td>5.3 Process adaptation/revision</td>
<td>Adaptation, revision, and improvement of procedures, timelines, or budget</td>
</tr>
<tr>
<td>5.4 <strong>Budget</strong></td>
<td>Budget that is necessary to finish the whole or part of the project</td>
</tr>
<tr>
<td>5.5 <strong>Timelines</strong></td>
<td>Time that is required to complete the whole or parts of the project</td>
</tr>
<tr>
<td>5.6 <strong>Quality</strong></td>
<td>Perceived (by ID team as a result of assessment) quality of instructional materials, processes, and tools</td>
</tr>
<tr>
<td>5.7 <strong>Client's requirements</strong></td>
<td>Includes requirements and constraints set by the client such as budget, deadlines, quality requirements, requirements that impact the decision of instructional interventions (such as the unavailability of computers) and so on</td>
</tr>
<tr>
<td>5.8 <strong>Client satisfaction</strong></td>
<td>Client's level of satisfaction</td>
</tr>
<tr>
<td>5.9 <strong>President's requirements</strong></td>
<td>Requirements/constraints set by the President of the Company. This may include budget, personnel, deadlines, getting that 10% bonus offered by the client, and so on.</td>
</tr>
<tr>
<td>6.0 <strong>President's satisfaction</strong></td>
<td>Company President's level of satisfaction</td>
</tr>
<tr>
<td>7.0 PROJECT TEAM REQUIREMENTS/CONSTRAINTS:</td>
<td></td>
</tr>
<tr>
<td>7.1 <strong>Team expertise</strong></td>
<td>Project team's level of expertise of working together in this project. This does not necessarily refer to individual expertise levels-rather, it also refers to the ability of the team to develop materials in this context, for this project, and therefore, take multiple roles when necessary</td>
</tr>
<tr>
<td>7.2 <strong>Personnel requirements</strong></td>
<td>Number of, and different roles, abilities, specializations (media developer, designer, subject-matter experts, etc.) of personnel who are required to take part in the project team</td>
</tr>
<tr>
<td>7.3 <strong>Personnel availability</strong></td>
<td>Number of, and different roles, abilities, specializations (media developer, designer, subject-matter experts, etc.) of personnel who are available for the project; and their availability to put in required time (even if it is overtime) for the project</td>
</tr>
</tbody>
</table>
understanding of each code. Then, both the investigator and the research assistant independently coded the annotated representations belonging to one of the two participants who did not qualify for this study. After this training coding, the investigator and the research assistant discussed their coding to ensure that the training assistant learned about the coding. During these discussions, both the investigator and the research assistant realized that additional coding categories addressing evaluation, project management, and instructional design team were required.

These new categories were added due to the authentic nature of the instructional design scenario used in this study. In previous studies of instructional design expertise reported by Greeno et al. (1990a, 1990b), Goel (1991) and Perez & colleagues (1995), the instructional design problem scenarios provided to participants lacked authentic features. In these studies, instructional design was thought of as being carried out by one person so the existence of the instructional design team was overlooked. The ID problem was provided to one person who was asked to think aloud while solving the problem. In the scenario used in this study (Appendix 7), since such restrictive assumptions were not made, the instructional design team was repeatedly brought up by the participants.

Moreover, the scenario used in this study addressed real-life constraints that instructional designers face every day in their jobs. These constraints included time, budget restrictions and other requirements by the clients and management of the designer’s organization. Previous studies did not allow for such real-life considerations or restrictions in the scenario; thus, the coding schema lacked related categories.
Therefore, three additional categories were added to the original coding schema used by Perez et al. (1995) related to evaluation, project management, and instructional design teams. These are shown in Table 7 in bolded and in italics.

After the addition of new categories, the same training protocol was re-coded by both the investigator and the research assistant independently of each other. Holstí’s (1969) method of inter-rater reliability was employed to analyze the reliability of coding for these two data sets. An initial inter-rater reliability rate of 67% was obtained in the first training protocol. Post-coding discussions showed that there were still several codes that were not clear. Several categories were added to distinguish between protocol segments that were different in theoretically meaningful ways. This effort produced the final coding schema presented in Table 7. Following revisions, the same training protocol was re-coded. This time, an inter-rater reliability rate of 100% was achieved. Then, both the research assistant and the investigator coded the second training protocol separate from each other. The inter-rater reliability rate was also 100% for this second training protocol. In order to test the stability of the coding schema and inter-rater reliability on the actual data, one of the expert protocols was randomly selected and coded independently by both the investigator and the research assistant. Again, the inter-rater reliability rate was 100%. The remaining five protocols were then coded independently by both parties and the inter-rater reliability for these protocols was determined based on Holstí’s (1969) method. Results showed that the investigator and the research assistant had an overall inter-rater reliability rate of 91%. According to Neuendorf (2002), inter-rater reliabilities of 85% and above are considered highly reliable content analysis in social sciences.
Table 8 presents the overall summary of the results of the semantic analysis on the node level. The first column presents the factors that were identified by respondents as important for the solution of the instructional design problem scenario, in other words the problem constituents. The second column displays the total number of frequency counts of the corresponding factors in all representations. In other words, the second column presents how many times each factor is mentioned as an important factor by all of the participants. The last column shows the ratios (in percentages) of the frequency count of each node to the total number of nodes in all representations.

As evident in Table 8, recognizable patterns were observed in the expert representations. Formative evaluation was the most frequently-mentioned factor in participant representations as an important problem constituent. Besides formative evaluation, timelines, instructional unit development, production process, budget, personnel availability, and client requirements were among most frequently-mentioned factors in participant representations.

On the other hand, some of the most common instructional design elements such as analysis of instructional goals or learner characteristics, materials/facilities design, and development of an assessment instrument were not mentioned in any of participants’ representations. All of the participants chose not to detail all of the elements of instructional design or development but to represent them simply as instructional unit design or development. Also, client satisfaction was not mentioned by any of the participants even though client requirements were one of the most frequently-mentioned factors.
Table 8. Overall summary of the results of semantic analysis on the node level

<table>
<thead>
<tr>
<th>Factors</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0. ANALYSIS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Instructional goals</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>1.2 Task analysis</td>
<td>1</td>
<td>1.16%</td>
</tr>
<tr>
<td>1.3 Learner characteristics</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>2.0 DESIGN:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Instructional Unit</td>
<td>4</td>
<td>4.65%</td>
</tr>
<tr>
<td>2.2 Scope/Sequencing</td>
<td>3</td>
<td>3.48%</td>
</tr>
<tr>
<td>2.3 Instructional strategies</td>
<td>1</td>
<td>1.16%</td>
</tr>
<tr>
<td>2.4 Materials/facilities</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>2.5 Content relevant non-design issues</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>3.0 DEVELOPMENT:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Instructional unit</td>
<td>7</td>
<td>8.13%</td>
</tr>
<tr>
<td>3.2 Instructional media</td>
<td>4</td>
<td>4.65%</td>
</tr>
<tr>
<td>3.3 Formative evaluation instrument</td>
<td>1</td>
<td>1.16%</td>
</tr>
<tr>
<td>3.4 Summative evaluation instrument</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>3.5 Assessment instrument</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>4.0 EVALUATION:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Formative evaluation</td>
<td>10</td>
<td>11.62%</td>
</tr>
<tr>
<td>4.2 Summative evaluation</td>
<td>1</td>
<td>1.16%</td>
</tr>
<tr>
<td>4.3 Revision</td>
<td>4</td>
<td>4.65%</td>
</tr>
<tr>
<td><strong>5.0 PROJECT MANAGEMENT/MONITORING:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Production process</td>
<td>6</td>
<td>6.97%</td>
</tr>
<tr>
<td>5.2 Progress monitoring</td>
<td>2</td>
<td>2.32%</td>
</tr>
<tr>
<td>5.3 Adaptation/Revision</td>
<td>5</td>
<td>5.81%</td>
</tr>
<tr>
<td>5.4 Budget</td>
<td>6</td>
<td>6.97%</td>
</tr>
<tr>
<td>5.5 Timelines</td>
<td>8</td>
<td>9.30%</td>
</tr>
<tr>
<td>5.6 Quality</td>
<td>1</td>
<td>1.16%</td>
</tr>
<tr>
<td>5.7 Client’s Requirements</td>
<td>5</td>
<td>5.81%</td>
</tr>
<tr>
<td>5.8 Client Satisfaction</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>5.9 President’s Requirements</td>
<td>2</td>
<td>2.32%</td>
</tr>
<tr>
<td>6.0 President’s Satisfaction</td>
<td>2</td>
<td>2.32%</td>
</tr>
<tr>
<td><strong>7.0 PROJECT TEAM REQUIREMENTS/CONSTRAINTS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.1 Team expertise</td>
<td>3</td>
<td>3.48%</td>
</tr>
<tr>
<td>7.2 Personnel requirements</td>
<td>4</td>
<td>4.65%</td>
</tr>
<tr>
<td>7.3 Personnel availability</td>
<td>6</td>
<td>6.97%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>86</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
Table 9 provides an individual look at each subject’s response. This table displays which factors each subject identified as important problem constituents and also the number of times a particular factor was present in each subject’s representation. For instance, representation of Subject#37 included one node representing instructional unit design, three nodes representing instructional unit development, and so on.

In Table 9, rows were highlighted for factors that were present in fifty percent or more of all the subjects. Similarities were observed among the expert subjects’ representations: Instructional unit development and formative evaluation were present in 83% of experts’ representations (n=5); instructional unit design, production process, timeliness and personnel availability were in 67% (n=4); and instructional media development, instructional material revision, budget, and personnel requirements were present in 50% of the subject’s representations (n=3).

Following semantic analysis, structural analysis was employed on the node level. Each node in each representation was characterized by total number of links, number of links emanating from the node, and number of links pointing to the node.

In each representation, it was possible to identify the nodes around which the links tended to cluster in participants’ responses. For instance, in Subject#42’s representation, three nodes were identified as central to the problem conceptualization: instructional unit design, formative evaluation & instructional material revision, and instructional media development (Figure 32).
Table 9. Frequency counts of factors identified by each subject.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Subject #37</th>
<th>Subject #39</th>
<th>Subject #41</th>
<th>Subject #42</th>
<th>Subject #45</th>
<th>Subject #51</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Task analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Instructional unit design</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2.2 Scope/Sequencing</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 Instructional strategies</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Instructional unit development</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Instructional media development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>3.3 Formative evaluation development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>4.1 Formative evaluation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4.2 Summative evaluation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>4.3 Instructional material revision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Production process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2 Progress monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>5.3 Process adaptation/revision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4 Budget</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5 Timelines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.6 Quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.7 Client's requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.9 President's requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0 President's satisfaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.1 Team expertise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.2 Personnel requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.3 Personnel availability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Identification of the central clusters was based solely on the centrality of the nodes; in other words, the number of links pointing to or emanating from these nodes.

Table 10 presents nodes (factors) that were identified by the majority of the respondents as central to the solution of the problem. All of the factors in Table 10 were also among the factors that were commonly present in the representations of fifty percent or more of all subjects in Table 9.
### Table 10. Nodes that were most central in subjects’ representations (n=6; Total # links=159)

<table>
<thead>
<tr>
<th>Nodes/Factor</th>
<th>#Links</th>
<th>From/To</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional material revision</td>
<td>18</td>
<td>13 / 7</td>
<td>11.32%</td>
</tr>
<tr>
<td>Formative evaluation</td>
<td>17</td>
<td>6 / 11</td>
<td>10.69%</td>
</tr>
<tr>
<td>Personnel availability</td>
<td>13</td>
<td>8 / 5</td>
<td>8.18%</td>
</tr>
<tr>
<td>Timelines</td>
<td>13</td>
<td>4 / 9</td>
<td>8.18%</td>
</tr>
<tr>
<td>Instructional unit development</td>
<td>13</td>
<td>6 / 7</td>
<td>8.18%</td>
</tr>
<tr>
<td>Instructional unit design</td>
<td>12</td>
<td>7 / 5</td>
<td>7.55%</td>
</tr>
<tr>
<td>Budget</td>
<td>10</td>
<td>2 / 8</td>
<td>6.29%</td>
</tr>
</tbody>
</table>

Do expert instructional designers identify similar interrelationships between the key factors for the given ID problem?

In order to address the third subquestion of whether expert instructional designers identify similar interrelationships between the key factors for the given ID problem, structural analysis was conducted on the level of the relationships between the nodes.

The coding scheme for the relationships between the nodes was adapted from Spector & Koszalka (2004) as follows:

- **Cause-Effect** (c/e): Results from, results in, as a result of, causes, influences, if-then, caused by, due to the fact that, leads to, helps, suggestive of, contributes to, indicative of, aids, plays a role, alters, makes, brings about, allows, gives insight, impacts, affects, determines, as … as…

- **Example** (e): A kind of, a part of, an example of, illustrated by.

- **Correlation** (c): Related factor, when factor is present other factor may also be present (no definite causal relationship can be established).

- **Process** (p): Next step, previous step, sequence.
Overall results are presented in Table 11. The type of relationships between important factors in participant representations was either cause-effect (50%; n=3) or process (31.94%; n=2), or both (16.67%; n=1). No links featuring examples or correlations were subjects’ representations. As evident in Table 11, the expert instructional designers in this study chose to base their solution approaches either on the relationships of the processes or on the cause-effect relationships of important factors that constitute the problem.

In order to identify whether there were differences between individual experts, Table 12 was constructed to provide an individual portrayal of each expert’s solution. In Table 12, subjects were ordered from right to left in descending years of hands-on instructional design experience. According to this table, it is possible to suggest that for these subjects, choosing either a process-based approach or a cause-and-effect-based approach was not a factor of the years of experience in the field.

<table>
<thead>
<tr>
<th>Type of Link</th>
<th>Number of Links</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause-Effect</td>
<td>49</td>
<td>68.06%</td>
</tr>
<tr>
<td>Process</td>
<td>23</td>
<td>31.94%</td>
</tr>
<tr>
<td>Example</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Correlation</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>72</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
**Table 12.** Type of links by subject

<table>
<thead>
<tr>
<th>Type of Link</th>
<th>Subjects</th>
<th>#37</th>
<th>#42</th>
<th>#39</th>
<th>#41</th>
<th>#45</th>
<th>#51</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause-Effect</td>
<td></td>
<td>0</td>
<td>18</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Process</td>
<td></td>
<td>8</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Example</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Correlation</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>8</td>
<td>18</td>
<td>14</td>
<td>11</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

**Do expert instructional designers offer similar solutions for the given instructional design problem?**

In order to address the last subquestion of whether expert instructional designers offer similar solutions for the given instructional design problem, experts’ recommended solutions and assumptions were analyzed.

Despite the similarities in their representations of the problem scenario, experts in this study showed differences in their assumptions and solutions. It was possible to categorize solution alternatives of experts under five headings:

1. Solution approaches based on process-modification
2. Solution approaches based on delivery-schedule adjustment
3. Solution approaches based on negotiation with the president of the company
4. Solution approaches based on negotiation with the client
5. Solution approaches based on motivating personnel to work overtime.
Subjects#37, #41, and #51 proposed solutions based on modifying the instructional design process to achieve faster results. Yet, differences were observed among these three experts as to how they proposed to modify the process. For instance, in the recommendations section, Subject#37 wrote “based upon the design of modules 1, 2, 3, & 4 and field-test results, modules 5 & 6 can be designed using the techniques already used in modules 1, 2, 3, & 4. So, they do not need to be field-tested.” Subject#37’s assumptions included:

1. All modules will be designed relatively the same way, i.e., using the same design model
2. The design methodology used in the first modules will be used in Modules 5 & 6
3. By successfully testing modules 1-4, and getting necessary feedback on design, the remaining two modules do not have to be designed and field-tested at this time.

Subject#37’s assumptions and recommendation for solution is consistent with his representation of the problem scenario (Figure 33), which included links describing processes among factors. Formative evaluation was the most central factor in his representation.

In order to reduce development time, Subject#41 suggested re-using codes and/or graphics developed in earlier modules while developing the remaining two modules. Additionally, the subject recommended identifying bottlenecks and areas where the process could be accelerated. In assumptions section, Subject#41 posed several questions:

— Why are we so behind schedule? Holiday? Bottlenecks (staff)? Insufficient staff etc.?
— What does “believed to be ready” mean?
— To what extent can I use the ready modules as templates for the remaining two?
— How flexible are the team members? Can the media specialist support the affairs of the web specialist where possible, for example?
— Can we get one module done and tested in the five remaining?
Figure 33. Subject#37's annotated representation

- What process have we been using? Are there places where we can take some shortcuts? (without sacrificing quality of work!)
- Can work on the 2 remaining modules take place concurrently?
- Can field testing not being on 1st modules anyway? These modules are more or less independent (one should really have been field-tested first, as a prototype)

These questions in the assumptions section suggest that the subject also thought about other solution alternatives including using already designed modules as templates in developing last two (like Subject#37), utilizing available personnel on multiple tasks, and other possible shortcuts depending on the process utilized. In sum, Subject#41 was mostly concerned with production process and its flexibility for modification for quicker production. Indeed, as shown in Figure 34, the production process was the node in her representation with the highest degree of centrality.
Unlike Subject#41, Subject#51 recommended a specific process to deliver all the modules on time. His solution plan was as follows:

1. Meet with team and present situation- come up with plan to deliver on time
2. Conduct brainstorming session to complete each module in 8 days
3. Ask team members to complete whatever they can do on their own without waiting for other team members to finish prior tasks
   i. Program develop shell for each module and logic and tracking
   ii. Graphic design create some graphics
4. Have SME work with ID and teacher ½ time to create content
5. ID write 1st module /teacher write 2nd module
6. Both writers feed graphic request to Graphic Designer as they finish segments
7. Graphic Designer sends completed graphics to ID/SME/teacher for immediate review
8. Graphics get revised and approved
9. Programmer is sent graphics and text for each individual screen as all components are completed
10. Once all screens are completed (day 9) SME and writers review entire modules and suggest changes/ programmer revises
11. Entire product delivered by day 10.

**STEP 4.4 PRESENTATION FOR PROBLEM SCENARIO-I**

**ANOTATIONS AND ELABORATIONS FOR EACH LINK IN CAUSAL MAP**

- **a)** As the clients unwillingness to negotiate on price/ delivery time increases, so does client pressure to complete.
- **b)** As client pressure increases, so does presidents insistence that team get work done on schedule.
- **c)** As presidents flexibility decreases, teams need to respond by becoming flexible increased.
- **d)** As presidents flexibility decreases, need to modify the process to make it more efficient increases.
- **e)** As need to modify the process increases, need to reduce delivery time increases
- **f)** As need to modify the process increases, ability to use templates increases.

Figure 34. Subject#41’s annotated representation
Subject#51 offered some specific ways to modify the process of instructional design. However, his solution also depended on the expertise, availability, and flexibility of members of the instructional design team. As shown in Figure 35, team members’ expertise and personnel availability are the two most central nodes in Subject#51’s annotated representation of given instructional design scenario. In fact, in the subject’s annotations of the relationships between the “B” nodes, Subject#51 states that team members’ expertise impact the time they require to complete all stages of the instructional design process.

A second type of solution was based on delivery schedule adjustment, which was recommended by Subject#39. In general, Subject#39 was more concerned with causes for failures than anything else. This is reflected in this subject’s assumptions (Figure 36) and annotated representation (Figure 37). However, this subject also emphasized that causes...
for failure to deliver on time should only be briefly examined; and that one should not spend valuable time with overanalyzing. If cause(s) for failure could not be identified and fixed easily, Subject#39 recommended continuing the production as standard but splitting delivery of modules 1-4 and modules 5-6.

<table>
<thead>
<tr>
<th>Determine cause for missing delivery date if possible/easily</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poorly estimated budget?</td>
</tr>
<tr>
<td>Poor estimate of tasks, hence resource is short</td>
</tr>
<tr>
<td>Resources are not appropriate</td>
</tr>
<tr>
<td>User changes requirements</td>
</tr>
<tr>
<td>SME provided bad inputs</td>
</tr>
<tr>
<td>Poor project management</td>
</tr>
<tr>
<td>Poor estimate of tasks, hence schedule not met</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Status of resources (production variables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget remaining</td>
</tr>
<tr>
<td>Projected costs to:</td>
</tr>
<tr>
<td>Complete the testing of modules 1-4</td>
</tr>
<tr>
<td>Develop modules 5-6</td>
</tr>
<tr>
<td>Test 5-6</td>
</tr>
<tr>
<td>Personnel required for above tasks:</td>
</tr>
<tr>
<td>9-5 normal work</td>
</tr>
<tr>
<td>w/ overtime</td>
</tr>
<tr>
<td>Test Group still available? Alpha? Beta? 2wks...4wks</td>
</tr>
<tr>
<td>SME still available? 2wks...4wks</td>
</tr>
<tr>
<td>Development team still available?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other variables: President’s requirements/expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence of modules; used simultaneously</td>
</tr>
<tr>
<td>Impact of split delivery</td>
</tr>
<tr>
<td>Date of first use; for training of teacher, for student</td>
</tr>
<tr>
<td>Current delivery standards: time, quantity, etc.</td>
</tr>
<tr>
<td>Impact of changes to this</td>
</tr>
<tr>
<td>Would outside experts enhance resolution of product development?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assume from above data gathering for recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. enough budget at standard rate for all</td>
</tr>
<tr>
<td>2. no internal concrete demands</td>
</tr>
<tr>
<td>3. Delay 1 wk OK</td>
</tr>
<tr>
<td>4. Split ship OK</td>
</tr>
<tr>
<td>5. Additional resources available</td>
</tr>
</tbody>
</table>

*Figure 36. Subject#39’s assumptions*
Subject#39 also suggested providing an additional option to the President of the company with no profit in order to produce sooner by either hiring outside experts or by paying overtime to available personnel. This type of solution, based on negotiation, was also seen in Subject#41’s protocol. However, Subject#41 chose to negotiate with the client rather than with the company President. If his first solution of process modification did not work as discussed earlier, Subject#41 recommended negotiating with the client for more time or money.

A different type of solution alternative was provided by Subject#42, which was based on providing incentives to motivate personnel to finish on time. Basically, Subject#42 recommended to:
1. Ask management to give 5% bonus if they bring it in on date
2. Throw beer-dinner party on Fridays- to develop ownership
3. Request people to work overtime – do what it takes to get done on time- there will be a 5% bonus

As can be observed Subject#42’s assumptions (Figure 38), the subject had analyzed, in detail, how much time the team required to develop a module and how much time the team would require to complete each phase of design and development. However, Subject#42 also assumed that as team expertise increased, design and development time would decrease.

In addition, Subject#42 assumed that the company desired repeat business so it was important to release proven quality products. All of these assumptions might explain why the subject did not want to modify process for quicker results, for instance, by proposing

ASSUMPTIONS
1. Based on data, it takes about 2 months to develop a module
2. As experience is gained, time to develop last two modules will be less
3. Assume staff worked normal work week of 40 hrs/wk
4. Assume do as is, it would be one week late- If keep going like we have, we will be one week late if no revision needed
5. Most time spent on graphics and SME → Design
6. Reason needed to have deadline 3 months ahead if schedule is to provide slack time to assure 10% bonus or – Feedback + revision →
7. Manager- can do design work also
8. Salaries are equivalent across people/positions
9. Need at least 20% of initial development time for revision time→ 1 wk per module = 6 weeks
10. Want repeat business- want to release proven quality products
11. Assume content and test developed valid- 1st time SME + consultant usually right on this.

Figure 38. Subject#42’s assumptions
not to pilot-test the last two modules, but instead, chose to provide incentives to get the
team members to work faster.

Subject#42’s annotated representation (Figure 39) did not include motivation of
personnel as an important factor. Instead, instructional unit design, instructional media
development, formative evaluation, and revision were the nodes with highest degree of
centrality in the subject’s representation.

In sum, all of the experts offered coherent solution approaches, in which
suggested solutions were woven together in terms of relationships that were cause-and-
effect or process-based. In other words, solution approaches offered by participants

---

Figure 39. Subject#42’s annotated representation
reflected the relationships among the problem constituents as depicted in their problem representations. Furthermore, participants’ solution approaches detailed rather flexible plans of action that involved considerations as to how they might be implemented and provided alternatives as additional information becomes available during the implementation of the solution.

CHAPTER SUMMARY

This chapter presented the results of the data analysis in relation to the research questions posed in the first chapter of this dissertation.

In sum, the results of surface, semantic, and structural analyses suggested the existence of recognizable patterns among expert responses. Surface level analysis results suggested that the number of nodes and links in an individual’s representation as well as the density of the representation could be instrumental in determining relative levels of instructional design expertise of different individuals. The results of analysis at this level also demonstrated the importance of specific task-based experiences as well as the number of years of hands-on experience. The representations of experts with the least amount of hands-on experience or specific task experiences relevant to the given problem had the least number of nodes and links.

*Formative evaluation, timeliness, instructional unit development, budget, production process, and personnel availability* were among the factors that were commonly present in expert representations. Furthermore, it was possible to identify the nodes around which the links tended to cluster in experts’ responses. These nodes represented the factors that were considered central to the solution of the given problem.
Among these nodes, the top ones included *revision of instructional units, formative evaluation, personnel availability, timelines, instructional unit development, instructional unit design*, and *budget*.

Structural analysis on the link level revealed that 67% of the experts (n=4) chose to explain the relationships among problem constituents as cause-and-effect relationships while 33% (n=2) took a process-based approach. This choice appeared to be an individual preference of each participant. It did not seem to be a function of years of hands-on experience in the field or any other variables measured with the background survey. However, the experts whose representations contained mostly process-based relationships recommended some sort of modification of ID processes as a possible solution approach.

Despite observed similarities among their representations, experts’ solution approaches showed differences. Multiple solution strategies were proposed by the experts based on (1) process-modification, (2) delivery-schedule adjustment, (3) negotiation with the President of the company, (4) negotiation with the client, or (5) motivating the personnel to work overtime. This result confirmed the assumption that ill-structured problems such as the instructional design problem scenario used in this study do not have a single solution. There are usually multiple solutions or solution paths. Therefore, assessment of learning in domains involving complex, ill-structured problem solving does not lend itself to performance-based assessment methods. The DEEP methodology was proposed (Spector & Koszalka, 2004) to address this issue. The DEEP methodology is different than performance-based assessment methods in that its focus is not the learner’s solution for a given problem. Instead, the DEEP methodology takes a more holistic approach and is mostly concerned with the learner’s problem space, in other
words their problem conceptualizations, how learners view a given problem, the factors they consider as important for the solution of the problem, and the kinds of relationships learners foresee among the problem constituents. In the DEEP methodology, learners are assessed based on how their problem representations progress to compare (or contrast) with those of the experts. For that reason, a critical part of investigating the utility of the DEEP methodology in any problem domain depends on investigating whether problem representations of domain experts show recognizable patterns. The fact that expert instructional designers in this study tended to represent the problem similarly is a promising indicator for the applicability of the DEEP methodology in the domain of instructional design. In this direction, the following chapter provides an in-depth discussion of the findings presented in this chapter.
CHAPTER 5. DISCUSSION

OVERVIEW

Forecasting on the year 2000, Gustafson, Tillman, and Childs (1992) proposed that “we shall eventually find ourselves on the path toward a theory of instructional design” (p.456) if instructional design is able to expand its intellectual basis in the not-too-distant future. Comes the year 2000, Gordon and Zemke (2000) observed that “the field of instructional design is as good as dead because its foundation is not suitable for facing new societal and technological demands” (p. 43). Reflecting on these pessimistic positions, Seel and Dijkstra (2004) ask, “what went wrong in an applied field of science that has contributed substantially to education and training? What happened – or what did not happen – within the field of ID in the last half of the previous century?” (p. 1).

Having reviewed the developments and trends in the field, Seel and Dijkstra (2004) concluded that within the last half of the previous century, training requirements have considerably changed. Training of complex problem skills have become increasingly important in today’s society where routine, procedural tasks are mostly automated by machines. As a consequence, complex problem-solving tasks, which cannot currently be taken over by machines, have formed the basis of training needs (van Merriënboer, 1997). Observing these developments, a number of researchers (e.g., Achtenhagen, 2000; Dijkstra & van Merriënboer, 1997; Gordon & Zemke, 2000; Jonassen, 1997; Spector et al., 2001) strongly argued that education and training should accommodate a diverse, widely distributed set of students who need to learn and transfer
complex problem-solving skills to an increasingly varied set of real-world contexts and settings.

The field of instructional design lagged behind of these developments. Existing ID theories and models are criticized for not being adequate in addressing higher-order, complex problem-solving skills outcomes. Having stated the requirement for powerful ID theories that can address higher-order, complex problem-solving skills outcomes, Dijkstra and van Merriënboer (1997) argued that “exploration and systematic empirical research are the kinds of activities that are badly needed to further develop and validate such ID theories” (p.42).

Scientific attitude with regard to developing ID theories that can address higher-order, complex, ill-structured problem-solving skills first requires measures of learning outcomes in a variety of contexts in order to determine what types of instruction work best, when, and why. What impedes progress in this arena is that, especially for ill-structured problems, there is no single approved way of performing a task, no single approved solution, and no clear criteria for successfully solving a problem. Therefore, assessment of learning becomes especially challenging. Yet, a valid, and reliable assessment methodology for higher-order, complex problem-solving outcomes do not exist. These factors brought about the motivation underlying this dissertation research.

Literature reviewed in the second chapter identified promising efforts of two different research groups (cf., Ifenthaler & Seel, 2005; Spector & Koszalka, 2004) in the direction of developing an assessment methodology for complex, ill-structured problem-solving outcomes. The underlying assumption of both methodologies was that simple causal representations can support externalization of the problem conceptualizations of
solvers’, therefore, making it possible to track changes in learners’ problem conceptualizations as a result of instructional interventions.

The purpose of this study was two-fold. First, this study aimed at investigating the assumption that simple annotated causal representations can be used to elicit problem conceptualizations of experts. Second, this study aimed at investigating whether it is possible to use experts’ problem conceptualizations as a basis of assessment for ill-structured problem-solving outcomes where agreed-upon performance-measures do not exist. As such, this study focused on the viability of annotated causal representations to measure expertise in a complex, ill-structured problem-solving domain such as instructional design. Therefore, the central research question was whether expert instructional designers exhibited recognizable patterns in their problem conceptualizations of a given instructional design problem. This central research question led to four subquestions: (1) Are the representations of expert instructional designers apparently similar? (2) Do expert instructional designers identify similar key factors as important for a given complex instructional design problem? (3) Do expert instructional designers identify similar interrelationships between the key factors for a given ID problem? (4) Do expert instructional designers offer similar solutions for the given instructional design problem?

The following section is organized around these four research subquestions and aims to provide a synthesis of the findings of the study. This section is followed by a discussion of the implications of these findings. This study was exploratory in nature. Therefore, while some of the initial choices made during the conceptualizations of the study supported thorough investigation of the researched phenomenon, in some ways,
these choices also limited the power of the generalizability of the findings. The fourth section in this chapter discusses these limitations. Three possible sources of limitations are identified: (1) the subjects who participated in the study, (2) the instructional design problem scenario used in the study; (3) the methodology used to elicit problem conceptualizations of the subjects. This section also offers recommendations for future research in order to address these limitations. The chapter concludes with an overview of future studies planned by the investigator in order to further this line of research.

SYNTHESIS OF THE FINDINGS

The results of surface, semantic, and structural analyses of expert protocols suggested similarities as well as differences among expert responses.

The first research question asked whether the representations of expert instructional designers were apparently similar. The response to this question was positive. Results of the surface level analysis suggested the existence of recognizable patterns among expert representations with respect to the number of nodes and links in expert representations. On average, expert representations included 9.5 nodes (maximum of 12; minimum of 7) and 10.8 links (maximum of 18; minimum of 6).

The results of surface level analysis also suggested that the representation density may be used as an indicator in determining how a learner’s problem conceptualizations compare to those of experts. In this study, the density of a representation was calculated via dividing the number of links in the representations by the number of all possible links. More specifically, the following formula was used:

\[
D = \frac{n}{(n^2 - n)}, \text{ where } n \text{ denotes the number of nodes in the representation}
\]
Since expertise is usually attributed to the number of years of hands-on experience in the field, initially it was assumed that individuals with more years of hands-on experience would be able to identify a larger number of factors and relationships among those factors. This assumption was reflected in Figure 3 of the first chapter — notice that expert representations include much larger numbers of nodes and links than those of novices.

As shown in Table 13, the results of surface level analysis were parallel to this assumption except for two cases. The representation of Subject#37, who had the most number of years of hands-on experience, contained eight nodes and seven links while the representation of Subject#39, who had 20 years of experience, contained twelve nodes and eighteen links. A similar irregularity was also seen with the representation of Subject#41, whose representation had fewer nodes and links than Subjects #45 and #51, both of whom had fewer years of experience than him. Moreover, subjects’ teaching and research experiences were not helpful in explaining these irregularities.

An explanation for the above irregularity may be that perhaps Subjects#37 and #41 did not have much relevant prior experiences with problem cases similar to the one used in this study. The analysis of their background surveys showed that Subjects#37 stated that he did not actively manage instructional design projects in his then-current job. In addition, Subject#37’s background survey showed that he did not teach any courses related to project management in ID. On the other hand, Subject#39 indicated working as a manager of instructional design at the time of the study. Since the instructional design problem scenario used in this study included managing limited resources in an ID project, task-relevant experiences of Subject#39 may explain why he identified more key factors.
Table 13. Overview of surface level analysis

<table>
<thead>
<tr>
<th>Subject</th>
<th># Years of Hands-On Experience</th>
<th># Years of Teaching Experience</th>
<th># Years of Research Experience</th>
<th># Nodes</th>
<th># Links [1-way / 2-way]</th>
<th>Density of the Representation D= #Links/ #All Possible Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>#37</td>
<td>37</td>
<td>15</td>
<td>10</td>
<td>8</td>
<td>7 [7 / 0]</td>
<td>0.13</td>
</tr>
<tr>
<td>#42</td>
<td>30</td>
<td>6</td>
<td>2</td>
<td>10</td>
<td>13 [10 / 3]</td>
<td>0.14</td>
</tr>
<tr>
<td>#39</td>
<td>20</td>
<td>9</td>
<td>18</td>
<td>12</td>
<td>18 [14 / 4]</td>
<td>0.14</td>
</tr>
<tr>
<td>#41</td>
<td>__</td>
<td>15</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>6 [6 / 0]</td>
</tr>
<tr>
<td>#45</td>
<td>__</td>
<td>11</td>
<td>__</td>
<td>1</td>
<td>10</td>
<td>12 [12 / 0]</td>
</tr>
<tr>
<td>#51</td>
<td>10</td>
<td>0</td>
<td>1 ½</td>
<td>10</td>
<td>9 [9 / 0]</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>20.5</strong></td>
<td><strong>5.3</strong></td>
<td><strong>5.75</strong></td>
<td><strong>9.5</strong></td>
<td><strong>10.8</strong></td>
<td><strong>0.13</strong></td>
</tr>
</tbody>
</table>

Important for the problem than Subject#37, who had more years of experience. However, this explanation is not viable for Subject#41 since the subject’s background survey showed experience in managing instructional design scenarios. Meanwhile, the subject’s background survey also showed that Subject#41 was the individual who scored the lowest in the visual aspect of the VARK questionnaire. Therefore, one conclusion may be that the subject’s preferences for receiving and giving-out information interfered with his performance on the task. Interestingly, after Subject#41, the lowest visual score on the VARK questionnaire belongs to Subject#37 and Subject#42 respectively. As discussed above, Subject#37’s representations also included fewer nodes and links despite high numbers of years of experience (but little or no experience related to the specific task in the problem scenario). As for Subject#42, his background survey indicated relevant task experience as well as many years of experience. This subject’s representation included ten nodes, which is just above average.
In general, results of surface level analysis suggested that problem conceptualizations of experts with more years of hands-on and task-related experience contained higher numbers of nodes, one-way links, and two-way links.

Having said that, the results of semantic analysis also hinted at the possibility of the reverse situation for highly complex and ill-structured problems. Overall, the results of semantic analysis demonstrated that expert instructional designers who participated in this study identified similar problem constituents as critical for the solution of the problem. For the instructional design problem provided to experts in this study, key factors mentioned by all of the experts were formative evaluation, timelines, instructional unit development, budget, production process, and personnel availability.

However, an interesting finding of the semantic analysis was the non-existence of some of the key tasks that were often mentioned by the experts in previous studies. These included items such as analysis of instructional goals or task analysis that are very important substeps of systematic instructional design models. All of the experts who participated in this study chose to ignore such substeps and represented the problem in a higher level of abstractedness. For instance, in the problem scenario used in this study, experts chose to mention only the design of a specific module instead of further breaking down the design component into, for example, analysis of learning characteristics, analysis of instructional goals, and so on as observed in the previous studies (see, e.g., Perez et al., 1995).

This finding suggests that as the complexity of the problem scenario increases, experts chose to combine a number of different key factors into one factor in order to reduce the cognitive load of dealing with a large number of variables. Due to de Groot’s
(1965) study on chess expertise, it makes sense to assume that such classification patterns are immediately available to experts due to their past experiences where they observed the existence of such patterns. Therefore, one may expect that an expert, when provided with the LOHHOUSEN problem situation (see Dörner et al, 1983) which contained about 2,000 variables, would unconsciously collapse a number of these variables into meaningful categories (which would not be available to novices) and the expert’s problem representation would include far few numbers of nodes. In sum, contrary to initial assumption, the results of this study suggest that when presented with highly-complex problems it is possible that those with more hands-on, task-related experience may identify fewer nodes than novices would.

In addition, semantic and structural analysis of expert representations showed that it was possible to identify factors around which the links tend to cluster. *Revision of instructional materials, formative evaluation, personnel availability, timeliness, instructional unit development, instructional unit design*, and *budget* were the most central factors in expert representations. Furthermore, results of structural analysis suggested that expert instructional designers identified similar interrelationships between key factors for the given instructional design problem. Fifty percent (n=3) of expert representations depicted cause-and-effect relationships among problem constituents; 33% of expert representations (n=2) depicted process-based relationships and 17% (n=1) depicted both cause-and-effect relationships and process-based relationships among problem constituents. However, choosing either a process-based or a cause-and-effect based approach did not seem to correlate with years of experience. Nevertheless, further analysis of expert protocols revealed that both of the experts whose problem
representations consisted of links depicting process-based relationships recommended solution approaches based on some kind of modification of ID process.

Despite the similarities in their problem conceptualizations, there was no agreement among experts with respect to the solution approach. In other words, each expert offered a different set of solution approaches for the given problem. These solution approaches included process modification, delivery schedule adjustment, negotiation with the president of the company, negotiation with the client, or motivating personnel to work overtime. This result confirmed the assertion that ill-structured problems such as the instructional design problem scenario used in this study do not have a single solution. There are usually multiple solutions or solution paths. Thus, this finding confirmed that performance- and outcomes-based assessment methods are not viable for complex, ill-structured problem-solving outcomes.

Finally, the results of this study shed light on how the processes underlying complex and ill-structured problem solving is different than those underlying well-structured problem solving. Deeper analysis of expert protocols suggested that all of the experts started thinking about possible solution approaches very early in the process—while writing their assumptions. The assumptions sections of expert protocols included several elements: (1) a number of questions in order to collect data to further understand/assess the problem such as “why are we so behind schedule?” or “how flexible are the team members? For instance, can the media specialist support the affairs of the web specialist where possible?”; (2) heuristics such as “it takes about two months to develop a module,” “as experience is gained, time to develop last two modules will be less,” or “by successfully testing modules 1-4, and getting necessary feedback on design,
the remaining two modules do not have to be designed and field-tested at this time;” (3)  
identification of existing constraints affecting problem situation such as legislated  
constraints, client- and president-imposed constraints, and rules or conditions that they  
imposed in order to limit the scope of the problem such as “assume content and test  
developed is valid,” “assume 1 week delay and split ship is OK,” or “the design  
methodology used in the first modules will be used in Modules 5 & 6.” During this study,  
participants spent a considerable amount of time during this stage of the process. They  
did not proceed to problem representations for about 30 to 45 minutes. This may be due  
to participants reflecting back on their prior experiences, looking for ‘missing’  
information, setting and clarifying constraints, and using this information to construct  
their problem conceptualizations.  

Analysis of assumptions, problem representations, and solution recommendation  
of each participant confirmed the notion that problem conceptualization and problem  
solution are not two separate activities in ill-structured problem solving. Rather, they are  
intimately connected; they complete each other and develop in parallel. The assumptions  
of expert protocols contained statements which showed that early in the process of  
problem conceptualization the subjects were already thinking of possible solution  
approaches based on their prior experiences with similar cases (e.g., Subject#41). Data  
sheets filled out by the experts were full of questions (that they would have asked in real  
life situations) in order to determine which one of the solution approaches were or were  
not viable. These questions help them understand the problem better. Therefore, the  
process of ill-structured problem solving can be said to be cyclic rather than linear as in  
well-structured problem solving (Figure 40).
Subjects’ protocols also showed that experts identified and used existing constraints (client- or president-imposed) while also imposing their own constraints to further set the problem. However, while their own-imposed constraints were completely flexible, experts saw constraints imposed by the president of the company, by the client, and by other personnel as somewhat flexible in that if subjects found that a requirement established by either the client or by the president led to a bad solution, they proposed to re-negotiate the requirement with the client, with the president of the company, or even with the personnel (by employing motivational tactics or offering more pay to complete
on time). Constraint-specification and negotiating are also an important part in problem restructuring activity observed in expert protocols. All experts who participated in the study developed clear and relevant solution plans that explicitly addressed the issues they had identified in the assumptions section of their protocols.

Furthermore, all of the participants in this study developed coherent solution plan, in which the suggested solution approaches were interwoven in terms of relationships reflected in their problem conceptualizations.

From expert protocols, it was clear that experts thoroughly thought out their solution ideas, explicitly considering how those ideas might be implemented and/or what effects they might have affecting the problem state. These implications were viewed in relatively broad terms, including considerations that may not be immediately apparent. Two main strategies were observed in expert protocols when developing solution approaches: (1) imposing strict constraints in the assumption section in order to narrow down the scope of the problem and then offering a single solution approach for the problem (e.g., Subject#51); or (2) suggesting more than one possible solution as trial balloons to modify or eliminate as additional information becomes available. Suggestions were made in tentative terms (“could,” “may”) acknowledging that things may not go as anticipated. For instance, Subject#39 suggested providing an additional option to the president of the company of zero profit to produce the product sooner by either hiring outside experts or by paying overtime to available personnel. However, in case this is not accepted by the president of the company, he also recommended continuing the production as usual but splitting delivery of modules 1-4 and modules 5-6. Such comments imply that complex and ill-structured problem solving is context- and
situation-dependent, which explains why experts show a wide array of performance-outcomes.

**IMPLICATIONS OF THE STUDY**

Overall, the results of surface, structural, and semantic analysis of expert responses to the given instructional design problem suggest that responses to the first three research questions were positive. In other words, (i) there were apparent similarities among experts’ representations; (ii) expert instructional designers identified similar key factors as important for the given ID problem; and (iii) expert instructional designers identified similar interrelationships between the key factors of the given ID problem. In relation to the central research question, the implication of these findings is that there are recognizable patterns among problem conceptualizations of instructional design experts for a given ID problem. In other words, despite their varying performance-outcomes, expert instructional designers understand and interpret the given complex, ill-structured problem similarly; identify similar factors that are important for the solution of the problem; and foresee similar relationships among these factors. So, an educational implication of these findings is that to assess complex, ill-structured problem-solving outcomes, expert patterns that emerged from problem conceptualizations of experts could be used as a basis of comparison and that differences between a novice’s problem conceptualization and that of an expert’s are likely to be reasonable predictors of performance and can be used to assess the relative level of expertise in complex, ill-structured problem domains such as instructional design.

It is important to emphasize that experts develop in-depth understandings of their domain of expertise as a result of many years of experience in the field and that is what
separates them from novices who only have a theoretical background but no field experience. As a result of these field experiences experts develop heuristics about what works best under which conditions so they are able to observe patterns that are not available to novices. In this regard, an important contribution of this study is to build on the DEEP methodology to show that it is capable of eliciting individuals’ conceptualizations of complex, ill-structured problems in order to articulate, describe, and explain the differences in how people ‘model’ complex and ill-structured problems. Therefore, with the methodology used in this study expert patterns and heuristics could be elicited for different types of complex and ill-structured problems within a domain. It is argued that based on their prior experiences, experts essentially create a new model to fit the requirements of a new situation where novices follow the procedures or rules they were taught because they lack the practical experience to know what works when. Such ‘expert patterns/models’ could be elicited through the methodology used in this study and could be used for the purposes of instruction in order to facilitate acquisition of expertise in complex, ill-structured problem domains and for the purpose of assessment to determine whether novice problem conceptualizations progress to look like those of experts and for determining levels of expertise of individuals.

LIMITATIONS & RECOMMENDATIONS FOR FURTHER RESEARCH

Two main issues exist concerning generalizability of the findings of this study. The first one is whether or not the results of this study could generalize outside the domain of instructional design. There is not sufficient evidence in this study to make such an argument. On the contrary, literature reviewed in the second chapter points out the domain and context-specific nature of ill-structured problem solving.
The second question concerning generalizability includes whether or not the results of this study could generalize to all problem solving in the domain of instructional design. The findings of this study imply that ill-structured problem solving is context- and situation-dependent. Therefore, it is not possible to argue that the expert patterns elicited for the problem type used in this study would be similar to other types of ID problems. Due to the limited number of subjects and ID problem involved, it is not possible to make an argument that the results of this study could generalize to how other instructional designers would respond to other instructional design problems. On the other hand, it is important to emphasize that this study was exploratory in nature. The small number of subjects allowed the investigator to fulfill the goal of the study by enabling an in-depth study of the problem conceptualizations of instructional design experts. As Creswell (2005) noted, “[i]t is typical in qualitative research to study only a few individuals or sites because the overall ability of a researcher to provide an in-depth picture diminishes with the addition of each new individual or site” (p.207).

The findings of this initial explorative study point out to a number of important issues that should be considered in future studies. These range from issues with respect to the selection of subjects and construction of instructional design problem scenarios to issues concerning eliciting and analyzing problem conceptualizations of experts. While these issues may be viewed as limitations of this current study, they should also be viewed as the issues identified through this exploratory study to be addressed in future studies.
**Issues Related to Identification of Subjects**

This study helped identify a number of issues surrounding identification of subjects. These include (1) identifying expertise in instructional design; (2) the types of experts in ID; and (3) individual versus team view of ID.

*Identifying expertise in instructional design.* Unlike expertise in a domain such as chess, which has recognized competitions and rankings, identifying expertise in instructional design proved to be a somewhat fuzzy affair. In domains such as instructional design, where standard performance measures do not exist, it was difficult to decide who could be considered an expert instructional designer.

As presented in the second chapter, attempts to describe instructional design expertise date back to 1980s. Unfortunately, instructional design researchers do not seem to be any clearer now. Perhaps, this is not particularly surprising given the fact that instructional design is a complex, ill-structured skill that is largely dependent on the context in which it is done. This means that there is not a single set of principles and procedures that can be applied in the same way in every situation. For example, as an ID problem, designing organizational training is different than designing post-secondary education; developing classroom instruction is different than developing e-learning; and teaching technical skills is different than teaching “soft” skills (Ertmer & Stepich, 2005). As Tennyson (1997) argues there is no “big wrench” (p.178) in instructional design that solves all instructional problems. In Cates’s (2001) words, “There is no formula for ‘good’ design” (p.5).
For the purposes of this study, an operational definition of instructional design expertise was adopted from the previous studies on ID expertise. According to this definition, the general selection criteria for expert instructional designers include:

- graduate degree in the field of instructional design, curriculum design, instructional technology or a related field (Goel, 1991; Goel & Pirolli, 1989; Perez & Emery, 1995; Perez et al., 1995a; Perez & Neiderman, 1992), and
- a minimum of ten years of hands-on instructional design experience (Chase & Simon, 1973b; Chi et al., 1988; Ericsson, 2001; Goel & Pirolli, 1989; Perez et al., 1995b; Simon, 1981).

Therefore, related items were added in the background survey for the purposes of distinguishing experts from non-experts according to the criteria above. Protocols of participants who did not fulfill the criteria of expertise mentioned above were removed from analysis for the purposes of this study.

However, it is important to note that a number of other issues exist surrounding the development of expertise. For instance, Anderson (1985) and Ericsson (1996) emphasized the role of practice in the development of expertise. In later publications, Ericsson (2002) also pointed out the fact that while ten years of hands-on experience is critical to many kinds of expertise, experience alone does not constitute expertise; what distinguishes experts from others with considerable experience appears dedication to a regimen of deliberate practice. Ericsson (2002) argues that deliberate practice is evident in the routines of champion chess players, sports figures, and so on. This does not directly
translate to the field of instructional design as there are no competitions that forces instructional designers to a regimen of deliberately practice. However, in the context of instructional design, this might refer to the existence of ID tasks that are repeatedly practiced by the designer.

**Different types of experts in ID.** For the purposes of this study, a decision was made to adopt the operational definition used previously in order to decide whether or not an instructional designer could be considered as an expert for this study. However, this was not a straightforward affair as it was possible to identify three different groups of instructional designers (N. M. Seel, personal communication, September 1, 2003): (1) people who have to design and develop instructional programs, (2) scholars who teach to develop instructional programs, and (3) meta-theorists who develop conceptual models such as the Dick and Carey (2004) model of instructional design. Due to Krem’s (1995) study on cognitive flexibility in complex problem solving, these are the three different types of experts in the field of instructional design.

For that reason, in the background survey, questions were included asking respondents of their experiences in these three different arenas: practicing instructional design, teaching instructional design related course(s), and conducting research in instructional design. All of the six respondents who participated in this study had experiences in all three areas. However, all had more years of experience in practicing instructional design compared to their teaching or research experience. The effect of the homogenous and special nature of the participants’ experiences on the results of this study will be unknown until a similar study is conducted with many different types of experts with various types of experience. It is interesting to note that a similar concern
was also observed in participants of this study when they were asked, in the background survey, to indicate the person(s) they consider as expert instructional designers. The resulting list consisted of a mix of practitioners, teachers of instructional design, and theoreticians. This result points out a similar confusion in the field of instructional design in defining who could be considered as an expert instructional designer.

Findings of this study suggested that participants with more hands-on instructional design experience identify more critical factors constituting the problem. No noticeable effects of teaching or research experience were identified.

When I asked Ericsson about his ideas on this topic during a later personal conversation, his response was succinct: “look at where the ‘real expertise’ of each group lies” (K. A. Ericsson, personal communication, 11 July 2004). What he meant was that expert practitioners are expert at practicing instructional design (and therefore designing and developing instructional design materials); scholars were expert in teaching instructional design; and theorists were expert at making instructional design theories. On the other hand, whether there are significant differences in how experts in these different groups approach instructional design problems would make an interesting study.

**Team versus individual expertise.** While this study concentrated on individual expertise, instructional design is often practiced as a team activity that also involves graphic designers, multimedia developers, programmers, subject-matter experts, and so on. Indeed, this point was voiced by a participant during the post-interview when he stated that he did not make such decisions by himself. However, even if a task is normally accomplished by many, having one person perform it may still be predictive of that person’s relative level of expertise.
Furthermore, since the main purpose of this study was to investigate the utility of the DEEP methodology in the domain of instructional design, a decision was made to ignore the team-view. Nevertheless, interesting questions remain as to how instructional design teams solve instructional design problems together and whether causal representations aid in this complex problem solving and decision-making process.

**Issues Related to ID Problem Scenario**

Another set of limitations that prevent the generalizability of the findings of this study are related to the issues concerning the selection of instructional design problem scenario. Basically, two issues are important in this regard: (1) the realization that instructional design consists of different tasks and (2) the context-depended nature of instructional design problems.

**Different tasks comprising ID.** Instructional design consists of a number of different tasks. Recent studies with instructional design practitioners (Holcomb *et al.*, 1996; Reigeluth, 1997; Rowland, 1992; Wedman & Tessmer, 1993) suggested that not all instructional designers conduct each and every task regularly and that instructional design practice is much different than what is prescribed with instructional design models. The International Board of Standards for Training, Performance and Instruction (ibstpi) make this point at length in their 2000 volume of instructional design standards (Richey *et al.*, 2000). For this reason, a question was included in the background survey that inquired about the ID activities respondents regularly perform in their current positions. The responses to this question in the background survey were confirmatory in that none of the instructional designers in this study declared actively performing all ID tasks.
Therefore, originally, this study intended to present expert instructional designers with three different instructional design scenarios, each with a different type of ID task, at different levels of difficulty. The goal was to investigate whether a difference in the type of task and in the level of difficulty of the task have any significant effects in the overall results. During data collection, it took the participants about three and a half hours to complete their responses on the first problem scenario. Upon completion of their responses to the first scenario, all of the participants were so (mentally) tired that one of the experts even used the term ‘brain-drain’ to describe how he felt. Therefore, the investigator had to abort the administration of the remaining two ID problem scenarios.

Therefore, the results of this study are based on only a single instructional design problem scenario. Nevertheless, the results of this study confirmed the importance of task-specific experiences since the observed differences between expert protocols suggested that relative levels of expertise is a function of number of years of hands-on experience and the particular task-experience called for the specific problem addressed in the study. For instance, an instructional designer with thirty years of hands-on ID expertise but no experience in managing an ID project might show characteristics of someone with much less expertise when it comes to managing ID projects. Therefore, future studies attempting to investigate the validity of the DEEP methodology for instructional design problem solving should include a wide array of different instructional design tasks and contexts.

**Different contexts of ID practice.** In addition to above considerations, results of this study also imply that different contexts instructional designers have to work in
(such as military, business, and education) may have an effect on their instructional design approach.

The instructional design problem administered in this study mainly dealt with managing an ID project in a K-12 setting. However, it was thought that regardless of its context, the problem was of the kind that could be faced in every context. However, approaches to some of the more design-focused problems could be affected by the contexts in which they are situated. Therefore, future studies should take the contextual-dependence of the instructional design problem solving into account. Furthermore, whether there are any differences in how ID experts in different contexts approach ID problems and whether it is still possible to diagnose recognizable response patterns among experts in a variety of different contexts would be yet other interesting questions to be addressed in future studies.

**Issues Related to Elicitation of Problem Conceptualizations**

The DEEP methodology is based on the elicitation and analysis of the problem conceptualizations of the experts via annotated causal mapping. Since problem conceptualizations are not directly observable, their character must be inferred from observations of overt human behavior.

In this study, participants were asked to represent problem constituents and relationships among them as annotated representations. Inherently, a number of limitations arise in all studies (including this study) involving the elicitation of conceptualizations. First of all, it may be argued that the expert knowledge is highly intuitive and automatized; therefore, experts are usually not explicitly aware of how they think about the problem or why their solution worked. Therefore, some may argue that
asking experts to externally represent the problem domain as causal relationships of key factors may be forcing them to think of the problem in a way they are not used to. However, the findings of recent studies in expert problem solving are encouraging in this regard. Ericsson (2002) and Goel and Pirolli (1989) report that upon completion of a task, experts typically reflect on the problem situation and why one approach worked but the other one failed (Ericsson, 2001; Goel & Pirolli, 1989). Therefore, especially for tasks involving complex, ill-structured problem solving, experts are used to reflecting on the factors that influence the solution approach and the relationships between them.

The data collection procedure was in fact intended to support simulation of experts’ reflective conversations with themselves during an actual complex problem solving task. Besides the properties of the ID problem scenario, which replicated an authentic ID problem scenario, the subjects were not simply asked to construct a causal representation. Instead, they were first asked to thoroughly think about the problem and to reflect on the problem recording their assumptions, reflections, and so on. Then, they were asked to identify the factors which they thought were important for the solution of the problem. They were encouraged to write each factor on pieces of sticky notepads and to arrange them on a piece of paper so that they can show the relationships among them with directional arrows. Furthermore, participants were asked to annotate each factor and each link in their representation in order to make sure their representations reflected what they had in mind.

Participants in this study were asked to also suggest solutions for the given problem. This was done in order to check whether the expert solution approaches were consistent with their representation. Analysis of expert protocols showed that
participants’ representations and their recommendations for solution were complimentary to each other. This finding suggested that annotated representation method used in this study was a useful method for eliciting conceptual representations (problem spaces) of individuals.

In addition, after the completion of data collection, participants were asked about their experiences with the task to determine whether the task influenced their performance. One out of six participants stated that he was not sure how he would do on the same task if it was provided again in the future. He was concerned that his performance would be different, which could affect the results of the study. However, this is normal and expected, since at a later point in time, the experiences of this and any other participants would be different, which would influence how that individual thought about the problem. What is more important is to be able to capture the details of those experiences. Therefore, above points mentioned in this section are very important in developing instruments to identify relevant levels of expertise of instructional designers. Furthermore, more detailed, follow-up interviews could be administered to the subjects after the study, which asks them to use the think-aloud method when they think about how they would approach the solution of the problem in question.

**CONCLUSION**

This study was intended to be an explorative investigation into the utility of the DEEP methodology in the domain of instructional design. Therefore, the intent was not to generalize the findings to the population of experts in general or the experts in ID, but to develop an in-depth exploration of expert patterns in instructional design. In this regard, this study has contributed (1) to the investigations with the DEEP assessment
methodology in general, and more specifically, (2) to the investigations on instructional design problem solving, when this activity is viewed as a complex, ill-structured problem solving activity.

The main goal of this study was to investigate the utility of the DEEP methodology in the domain of instructional design. Therefore, the main research question was formulated to explore whether the problem conceptualizations of expert instructional designers exhibit recognizable patterns. The results of this study suggest that the answer to this question is positive. However, this study also identified differences among experts in how they approached the instructional design problems. In this regard, this study is one of the very few. This expanded understanding of the instructional design problem solving is significant in determining relative levels of expertise in instructional design. In this regard, a series of follow-up studies are recommended to take into account the above-mentioned limitations and to include a larger pool of subjects and a variety of different ID tasks in a variety of contexts in order to elaborate on the sources of variance among expert instructional designers.

In addition, the findings of this study are encouraging for the utility of the DEEP methodology in the domain of instructional design. Future research plans of the investigator include further investigations with this methodology in the domain of instructional design. Taking into account of the findings and limitations of this study, a number of studies are being planned that will include a larger number of expert and novice instructional designers across a variety of ID tasks in different contexts with the goal of identifying whether there are recognizable similarities in expert responses and whether the novice responses are recognizably different than those of experts. Also, these
follow up studies will aim at developing a similarity metric for instructional design problem solving that will aid in assessing progress of learning and determining relative level of expertise in the domain of instructional design.

An interesting question for the future studies would be to determine if and how experts switch their problem conceptualizations based on different tasks. Due to previous studies, it is expected that expert representations of different instructional design problems would include different elements depending on the patterns perceived by the experts as useful for the problem situation. For instance, in a study on software design problem solving, Bennet & Morgan (1987) found out that experts quickly and frequently switch between different models and representations based on the task. They concluded that experts were able to quickly generate different problem representations for different situations as their understanding of the problem evolved. Software design problems might be another avenue to investigate the utility of the DEEP methodology. Along these lines, an attractive approach might be to perform data mining of “design patterns.” There is a great deal of research and development in creating patterns in both the hardware and software domain (see Klein & Eseryel, 2005). It would be worthwhile to see how expert solutions as measured by the DEEP methodology match with design patterns that are published by the experts. In sum, it is imperative that the investigations with the DEEP methodology continue in other domains involving complex, ill-structured problem solving.

Forecasting on the year 2010, the investigator maintains that we shall eventually find ourselves on the path toward a theory of instructional design provided that we continue working towards the goal of developing a valid and reliable assessment
methodology for higher-order, complex problem outcomes, and then use this assessment methodology to scientifically test which instruction works, and under what conditions.
APPENDICES
APPENDIX 1.

COVER PAGE OF THE DATA COLLECTION PACKAGE PROVIDED TO PARTICIPANTS
THE COMPLEXITY OF INSTRUCTIONAL DESIGN

Facilitator: Deniz Eseryel

PIDT 2002 Smith Lake, Virginia

May 19, 2002

Step 1. Listen to/Read the background information About This Study

Step 2. Fill in Participant Information Sheet

Step 3. Take the Background Survey

Step 4. Problem Solving Activity
APPENDIX 2.

LETTER OF INFORMED CONSENT
Step 1. ABOUT THIS STUDY

This study is about learning in complex domains. The complex domain involved in this study is instructional design.

For the purposes of this study, I am collecting basic demographic information including age, gender, educational background, instructional design experience, and instructional preferences. You will then be provided with problem scenarios and asked to represent each scenario identifying assumptions and key causal factors in the problem situation.

I have received IRB approval for this effort. Your anonymity will be protected throughout this study. Your name will never be associated with any of your products nor will it be disclosed to any third party. Participation to this study is voluntary. You are free to choose to participate or not to participate. Your choice will have no detrimental effect on your relationship with Syracuse University. By participating in this study, you will be contributing to our understanding of the skills and knowledge needed to assess progress of learning in complex domains. This will enable us and others to contribute to research about facilitating learning in and about complex domains. Your participation and expertise is important to the success of this study. I would be pleased to send you a summary of the results of this and subsequent studies if you are interested.

Sincerely

Deniz ESERYEL, Ph.D. Student
IDD&E, Syracuse University
APPENDIX 3.

PARTICIPANT INFORMATION SHEET
Step 2. PARTICIPANT INFORMATION SHEET

NAME [optional]:

TITLE [optional]:

AFFILIATION [optional]:

ADDRESS [optional]:

E-MAIL [optional]:

☐ Please check if you want to receive summary of the results of this and subsequent studies (you should provide at least your name and email address)
APPENDIX 4.

BACKGROUND SURVEY
Step 3. BACKGROUND SURVEY

The purpose of this survey is to collect basic background information about the participants. The survey has three sections:

- Part A. Background Information
- Part B. Instructional Design Experience
- Part C. Instructional Preferences

Please answer all of the questions. The survey should take about 5 to 10 minutes to complete.

PART A. BACKGROUND INFORMATION

1. Age: ___________

2. Gender:   a. Male   b. Female

3. Highest degree attained:
   e. Other (specify) ___________________________________________________

4. Which descriptors would you use to identify your area(s) of specialization for your highest-level degree(s)?

<table>
<thead>
<tr>
<th>Most Descriptive (pick one)</th>
<th>Descriptor (pick all that apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>Instructional design and development</td>
</tr>
<tr>
<td>□</td>
<td>Instructional/educational technology</td>
</tr>
<tr>
<td>□</td>
<td>Educational psychology, learning</td>
</tr>
<tr>
<td>□</td>
<td>Evaluation and assessment</td>
</tr>
<tr>
<td>□</td>
<td>Adult education</td>
</tr>
<tr>
<td>□</td>
<td>Online learning</td>
</tr>
<tr>
<td>□</td>
<td>Training and development</td>
</tr>
</tbody>
</table>
| □                           | Other (specify) _________________________________
| □                           | ________________________________________________
| □                           | ________________________________________________|
PART B. INSTRUCTIONAL DESIGN EXPERIENCE

1. Years of full-time equivalent experience in designing and developing instruction: _______ years

2. Years of full-time equivalent experience in teaching instructional design and development related courses: _______ years

3. Years of full-time equivalent experience in conducting research in areas related to instructional design and development: _______ years

4. Title of current position:
   a. Instructional designer
   b. Instructional/educational technologist
   c. Training designer/developer
   d. Instructional media specialist
   e. Performance engineer/human performance technologist
   f. Instructional delivery specialist
   g. Professor of instructional design and technology
   h. Graduate student of instructional design and technology
   i. Other ______________________________________________________

5. Select activities you regularly perform in your current position. Check all that apply:
   - Conduct needs assessments
   - Determine solution alternatives and approaches
   - Propose solutions
   - Write learning objectives
   - Conduct task analyses
   - Identify types of learning outcomes
   - Assess learner’s entry level skills
   - Assess learner characteristics
   - Develop test items
   - Select instructional strategies
   - Select media formats
   - Conduct formative evaluations
   - Conduct summative evaluations
   - Manage instructional/training projects
   - Other ________________________________________________________
6. Which courses relevant to instructional design have you taught? Check all titles similar to those you have taught:
   - Instructional analysis
   - Needs assessment
   - Human performance technology
   - Instructional design
   - Instructional systems development
   - Educational/instructional technology
   - Multimedia design and development
   - Advanced multimedia design and development
   - Distance education
   - Educational simulations and games
   - Message design
   - Program evaluation
   - Evaluation methods and techniques
   - Test and measurement
   - Project management
   - Principles of learning and instruction
   - Theories of adult learning
   - Instructional research and methods
   - Other __________

7. How do you rate your level of expertise as an instructional designer?
   - None
   - Low
   - Moderate
   - High
   - Very high

8. Indicate people you consider to be expert instructional designer(s):
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________

9. Indicate the criteria that you believe are most relevant in determining whether someone is an expert instructional designer:
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
   ___________________________________________________________
PART C. INSTRUCTIONAL PREFERENCES

Direction: The following questions are adapted from VARK Questionnaire developed by Fleming (2001)¹ and are intended to identify preferences for working with information.

Choose the answer which best explains your preference. You may choose more than one answer if a single answer does not match your perception.

1. You are about to give directions to a person who is standing near you. She is staying in a hotel in town and wants to visit your house later. She has a rental car. You would:
   a. draw a map on paper
   b. tell her the directions
   c. write down the directions (without a map)
   d. collect her from the hotel in your car

2. You are not certain whether a word should be spelled 'dependent' or 'dependant'. You would:
   a. look it up in the dictionary.
   b. see the word in your mind and choose by the way it looks
   c. sound it out in your mind.
   d. write both versions down on paper and choose one.

3. You have just received a copy of your itinerary for an international trip. This is of interest to a friend. You would:
   a. phone her immediately and tell her about it.
   b. send her a copy of the printed itinerary.
   c. show her on a map of the world.
   d. share what you plan to do at each place you visit.

4. You are going to cook something as a special treat for your family. You would:
   a. cook something familiar without the necessity for instructions.
   b. thumb through the cookbook looking for ideas from the pictures.
   c. refer to a specific cookbook where there is a good recipe.

5. A group of tourists has been assigned to you to find out about wildlife reserves or parks. You would:
   a. drive them to a wildlife reserve or park.
   b. show them slides and photographs
   c. give them pamphlets or a book on wildlife reserves or parks.
   d. give them a talk on wildlife reserves or parks.

¹ Copyright © 2001 for this version of VARK is held by Neil D. Fleming, Christchurch, New Zealand and Charles C. Bonwell, Green Mountain, Colorado, USA. Reprinted here with permission.
6. You are about to purchase a new stereo. Other than price, what would most influence your decision?
   a. the salesperson telling you what you want to know.
   b. reading the details about it.
   c. playing with the controls and listening to it.
   d. it looks really smart and fashionable.

7. Recall a time in your life when you learned how to do something like playing a new board game. Try to avoid choosing a very physical skill, e.g. riding a bike. You learned best by:
   a. visual clues -- pictures, diagrams, charts
   b. written instructions.
   c. listening to somebody explain it.
   d. doing it or trying it.

8. You have an eye problem. You would prefer the doctor to:
   a. tell you what is wrong.
   b. show you a diagram of what is wrong.
   c. use a model to show you what is wrong.

9. You are about to learn to use a new program on a computer. You would:
   a. sit down at the keyboard and begin to experiment with the program's features.
   b. read the manual which comes with the program.
   c. telephone a friend and ask questions about it.

10. You are staying in a hotel and have a rental car. You would like to visit friends whose address/location you do not know. You would like them to:
   a. draw you a map on paper.
   b. tell you the directions.
   c. write down the directions (without a map).
   d. collect you from the hotel in their car.

11. Apart from the price, what would most influence your decision to buy a particular textbook?
   a. you have used a copy before.
   b. a friend talking about it.
   c. quickly reading parts of it.
   d. the way it looks is appealing.

12. A new movie has arrived in town. What would most influence your decision to go (or not go)?
   a. You heard a radio review about it
   b. You read a review about it.
   c. You saw a preview of it.
13. Do you prefer a lecturer or teacher who likes to use:
   a. a textbook, handouts, readings
   b. flow diagrams, charts, graphs.
   c. field trips, labs, practical sessions.
   d. discussion, guest speakers.

*Thank you for completing this survey!*

Please continue with the problem scenarios provided in the package distributed to you. Please understand that there are no right or wrong answers to these scenarios. The intent is only to explore how various individuals think about complex problems.
APPENDIX 5.

DIRECTIONS FOR THE PROBLEM SOLVING ACTIVITY
Step 4. PROBLEM SOLVING ACTIVITY

The purpose of this task is to explore how different people approach problem solving in complex domains. There are no right or wrong answers to these problems so please do not feel any kind of performance pressure. The procedure involves responding to a problem scenario by providing a set of assumptions and contextual remarks, identifying factors likely to influence the situation, annotating those factors with regard to what they represent and how they are related and influence other aspects of the problem, and then recommending a solution approach consistent with the aforementioned items.

DIRECTIONS:

Step 4.1 Before you start please review the Example enclosed. This example illustrates annotated causal mapping method for the given problem scenario.

Step 4.2 Read Problem Scenario I.

Step 4.3 By using Worksheet for Step 4.3 provide your assumptions and contextual remarks for your representation.

Step 4.4 By using Worksheet for Step 4.4 create a representation of problem scenario I, identifying the factors (nodes) and the relationships (links) between them. You can write the names of each factor on a yellow sticky-pad and construct your representation with those. After constructing your causal map, number each node (factor) in your map starting from 1 and assign a letter to each link (relationship) in your map starting from the letter a.

Step 4.5 By using Worksheet for Step 4.5 annotate each node (factor) by elaborating on the meaning of that factor.

Step 4.6 By using Worksheet for Step 4.6 annotate each link (relationship) by elaborating on the relationship of the factors involved.

Step 4.7 By using Worksheet for Step 4.7 write your recommendations for this problem scenario based on your analysis reflected on your representation.

Step 4.8 Repeat the steps from 4.2 to 4.7 for Problem Scenario II & Problem Scenario III.
EXAMPLE PROBLEM SCENARIO
You are a consultant to an internal needs assessment team at an organization that is considering converting many of its existing face-to-face technical training courses to web-based and web-supported courses. motivations include the distributed locations of clientele, a requirement to keep up with new technologies, and a desire to change the corporate image to be more in touch with modern technology. Your task is to reflect how various stakeholder interests might impact this effort.

SAMPLE SOLUTION
Assumptions and contextual remarks
1. The organization is mid-size; Stakeholders include upper-management, middle management, instructional designers, trainers, clients (management), and learners.
2. Middle management consists of instructional design and/or training managers who are responsible of overseeing the overall effort.
3. This particular training organization has distributed clientele who have been sending their employees to the organization's face-to-face training facility. Recently, they are complaining that sending employees for training are getting more expensive and therefore they are bargaining very hard or otherwise seem to be looking for other options.
4. Some of the competitive organizations have started offering Web-based technical training courses.

Representation

Notice that each node (factor) as well as each link (relationship) is numbered /lettered. The next section requires an elaboration for each node and link.
Annotations and elaboration of factors and relationships depicted

Nodes/Factors
1. The pressure from clients including client complaints (i.e., clients might be complaining that sending employees for training are getting more expensive and therefore they may be bargaining very hard or otherwise seem to be looking for other options.)
2. The pressure from environment (i.e., Internet and related technologies are becoming commonplace in education and training and define the competitive edge; a number of competitive training companies start offering web-based technical training courses)
3. Upper management’s resistance to adopt Web-based training
4. Middle management’s (i.e., training manager and instructional design manager) resistance to adopt Web-based training
5. Staff’s (i.e., instructional designers, trainers, etc.) resistance to adopt Web-based training
6. Rate of internal adoption including #staff developing/implementing Web-based courses; # courses offered via Web.
7. Estimated project size including budget, time, personnel involved
8. The number of personnel that needs to be hired
9. Expertise of staff in developing/training with Web-based courses
10. The rate of production of Web-based courses and materials
11. The number of products pilot tested
12. The number and the variety of products ready to be delivered to the clients
13. The number of orders placed by the client

Links/Relationships
(a) As the pressure from the clients increase the rate of adoption also increases
(b) As the pressure form environment increase the rate of adoption also increases
(c) As upper management’s resistance increase the rate of adoption decreases
(d) As middle management’s resistance increase the rate of adoption decreases
(e) As staff’s resistance increase the rate of adoption decreases
(f) As the rate of adoption increases so does the estimated project size
(g) As the estimated project size increases more personnel can be hired
(h) As more personnel hired internal expertise of organization increases
(i) As the expertise in the organization increases so does the production capacity

(j) As the rate of production increases there will be more courses to be pilot-tested

(k) As more courses are pilot tested there will be more variety of courses ready for clients

(l) As more products are available for online delivery there will be more client orders

(m) As client orders increases the rate of adoption of courses increases

**Recommendations for a solution**

1. Identify upper management’s, middle management’s and staff’s concerns, requirements and perceptions

2. Conduct environmental scanning to identify market trends and competitive organizations

3. Talk to existing clients to identify current issues and whether they are interested in Web-based training

4. Identify organization’s existing level of expertise in designing, developing and delivering Web-based training courses

5. Identify organization’s technical capacity including equipment, software

6. External pressures might be enough to break upper management’s resistance to change, however, internal personnel will continue to resist due to a number of factors including insufficient expertise in the area, and therefore, job insecurity coming along with the change. Middle management, on the other hand, may be inclined to keep the project size (in terms of required resources) large so that training and incentive structure could be put in place. However, the upper management will not be willing to spend a lot of money, as they may still be skeptic of this adoption. Therefore, the best way may to start could be to start small but to think big. For the purposes of initiating this innovation, an immediate action could be to hire a full-time, experienced person and utilize internal resources to develop a few courses for immediate existing clients and establish the Web-based development standards and procedures in the organization.

7. As more products client orders, slowly train early adopters inside the organization till everybody is capable of producing/implementing Web-based courses. Then hire external staff if the size of this project gets unmanageable
APPENDIX 7.

INSTRUCTIONAL DESIGN PROBLEM SCENARIO PROVIDED TO PARTICIPANTS
Step 4.2 PROBLEM SCENARIO I

You are the manager of a group of instructional developers and educational technologists at a small private enterprise named Learning Designs for Fun and Profit, Ltd. located in the mid-western United States. Your team is working on a project called “Six Simple Steps” that involves the development of a set of six short learning modules on the topic of integrating technology into middle school science teaching to be delivered via the Internet to rural teachers all across the USA. The project team includes a manager (you), an instructional designer, a media and graphics specialist, a web specialist, a subject matter specialist, and a consulting middle school science teacher. The project is currently at the end of the eighth month of a twelve-month effort. There is a bonus of 10% for on-time completion according to established requirements. There is no provision for cost overruns other than renegotiating the contract, which is with a large book publisher.

The completed set of modules is supposed to be ready for a one-week field test at selected schools in six states in two weeks time. Four of the six modules have been completed and have been tested informally within your enterprise. Those four are believed to be ready for the field test. Work has not yet begun on the remaining two modules: (a) Supporting Web-based Collaborative Experiments in Earth Science, and, (b) Conducting Webquests for Science Education. The framework and approach used in the previous four modules are somewhat adaptable and suitable for the remaining two modules. Based on the time and expertise used to develop the first four modules, it appears very unlikely that the team can complete the remaining two modules and conduct an internal test within two weeks. In order to resolve this situation, your task is to first determine what factors are relevant to successful completion of the effort. Based on that analysis, you will make a recommendation to the President of the company with regard to resource allocation to support the completion of the effort.
APPENDIX 8.

WORKSHEETS PROVIDED TO PARTICIPANTS
Worksheet for Step 1
ASSUMPTIONS & CONTEXTUAL REMARKS

Write your assumptions and contextual remarks for problem scenario below:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Worksheet for Step 2 REPRESENTATION

Create a representation for the given problem scenario identifying the factors (nodes) and the relationships (links) between them. You can write the name of each factor on a yellow sticky-pad and construct your representation with those. After constructing your representation, number each node (factor) in your representation starting from “1” and assign a letter to each link (relationship) in your representation starting from the letter “a”.
# Worksheet for Step 3
ANNOTATIONS & ELABORATIONS for EACH FACTOR (NODE) IN MY REPRESENTATION

<table>
<thead>
<tr>
<th># Node/Factor</th>
<th>Annotation/Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Worksheet for Step 4

**ANNOTATIONS & ELABORATIONS for EACH LINK**

(RELATIONSHIP) IN MY REPRESENTATION

<table>
<thead>
<tr>
<th>Letter of the Link/Relationship</th>
<th>Annotation/Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Worksheet for Step 5.
RECOMMENDATIONS FOR PROBLEM SCENARIO

Based on your analysis of the given problem scenario, please recommend a solution approach below:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
APPENDIX 9.

INSTITUTIONAL REVIEW BOARD NOTIFICATION
MEMORANDUM

FACULTY: Michael Spector
DEPT: Instructional Technology
STUDENT: Deniz Eseryel
IRB#: 02105
RE: EXEMPT FROM REVIEW
TITLE: Annotated Causal Influence Diagram Assessment Methodology

The information you submitted pertaining to the above proposal was reviewed for evaluation of your judgment in determining:

1. the rights and welfare of the individual(s) under investigation.
2. the appropriate methods to secure informed consent, and
3. the risks and potential benefits of the investigation.

It is my judgment that your proposal is not research and does not require Board approval. Should there be any change in the nature of the activity (e.g., testing results used for research purposes), then a new, specific protocol would need to be submitted.

Steven Taylor, Chair
TO: Steve Taylor
FROM: Patty Brundage

For Preliminary Review: SPECTOR, MICHAEL  IRB# 02-105
Deniz Eseryel  IDD&E
Annotated Causal Influence

CHECKLIST:
______ A copy of your consent for subjects is needed.
______ The informed consent needs to be typed on departmental letterhead.
______ The consent form should list the name, with contact information, of the faculty advisor if people have questions.
______ A copy of your measures or sample questions are needed.
______ A permission letter is needed from the institution/organization to interview subjects
______ How will confidentiality be maintained?

OTHER COMMENTS:

EXEMPT

5/18/02

EXPEDITED APPROVAL
PROVISIONAL EXPEDITED APPROVAL
HOLD FOR COMMITTEE
APPENDIX 10.

SAMPLE DATA PROTOCOL OBTAINED FROM ONE OF THE SUBJECTS
Step 3. BACKGROUND SURVEY

The purpose of this survey is to collect basic background information about the participants. The survey has three sections:
- Part A. Background Information
- Part B. Instructional Design Experience
- Part C. Instructional Preferences

Please answer all of the questions. The survey should take about 5 to 10 minutes to complete.

PART A. BACKGROUND INFORMATION

5. Age: __55________


7. Highest degree attained:
   e. Other (specify) ___________________________________________________

8. Which descriptors would you use to identify your area(s) of specialization for your highest-level degree(s)?

<table>
<thead>
<tr>
<th>Most Descriptive (pick one)</th>
<th>Descriptor (pick all that apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>🗼 🗼</td>
<td>Instructional design and development</td>
</tr>
<tr>
<td>🗼</td>
<td>Instructional/educational technology</td>
</tr>
<tr>
<td>🗼</td>
<td>Educational psychology, learning</td>
</tr>
<tr>
<td>🗼</td>
<td>Evaluation and assessment</td>
</tr>
<tr>
<td>🗼</td>
<td>Adult education</td>
</tr>
<tr>
<td>🗼</td>
<td>Online learning</td>
</tr>
<tr>
<td>🗼</td>
<td>Training and development</td>
</tr>
<tr>
<td>🗼</td>
<td>Other (specify)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PART B. INSTRUCTIONAL DESIGN EXPERIENCE

10. Years of full-time equivalent experience in designing and developing instruction: ___30____ years

11. Years of full-time equivalent experience in teaching instructional design and development related courses: ___6____ years

12. Years of full-time equivalent experience in conducting research in areas related to instructional design and development: ___2____ years

13. Title of current position:
   a. Instructional designer
   b. Instructional/educational technologist
   c. Training designer/developer
   d. Instructional media specialist
   e. Performance engineer/human performance technologist
   f. Instructional delivery specialist
   g. Professor of instructional design and technology
   h. Graduate student of instructional design and technology
   i. Other

   __________________________________________

14. Select activities you regularly perform in your current position? Check all that apply:
   □ Conduct needs assessments
   □ Determine solution alternatives and approaches
   □ Propose solutions
   □ Write learning objectives
   □ Conduct task analyses
   □ Identify types of learning outcomes
   □ Assess learner’s entry level skills
   □ Assess learner characteristics
   □ Develop test items
   □ Select instructional strategies
   □ Select media formats
   □ Conduct formative evaluations
   □ Conduct summative evaluations
   □ Manage instructional/training projects
   □ Other________________________________________________________
   __________________________________________
15. Which courses relevant to instructional design have you taught? Check all titles similar to those you have taught:

- [ ] Instructional analysis
- [ ] Needs assessment
- [ ] Human performance technology
- [x] Instructional design
- [ ] Instructional systems development
- [ ] Educational/instructional technology
- [ ] Multimedia design and development
- [ ] Advanced multimedia design and development
- [ ] Distance education
- [ ] Educational simulations and games
- [ ] Message design
- [ ] Program evaluation
- [ ] Evaluation methods and techniques
- [ ] Test and measurement
- [ ] Project management
- [x] Principles of learning and instruction
- [ ] Theories of adult learning
- [ ] Instructional research and methods
- [ ] Other

16. How do you rate your level of expertise as an instructional designer?

- [ ] None
- [ ] Low
- [ ] Moderate
- [ ] High
- [x] Very high

17. Indicate people you consider to be expert instructional designer(s):

GAGNE

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

18. Indicate the criteria you believe most relevant in determining whether someone is an expert instructional designer:

- [ ] DEPTH OF KNOWLEDGE IN LEARNING AND INSTRUCTION
- [ ] APPLIED THEORY TO REAL PROBLEMS
PART C. INSTRUCTIONAL PREFERENCES

Direction: The following questions are adapted from VARK Questionnaire developed by Fleming (2001)\(^2\) and are intended to identify preferences for working with information.

Choose the answer which best explains your preference. You may choose more than one answer if a single answer does not match your perception.

14. You are about to give directions to a person who is standing near you. She is staying in a hotel in town and wants to visit your house later. She has a rental car. You would:
   a. draw a map on paper
   b. tell her the directions
   c. write down the directions (without a map)
   d. collect her from the hotel in my car

15. You are not certain whether a word should be spelled 'dependent' or 'dependant'. You would:
   a. look it up in the dictionary.
   b. see the word in your mind and choose by the way it looks
   c. sound it out in your mind.
   d. write both versions down on paper and choose one.

16. You have just received a copy of your itinerary for an international trip. This is of interest to a friend. You would:
   a. phone her immediately and tell her about it.
   b. send her a copy of the printed itinerary.
   c. show her on a map of the world.
   d. share what you plan to do at each place you visit.

17. You are going to cook something as a special treat for your family. You would:
   a. cook something familiar without the necessity for instructions.
   b. thumb through the cookbook looking for ideas from the pictures.
   c. refer to a specific cookbook where there is a good recipe.

18. A group of tourists has been assigned to you to find out about wildlife reserves or parks. You would:
   a. drive them to a wildlife reserve or park.
   b. show them slides and photographs
   c. give them pamphlets or a book on wildlife reserves or parks.
   d. give them a talk on wildlife reserves or parks.

---

19. Your are about to purchase a new stereo. Other than price, what would most influence your decision?
   a. the salesperson telling you what you want to know.
   b. reading the details about it.
   c. playing with the controls and listening to it.
   d. it looks really smart and fashionable.

20. Recall a time in your life when you learned how to do something like playing a new board game. Try to avoid choosing a very physical skill, e.g. riding a bike. You learned best by:
   a. visual clues -- pictures, diagrams, charts
   b. written instructions.
   c. listening to somebody explain it.
   d. doing it or trying it.

21. You have an eye problem. You would prefer the doctor to:
   a. tell you what is wrong.
   b. show you a diagram of what is wrong.
   c. use a model to show you what is wrong.

22. You are about to learn to use a new program on a computer. You would:
   a. sit down at the keyboard and begin to experiment with the program's features.
   b. read the manual which comes with the program.
   c. telephone a friend and ask questions about it.

23. You are staying in a hotel and have a rental car. You would like to visit friends whose address/location you do not know. You would like them to:
   a. draw you a map on paper.
   b. tell you the directions.
   c. write down the directions (without a map).
   d. collect you from the hotel in their car.

24. Apart from the price, what would most influence your decision to buy a particular textbook?
   a. you have used a copy before.
   b. a friend talking about it.
   c. quickly reading parts of it.
   d. the way it looks is appealing.

25. A new movie has arrived in town. What would most influence your decision to go (or not go)?
   a. You heard a radio review about it
   b. You read a review about it.
   c. You saw a preview of it.
26. Do you prefer a lecturer or teacher who likes to use:
   a. a textbook, handouts, readings
   b. flow diagrams, charts, graphs.
   c. field trips, labs, practical sessions.
   d. discussion, guest speakers.

   Thank you for completing this survey!

   Please continue with the problem scenarios provided in the package distributed to you. Please understand that there are no right or wrong answers to these scenarios. The intent is only to explore how various individuals think about complex problems.
Step 4.2 PROBLEM SCENARIO I

You are the manager of a group of instructional developers and educational technologists at a small private enterprise named Learning Designs for Fun and Profit, Ltd. located in the mid-western United States. Your team is working on a project called “Six Simple Steps” that involves the development of a set of six short learning modules on the topic of integrating technology into middle school science teaching to be delivered via the Internet to rural teachers all across the USA. The project team includes a manager (you), an instructional designer, a media and graphics specialist, a web specialist, a subject matter specialist, and a consulting middle school science teacher. The project is currently at the end of the eighth month of a twelve-month effort. There is a bonus of 10% for on-time completion according to established requirements. There is no provision for cost overruns other than renegotiating the contract, which is with a large book publisher.

The completed set of modules is supposed to be ready for a one-week field test at selected schools in six states in two weeks time. Four of the six modules have been completed and have been tested informally within your enterprise. Those four are believed to be ready for the field test. Work has not yet begun on the remaining two modules: (a) Supporting Web-based Collaborative Experiments in Earth Science, and, (b) Conducting Webquests for Science Education. The framework and approach used in the previous four modules are somewhat adaptable and suitable for the remaining two modules. Based on the time and expertise used to develop the first four modules, it appears very unlikely that the team can complete the remaining two modules and conduct an internal test within two weeks. In order to resolve this situation, your task is to first determine what factors are relevant to successful completion of the effort. Based on that analysis, you will make a recommendation to the President of the company with regard to resource allocation to support the completion of the effort.

2 months/module
Worksheet for Step 4.3
ASSUMPTIONS & CONTEXTUAL REMARKS

Write your assumptions and contextual remarks for problem scenario I below:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Based on data, it takes about 2 months to develop a module</td>
</tr>
<tr>
<td>2.</td>
<td>As gained experience, time to develop last two modules will be less</td>
</tr>
<tr>
<td>3.</td>
<td>Assume staff worked normal work week of 40 hrs/week</td>
</tr>
<tr>
<td>4.</td>
<td>Assume do as is, it would be one week late - If keep going like we have, we will be one week late if no revision needed</td>
</tr>
<tr>
<td>5.</td>
<td>Most time spent on graphics + SME → Design</td>
</tr>
<tr>
<td>6.</td>
<td>Reason needed to have deadline 3 months ahead of schedule is to provide slack time to assume 10% bonus OR Feedback + Revision →</td>
</tr>
<tr>
<td>7.</td>
<td>Manager - can do design work also</td>
</tr>
<tr>
<td>8.</td>
<td>Salaries are equivalent across people/positions</td>
</tr>
<tr>
<td>9.</td>
<td>Need at least 20% of initial development time for revision time → 1 week per module → 6 weeks</td>
</tr>
<tr>
<td>10.</td>
<td>Want repeat business- want to release proven quality product</td>
</tr>
<tr>
<td>11.</td>
<td>Assume content + test developed - valid- 1st time SME + Consultant usually right as this</td>
</tr>
<tr>
<td>12.</td>
<td></td>
</tr>
</tbody>
</table>
Worksheet for Step 4.4 REPRESENTATION

Create a representation for the given problem scenario identifying the factors (nodes) and the relationships (links) between them. You can write the name of each factor on a yellow sticky-pad and construct your representation with those. After constructing your representation, number each node (factor) in your representation starting from “1” and assign a letter to each link (relationship) in your representation starting from the letter “a”.

1. Content Research + Definition
2. Test Development
3. Learning Design
4. Graphics Materials Development
5. Development Time
6. Trials + Feedback
7. Costs to Develop
8. Real Time
9. Quality
10. Non-Standard Work Time

- Delivery Date
- Linear time
**Worksheet for Step 4.5**

**ANNOTATIONS & ELABORATIONS for EACH FACTOR (NODE) IN MY REPRESENTATION**

<table>
<thead>
<tr>
<th># Node/Factor</th>
<th>Annotation/Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time spent research determining the content to be learned</td>
<td>Clarify, elaborate, and understanding content to be learned</td>
</tr>
<tr>
<td>2. Effort on defining and developing test</td>
<td>Defining exactly what is to be learned - content knowledge, procedures, strategies,</td>
</tr>
<tr>
<td>3. Learning design</td>
<td>Instructional lesson design, activities, sequence of instruction, amount of adaptation, sophistication of the instructional model</td>
</tr>
<tr>
<td>4. Graphic/material development</td>
<td>Effort in creation, and programming and implementing the instructional model</td>
</tr>
<tr>
<td>5. Cumulated time to develop a module</td>
<td>Amount of time to develop a complete set of materials to market ready</td>
</tr>
<tr>
<td>6. Trials and revision</td>
<td>Effort spent in field testing and getting feedback</td>
</tr>
<tr>
<td>7. Costs to develop</td>
<td>Total cost - staff time - salaries</td>
</tr>
<tr>
<td>8. Delivery date - linear time</td>
<td>Actual date for completion the project</td>
</tr>
<tr>
<td>9. Quality</td>
<td>-</td>
</tr>
<tr>
<td>10. Non-standard time</td>
<td>Work overtime at no charge</td>
</tr>
</tbody>
</table>
## Worksheet for Step 4.6

**ANNOTATIONS & ELABORATIONS for EACH LINK (RELATIONSHIP) IN MY REPRESENTATION**

<table>
<thead>
<tr>
<th>Letter of the Link/Relationship</th>
<th>Annotation/Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a.</strong></td>
<td>As content gets more sophisticated it affects the sophistication of design</td>
</tr>
<tr>
<td><strong>b.</strong></td>
<td>As content is more precisely defined, then design may decrease - less clarification needed - same for test development</td>
</tr>
<tr>
<td><strong>c.</strong></td>
<td>As learning design gets more sophisticated/deeper then tests will need to be more sophisticated</td>
</tr>
<tr>
<td><strong>d.</strong></td>
<td>As tests get more sophisticated - defines more complex learning affects design of learning</td>
</tr>
<tr>
<td><strong>e.</strong></td>
<td>As learning design gets more sophisticated the graphics/ programming gets more sophisticated but as lesson designs more precisely articulates and scripted then development decreases</td>
</tr>
<tr>
<td><strong>f.</strong></td>
<td>Time is “sunk” at graphics time/ development time</td>
</tr>
<tr>
<td><strong>g, h, i, j</strong></td>
<td>As design gets more elaborate feedback /revision gets more risky + more chance that revision is needed → (test immediately)</td>
</tr>
<tr>
<td><strong>k.</strong></td>
<td>Quality is primarily a function of effort spent on trial-feedback-revision cycle</td>
</tr>
<tr>
<td><strong>l + m</strong></td>
<td>As more time spent - increase cost + delivery date</td>
</tr>
<tr>
<td><strong>n + o</strong></td>
<td>Willingness to work overtime - what it takes to bring in on time then delivery date + cost will decrease</td>
</tr>
</tbody>
</table>
Worksheet for Step 4.7
RECOMMENDATIONS FOR PROBLEM SCENARIO I

Based on your analysis of the given problem scenario, please recommend a solution approach below:

1. Ask management to give 5% bonus if bring in on date

2. Throw “beer-dinner” party on Fridays- to develop “ownership”

3. Request people to work overtime- do what it takes to get done on time- there will be a 5% bonus
APPENDIX 11.

ANALYSIS OF THE SAMPLE DATA PROTOCOL
Worksheet for Step 4.3
ASSUMPTIONS & CONTEXTUAL REMARKS

Write your assumptions and contextual remarks for problem scenario I below:

1. Based on data, it takes about 2 months to develop a module

2. As gained experience, time to develop last two modules will be less heuristic - from prior experience

3. Assume staff worked normal work week of 40 hrs/week

4. Assume do as is, it would be one week late - If keep going like we have, we will be one week late if no revision needed

5. Most time spent on graphics + SME → Design heuristic

6. Reason needed to have deadline 3 months ahead of schedule is to provide slack time to assume 10% bonus OR Feedback + Revision → heuristic

7. Manager - can do design work also

8. Salaries are equivalent across people/positions

9. Need at least 20% of initial development time for revision time → 1 week per module → 6 weeks heuristic

10. Want repeat business - want to release proven quality product

11. Assume content + test developed - valid 1st time SME + Consultant usually right as this

12. 
STEP 4.4 REPRESENTATION FOR PROBLEM SCENARIO-I

1) CONTENT RESEARCH & DEFINITION (Time spent research defining the content to be learned: Clarifying/ elaborating and understanding content to be learned)

2) TEST DEVELOPMENT (Effort on defining and developing test: Defining exactly what is to be learned- content knowledge, processes, strategies, etc.)

3) LEARNING DESIGN (Learning Design: Instructional lesson design, activities, sequence of instruction, amount of adaptation, sophistication of the instr. model)

4) GRAPHICS MATERIALS DEVELOPMENT (Graphics / materials development: Effort in creating, and programming & implementing the instr. model)

5) DEVELOPMENT TIME (Cumulated time to develop a model: Amount of time to develop a complete set of materials to Market Ready)

6) TRIALS & FEEDBACK (Trials & Revision: Effort spent in field testing & getting feedback)

7) COSTS TO DEVELOP (Costs to Develop: Total Cost- Staff Time- Salaries)

8) REAL TIME - DELIVERY DATE - LINEAR TIME (Delivery Date - Linear Time: Actual date for completing the project)

9) QUALITY

10) NON STANDARD WORK TIME (Non Standard Time - Work overtime at no charge)

SURFACE-LEVEL ANALYSIS (Centrality, Density, Number of nodes and links, avg. words per node, per node name, and per link)
**SEMANTIC ANALYSIS – Coder#2**

**STEP 4.4 PRESENTATION FOR PROBLEM SCENARIO**

1. **CONTENT RESEARCH & DEFINITION**
   - Time spent researching defining the content to be learned; clarifying and understanding content to be learned.

2. **TEST DEVELOPMENT**
   - Effort on defining and developing test; defining exactly what is to be learned—content knowledge, processes, strategies, etc.

3. **LEARNING DESIGN**
   - Learning Design: Instructional lesson design, activities, sequence of instruction, amount of adaptation, sophistication of the instr. model.

4. **GRAPHICS MATERIALS DEVELOPMENT**
   - Graphics / materials development; Effort in creating, and programming & implementing the instr. model.

5. **DEVELOPMENT TIME**
   - Cumulated time to develop a model: Amount of time to develop a complete set of materials to Market Ready.

6. **TRIALS & FEEDBACK**
   - Trials & Revision: Effort spent in field testing & getting feedback.

7. **QUALITY**

8. **REAL TIME DELIVERY DATE - LINEAR TIME**
   - Delivery Date - Linear Time: Actual date for completing the project.

9. **COSTS TO DEVELOP**
   - Costs to Develop: Total Cost—Staff Time—Salaries.

**ANNOTATIONS AND ELABORATIONS FOR EACH LINK IN CAUSAL MAP**

A) As content gets more sophisticated, affects the sophistication of design.
B) As content is more precisely defined, then designed may decrease - less clarification needed - same for test development.
C) As learning design gets more sophisticated/deeper, then tests will need to be more sophisticated.
D) As test gets more sophisticated/defines more complex learning effects design of learning.
E) As learning design gets more sophisticated, then graphical/programs get more sophisticated.
F) Time is "sink" at graphics time/development time.
G, H, I, J) As design gets more elaborate feedback/revision gets more risky and more chance that revision is needed to test immediately.
K) Quality is primarily a function of effort spent on Trial-Feedback-Revision cycle.
L, M) As more time spent—increased cost & delivery date.
N, O) Willingness to work overtime—what it takes to bring in on time then delivery date & costs will decrease.
STEP 4.4 PRESENTATION FOR PROBLEM SCENARIO-I

1) CONTENT RESEARCH & DEFINITION
(Time spent research defining the content to be learned: Clarifying/ elaborating and understanding content to be learned)

2) TEST DEVELOPMENT
(Effort on defining and developing test: Defining exactly what is to be learned- content knowledge, processes, strategies, etc.)

3) LEARNING DESIGN
(Learning Design: Instructional lesson design, activities, sequence of instruction, amount of adaptation, sophistication of the instr. model)

4) GRAPHICS MATERIALS DEVELOPMENT
(Graphics / materials development: Effort in creating, and programming & implementing the instr. model)

5) DEVELOPMENT TIME
(Cumulated time to develop a model: Amount of time to develop a complete set of materials to Market Ready)

6) TRIALS & FEEDBACK
(Trials & Revision: Effort spent in field testing & getting feedback)

7) COSTS TO DEVELOP
(Costs to Develop: Total Cost- Staff Time- Salaries)

8) REAL TIME - DELIVERY DATE - LINEAR TIME
(Delivery Date - Linear Time: Actual date for completing the project)

9) QUALITY

10) NON STANDARD WORK TIME
(Non Standard Time - Work overtime at no charge)

ANNOTATIONS AND ELABORATIONS FOR EACH LINK IN CAUSAL MAP

A) As content gets more sophisticated, affects the sophistication of design.
B) As content is more precisely defined, then designed may decrease - less clarification needed -same for test development.
C) As learning design gets more sophisticated/deeper, then tests will need to be more sophisticated.
D) As test gets more sophisticated - defines more complex learning effects design of learning.
E) As learning design gets more sophisticated, then graphics/programs get more sophisticated.
F) Time is "sunx" at graphics time/ development time.
G, H, I, J) As design gets more elaborate feedback/ revision gets more risky and more chance that revision is needed -> test immediately.
K) Quality is primarily a function of effort spent on Trial-Feedback-Revision cycle.
L, M) As more time spent- increased cost & delivery date.
N, O) Willingness to work overtime- what it takes to bring in on time then delivery date & costs will decrease.
STEP 4.4 PRESENTATION FOR PROBLEM SCENARIO-I

1) CONTENT RESEARCH & DEFINITION
   (Time spent research defining the content to be learned: Clarifying/elaborating and understanding content to be learned)

2) TEST DEVELOPMENT
   (Effort on defining and developing test: Defining exactly what is to be learned- content knowledge, processes, strategies, etc.)

3) LEARNING DESIGN
   (Learning Design: Instructional lesson design, activities, sequence of instruction, amount of adaptation, sophistication of the instr. model)

4) GRAPHICS MATERIALS DEVELOPMENT
   (Graphics / materials development: Effort in creating, and programming & implementing the instr. model)

5) DEVELOPMENT TIME
   (Cumulated time to develop a model: Amount of time to develop a complete set of materials to Market Ready)

6) TRIALS & FEEDBACK
   (Trials & Revision: Effort spent in field testing & getting feedback)

7) COSTS TO DEVELOP
   (Costs to Develop: Total Cost- Staff Time- Salaries)

8) REAL TIME - DELIVERY DATE - LINEAR TIME
   (Delivery Date - Linear Time: Actual date for completing the project)

9) QUALITY

10) NON STANDARD WORK TIME
    (Non Standard Time - Work overtime at no charge)

ANNOTATIONS AND ELABORATIONS FOR EACH LINK IN CAUSAL MAP

A) As content gets more sophisticated, affects the sophistication of design.
B) As content is more precisely defined, then designed may decrease - less clarification needed - same for test development.
C) As learning design gets more sophisticated/deeper, then tests will need to be more sophisticated.
D) As test gets more sophisticated - defines more complex learning effects design of learning.
E) As learning design gets more sophisticated, then graphics/programs get more sophisticated.
F) Time is "sunk" at graphics time/ development time. 
G) More time spent on revisions gets more risky and more chance that revision is needed - test immediately.
H) Quality is primarily a function of effort spent on Trial-Feedback-Revision cycle.
I) As more time spent - increased cost & delivery date.
J) Willingness to work overtime - what it takes to bring in on time then delivery date & costs will decrease.
Worksheet for Step 4.7
RECOMMENDATIONS FOR PROBLEM SCENARIO I

Based on your analysis of the given problem scenario, please recommend a solution approach below:

1. Ask management to give 5% bonus if bring in on date

2. Throw “beer-dinner” party on Fridays- to develop “ownership”

3. Request people to work overtime- do what it takes to get done on time- there will be a 5% bonus

Provide incentives to motivate personnel to work faster to finish on time & decrease the quality of products
APPENDIX 12.

LETTERS OF PERMISSION TO USE COPYRIGHTED MATERIAL
Permission to Use Figure 3.

>>> "Robert Tennyson" <rtenny@umn.edu> 2/8/2006 11:07 AM >>>
Dear Deniz Eseryel,

You have my permission to use any of my published articles on the ISD4 model. Please send me a copy of your dissertation when it is finished. I would also like to offer the journal, *Computers in Human Behavior*, as an outlet for your work.

Best regards,

Robert D. Tennyson, Ph.D.
Professor
Learning and Cognition
Department of Educational Psychology
University of Minnesota
178 Pillsbury Dr. S.E.
Minneapolis, MN 55455
Voice: 612-626-1618
Fax: 612-624-8241
Email: rtenny@umn.edu
Permission to Use Figure 5.

Deniz Eseryel  
Syracuse University  
Instructional Design, Development & Evaluation (IDD&E)  
330 Huntington Hall  
Syracuse, NY 13244-4100  

Permission is granted for the nonexclusive use of APA-copyrighted material specified on the attached request contingent upon fulfillment of the conditions indicated below:

☐ A fee of $0 shall be paid to APA on or before publication.

☐ This fee is waived.

☐ The reproduced material must include a full bibliographic citation and the following notice: Copyright © 1966 by the American Psychological Association. Reprinted or Adapted with permission.

☐ You must obtain the author's (or, in the case of multiple authorship, one author's) permission. APA's permission is subject to the condition that the author of the cited material does not object to your usage.

☐ A complimentary copy of the work shall be sent to the APA Permissions Office upon publication.

☐ Other/Comments: Reference: Figure 2.2

This agreement constitutes permission to reprint only for the purposes specified on the attached request and does not apply to subsequent uses, nor any form of electronic use. Permission applies solely to publication and distribution in the English language throughout the world, unless otherwise stated. No changes, additions, or deletions to the material other than any authorized in this correspondence shall be made without prior written consent by APA. This permission does not include permission to use any copyrighted matter obtained by APA or the author(s) from other sources that may be incorporated in the material. It is the responsibility of the applicant to obtain permission from such other sources.

ACCEPTED AND AGREED TO BY:  

[Signature]

APPLICANT:  
February 18, 2006

DATE:  

PERMISSION GRANTED ON ABOVE TERMS:  

[Signature]

for the American Psychological Association  
February 15, 2006

DATE:  

☐ I wish to cancel my request for permission at this time.
I am not sure that you need my permission to reproduce that figure, but in case you do, I am pleased to grant it.

Robert W. Weisberg  
Professor and Director  
Graduate Program in Brain, Behavior, and Cognition  
Department of Psychology  
Temple University  
Philadelphia, PA 19122  
215 204 7567

On Feb 16, 2006, at 8:57 AM, Deniz Eseryel wrote:

> Dear Dr. Weisberg:
> 
> First of all, I would like to let you know how much I enjoy your work  
> on problem solving. I am a doctoral candidate at Syracuse University  
> at the Department of Instructional Design, Development, and  
> Evaluation.  
> 
> I am writing today, to request reprint permission of the figure you  
> have in the article entitled “Verbal behavior and problem solving:  
> Some effects of labeling in a functional fixedness problem” you  
> 659-664, namely, Figure 1. Candle problem illustration used in three  
> experiments (the all labeled form is shown) on page 660.  
> 
> I’d like to use this figure in my doctoral dissertation. My  
> dissertation is entitled: Expert Conceptualizations Of The Domain Of  
> Instructional Design: An Investigative Study On The Deep Assessment  
> Methodology For Complex Problem-Solving Outcomes. In chapter 2, where  
> I am reviewing the literature on problem solving, I’d like to use  
> this figure to accompany your synthesis of problem solving literature  
> of the time.  
> 
> Of, course, full reference will be provided according to APA 5th  
> guidelines.  
> 
> My dissertation is almost ready. I am planning to submit it to the  
> graduate school within 2 weeks. Dissertation defense is set for March  
> and, hopefully, I will be graduating in May 2006. I would be happy to  
> send you a copy of my dissertation upon your request.  
> 
> I am looking forward to hearing from you,  
> 
> Sincerely,  
> 
> Deniz Eseryel  
> Syracuse University  
> Instructional Design, Development, & Evaluation (IDD&E)  
> Syracuse, NY 13244-2340
Permission to Use Figure 7.

Date: 2/16/2006

Title: Organizing and memorizing: Studies in the psychology of learning and teaching


Author/Editor: George Katona Year of Publication/Edition: 1967 (2nd ed)

Selection (page numbers and total number of pages used): Figure 15 on page 78 (Total of 1 pages)

PART II: FOR COMPLETION BY COLUMBIA UNIVERSITY PRESS

We do indeed control the rights to this title and grant this request in accordance with the terms listed below.

- This is a one-time, non-exclusive grant subject to the following: Permission if dissertation is published Payment of a fee of $200 (tax ID # 13-1623968). Payment is due upon your signature and MUST be accompanied with this form. We can not process the permission if you mail the check without the letter.

- Use of a standard credit line that follows the form outlined below (with respect to the variables):
  "from [title of the book], by [author/editor/translator]. Copyright © [date]
  Columbia University Press. Reprinted with permission of the publisher."

Signature ____________________________

Agreed: I have read and accepted the terms outlined above.

Declined: I will be unable to use the material under those terms.
Permission to Use Figure 8.

American Psychological Association
Copyright Permission Request Form

APA Rank:

Please fill out the relevant information in the form below and mail to: APA Permissions Office, 750 First Street, NE, Washington, DC 20002-4242 or fax to: 202-336-5633.

Date: January 31, 2006

Your contact information:

Your name and organization: DENIZ ESENYEL, SYRACUSE UNIVERSITY
Department: INSTRUCTIONAL DESIGN, DEVELOPMENT & EVALUATION (IDDE)
Street Address: 330 HUNTINGTON HALL
City: SYRACUSE
State, Zip/Postal Code, and Country: NY 13244-4100
Office Phone: (315) 443-3703
Fax number: (315) 443-1218
Email: DESERGEL@SYR.EDU

Your Reference Code Number: (If required)

The APA book material that you wish to use:

Book citation (must include book title, copyright year, authors, book chapter title, and page numbers):

JOURNAL OF COMPARATIVE PSYCHOLOGY, 10 (2), 115-143.

Material that you wish to use from the book (check block and fill in information for one of the following):

☐ Entire book chapter (if you wish to use portions of the chapter, you must also provide a copy of the APA book chapter with the portions highlighted or otherwise indicated that you wish to use):

Page 1

Please cite source.

NO PERMISSION OR FEE IS NECESSARY
This material is now in the Public Domain

Beverly Rector 2-17-06

PERMISSIONS OFFICE
AMERICAN PSYCHOLOGICAL ASSOCIATION
Permission to Use Figure 9.

Feb 17, 2006

Deniz Eseryel
SYRACUSE UNIVERSITY
IDD & E
330 Huntington Hall
Syracuse, NY 13244

Fax #: 315-443-1218

You have our permission to include content from our text, PATTERNS OF PROBLEM SOLVING, 1st Ed, in your doctoral dissertation for your degree in at Syracuse University.

Content to be included is:

p. 5 Fig. 1-1

Permission is extended to include the reproduction of a maximum of 5 copies for scholarly and research use at Syracuse University. Should further reproduction and/or publication of this material be anticipated, additional permission must be sought.

Please credit our material as follows:

Sincerely,

Barbara Wood
Permissions Administrator
Permission to Use Figure 13.

>>> "Mary Gick" <mgick@ccs.carleton.ca> 2/8/2006 7:25 AM >>>
Hello,

You have permission to use the figure.

Yes, please send a copy of the dissertation when it is complete.

Best wishes,

Mary Gick, Ph.D.
Chair, Psychology

----- Original Message ----- 
From: "Deniz Eseryel" <deseryel@syr.edu> 
To: <mary_gick@carleton.ca> 
Cc: "Deniz Eseryel" <DEseryel@syr.edu> 
Sent: Wednesday, February 08, 2006 2:54 AM 
Subject: Reprint Permission Request 
>
> Dear Prof. Mary Gick: 
>
> First of all, I would like to let you know how much I enjoy your work on 
problem solving. I am a doctoral candidate at Syracuse University at the 
Department of Instructional Design, Development, and Evaluation. 
>
> I am writing today, to request reprint permission of the figure you have 
in the article entitled "Problem solving strategies" you published in 1986 
in Educational Psychologist 21(1&2), 99-120, namely, Figure 1. Schematic 
diagram of the problem solving process on page 101. 
>
> I’d like to use this figure in my doctoral dissertation. My dissertation 
is entitled: Expert Conceptualizations Of The Domain Of Instructional 
Design: An Investigative Study On The Deep Assessment Methodology For 
Complex Problem-Solving Outcomes. In chapter 2, where I am reviewing the 
literature on problem solving, I’d like to use this figure to accompany your 
synthesis of problem solving literature of the time. 
>
> Of, course, full reference will be provided as: Gick, M. L. (1986). Problem-solving strategies. 
Educational Psychologist, 21(1&2), 99-120. 
>
> My dissertation is almost ready. I am planning to submit it to the 
graduate school within 2 weeks. Dissertation defense is set for late March and, 
hopefully, I will be graduating in May 2006. I would be happy to send you a 
copy of my dissertation upon your request. 
>
> I am looking forward to hearing from you, 
>
> Sincerely, 
>
> Deniz Eseryel
Hello Deniz,

Permission granted under the following conditions:

PERMISSION GRANTED provided that material has appeared in our work without credit to another source; you obtain the consent of the author(s); you credit the original publication; and reproduction is confined to the purpose for which permission is hereby given.

This is an original email document; no other document will be forthcoming. Should you have any questions, please don't hesitate to contact me.

Regards,
Bonita

Bonita R. D'Amil
Executive Assistant/Office Manager
Permissions and Translations Manager
Office of Rights and Permissions
Lawrence Erlbaum Associates
10 Industrial Avenue
Mahwah, NJ 07430
E-mail: Bonita.D'Amil@erlbaum.com
Phone: (201) 258-2211
Fax: (201) 236-0072

For more information on LEA visit our website at: www.erlbaum.com

-----Original Message-----
From: deseryel@syr.edu [mailto:deseryel@syr.edu]
Sent: Wednesday, February 08, 2006 3:35 AM
To: Bonita D'Amil
Subject: Rights and Permissions Request from the Web

Applicant: Deniz Eseryel
Address 1: Syracuse University IDD&E
Address 2: 330 Huntington Hall
City: Syracuse
State/Province: NY
Zip/Postal Code: 13244
Country: USA
Phone: 3
Fax: 315-443-1218

E-mail: deseryel@syr.edu

Reprint Title: EXPERT CONCEPTUALIZATIONS OF THE DOMAIN OF INSTRUCTIONAL DES

Reprint Author/Editor: Deniz Eseryel

Reprint Publisher: N/A - unpublished doctoral dissertation

Additional Information: Hello, I am a doctoral student at Syracuse University. I would like to receive permission to use above-mentioned figure in my dissertation, which will not be a published work. In my literature review, I review Gick's work on problem solving and I thought above-mentioned figure will be explanatory for the readers.

I am planning to submit my dissertation within a couple of weeks and appreciate if I can get the permission letter from you ASAP. Thank you very much for your help in this matter. Sincerely, Deniz Eseryel

Title #1 (ISBN or ISSN): Volume 21; Issue 1&2 (1986)

Title #1 (Title): Educational Psychologist

Title #1 (Author/Editor): Mary L. Gick

Title #1 (Selection): Figure 1. Schematic diagram of the problem solving process on page 101.

Title #2 (ISBN or ISSN):

Title #2 (Title):

Title #2 (Author/Editor):

Title #2 (Selection):

Title #3 (ISBN or ISSN):

Title #3 (Title):

Title #3 (Author/Editor):

Title #3 (Selection):
Permission to Use Figure 14.

Dear Denise Eseryel

Thank you for your request.

Permission granted for the use requested.

If material appears within our work with credit to another source, authorisation from that source must be obtained.

Proper credit must be given to our publication.

Credit must include the following components:
Title of the Work, Author(s) and/or Editor(s) Name(s). Copyright year.
Copyright John Wiley & Sons Limited. Reproduced with permission.

Yours sincerely

Sue Keil
Permissions Department

----- Forwarded by Bradley Johnson/P&T/Hoboken/Wiley on 02/07/2006 11:05 AM -----
republication <republication@wiley.com> To <republication@wiley.com>
cc Subject Republication/Electronic Request Form

A01_First_Name: Deniz
A02_Last_Name: Eseryel
A03_Company_Name: Syracuse University IDD&E
A04_Address: 330 Huntington Hall
A05_City: Syracuse
A06_State: NY
A07_Zip: 13244
A08_Country: USA
A09>Contact_Phone_Number: (315) 395-4480
A10_Fax: (315) 443-1218
A11_Emails: deseryel@syr.edu
A12_Reference: 2.11
A13_Book_Title: New technology and human error
A40_Book_or_Journal: Book
A14_Book_Author: J. Rasmussen; K. Duncan, & J. Leplat
A15_Book_ISBN: 0471910449
A16_Journal_Month:
A17_Journal_Year:
A18_Journal_Volume:
A19_Journal_Issue_Number:
A20_Copy_Pages: Page 98; Figure 1: The map of the town of Lohhausen
Hello, I am a doctoral student at Syracuse University. I would like to receive permission to use above-mentioned figure in my dissertation, which will not be a published work. I review Dorner's work on complex problem solving in my dissertation and thought this figure will be explanatory for the readers.

I am planning to submit my dissertation within a couple of weeks and appreciate if I can get the permission letter from you ASAP. Thank you very much for your help in this matter. Sincerely, Deniz Eseryel

The information contained in this e-mail and any subsequent correspondence is private and confidential and intended solely for the named recipient(s). If you are not a named recipient, you must not copy, distribute, or disseminate the information, open any attachment, or take any action in reliance on it. If you have received the e-mail in error, please notify the sender and delete the e-mail.

Any views or opinions expressed in this e-mail are those of the individual sender, unless otherwise stated. Although this e-mail has been scanned for viruses you should rely on your own virus check, as the sender accepts no liability for any damage arising out of any bug or virus infection.
Permission to Use Figure 15.

>>> "Gary Klein ARA/KAD" <Gary@decisionmaking.com> 2/10/2006 6:12 PM >>>

Deniz ...

I am pleased that you are interested in the research I have done. I have no problems at all with you reprinting the figure.

Good luck with the defense.

Gary

-----Original Message-----
From: Deniz Eseryel [mailto:deseryel@syr.edu]
Sent: Wednesday, February 08, 2006 3:25 AM
To: gary@klein-inc.com
Cc: Deniz Eseryel
Subject: Request for Reprint Permission

Dear Gary Klein:

First of all, I would like to let you know how much I enjoy your work on decision making.

I am a doctoral candidate at Syracuse University at the Department of Instructional Design, Development, and Evaluation. I am writing today, to request reprint permission of the figure you have in the article entitled "Naturalistic Decision Making" you published in 1991 with David Klinger in Human Systems IAC Gateway 11(3), 16-19, namely, Figure 2. Recognition-rimed decision model on page 18.

I'd like to use this figure in my doctoral dissertation. My dissertation is entitled: Expert Conceptualizations Of The Domain Of Instructional Design: An Investigative Study On The Deep Assessment Methodology For Complex Problem-Solving Outcomes. In chapter 2, where I am reviewing the literature on complex problem solving, I'd like to use this figure to accompany your work on decision making.

Of, course, full reference will be provided as:


My dissertation is almost ready. I am planning to submit it to the graduate school within 2 weeks. Dissertation defense is set for March and, hopefully, I will be graduating in May 2006. I would be happy to send you a copy of my dissertation upon your request.

I am looking forward to hearing from you,
Sincerely,
Deniz Eseryel
Permission to Use Figure 17.

Hello Deniz,

Permission granted under the following conditions:

PERMISSION GRANTED provided that material has appeared in our work without credit to another source; you obtain the consent of the author(s); you credit the original publication; and reproduction is confined to the purpose for which permission is hereby given.

This is an original email document; no other document will be forthcoming. Should you have any questions, please don't hesitate to contact me.

Regards, Bonita

Bonita R. D'Amil
Executive Assistant
Permissions and Translations Manager
Office of Rights and Permissions
Lawrence Erlbaum Associates/The Analytic Press
10 Industrial Avenue
Mahwah, NJ 07430
E-mail: Bonita.D'Amil@erlbaum.com
Phone: (201) 258-2211
Fax: (201) 236-0072

For more information on LEA visit our website at: www.erlbaum.com

----Original Message-----
From: deseryel@syr.edu [mailto:deseryel@syr.edu]
Sent: Tuesday, April 11, 2006 2:39 PM
To: Bonita D'Amil
Subject: Rights and Permissions Request from the Web

Applicant: Deniz Eseryel
Address 1: Syracuse University IDD&E
Address 2: 330 Huntington Hall
City: Syracuse
State/Province: NY
Zip/Postal Code: 13205
Country: USA
Phone: 315-4433704
Fax: 315-4431218
E-mail: deseryel@syr.edu

Reprint Title: EXPERT CONCEPTUALIZATIONS OF THE DOMAIN OF INSTRUCTIONAL DES
Reprint Author/Editor: Deniz Eseryel
Reprint Publisher: N/A - unpublished doctoral dissertation

Additional Information: Hello, I am a doctoral student at Syracuse University. I would like to receive permission to use above-mentioned figure in my dissertation, which will not be a published work. In my literature review, I review problem solving literature and I thought above-mentioned figure will be explanatory for the readers.

I am planning to submit my dissertation within a week and appreciate if I can get the permission letter from you ASAP. Thank you very much for your help in this matter. Sincerely, Deniz Eseryel

Title #1 (ISBN or ISSN): 0-8058-1397-7
Title #1 (Title): Instructional Design: International Perspective
Title #1 (Author/Editor): S. Dijktra, N. Seel, F. Schott, & R. D. Tennyson
Title #1 (Selection): Figure 2.3 on Page 37 (I am changing the figure; it will be an adaptation not an exact replica of the figure as printed)
Permission to Use Figure 18.

Hello Deniz,

Permission granted under the following conditions:

PERMISSION GRANTED provided that material has appeared in our work without credit to another source; you obtain the consent of the author(s); you credit the original publication; and reproduction is confined to the purpose for which permission is hereby given.

This is an original email document; no other document will be forthcoming. Should you have any questions, please don't hesitate to contact me.

Regards,

Bonita

Bonita R. D'Amil
Executive Assistant/Office Manager
Permissions and Translations Manager
Office of Rights and Permissions
Lawrence Erlbaum Associates
10 Industrial Avenue
Mahwah, NJ 07430
E-mail: Bonita.D'Amil@erlbaum.com
Phone: (201) 258-2211
Fax: (201) 236-0072

For more information on LEA visit our website at: www.erlbaum.com

-----Original Message-----
From: deseryel@syr.edu [mailto:deseryel@syr.edu]
Sent: Wednesday, February 08, 2006 12:55 AM
To: Bonita D'Amil
Subject: Rights and Permissions Request from the Web

Applicant: Deniz Eseryel

Address 1: Syracuse University IDD&E

Address 2: 330 Huntington Hall

City: Syracuse

State/Province: NY

Zip/Postal Code: 13244
Country: USA
Phone: 315-395-4480
Fax: 315-443-1218
E-mail: deseryel@syr.edu

Reprint Title: EXPERT CONCEPTUALIZATIONS OF THE DOMAIN OF INSTRUCTIONAL DES
Reprint Author/Editor: Deniz Eseryel
Reprint Publisher: N/A - unpublished doctoral dissertation

Additional Information: Hello, I am a doctoral student at Syracuse University. I would like to receive permission to use above-mentioned figure in my dissertation, which will not be a published work. In my literature review, I review problem solving tools like concept mapping and I thought above-mentioned figure will be explanatory for the readers.

I am planning to submit my dissertation within a couple of weeks and appreciate if I can get the permission letter from you ASAP. Thank you very much for your help in this matter. Sincerely,
Deniz Eseryel

Title #1 (ISBN or ISSN): 0-8058-2626-2
Title #1 (Title): Learning, Creating, And Using Knowledge
Title #1 (Author/Editor): Joseph D. Novak
Title #1 (Selection): Figure 3.9 A concept map showing key ideas and principles exhibited in a good concept map [on Page 32]

Title #2 (ISBN or ISSN):
Title #2 (Title):
Title #2 (Author/Editor):
Title #2 (Selection):

Title #3 (ISBN or ISSN):
Title #3 (Title):
Title #3 (Author/Editor):
Title #3 (Selection):
Permission to Use Figures 19, 20, 21, & 22.

>>> "cyber" <cyber@cyberlearningcorp.com> 2/14/2006 11:31 AM >>>

Dear Deniz,

I'm glad to hear that things are going well for you and congratulations on your degree.

Yes you do have permission to use what you need for your studies.

Good Luck and let me know when you publish so I can read the article(s).

Dean Christensen, Ph.D.

-----Original Message-----
From: Deniz Eseryel [mailto:deseryel@syr.edu]
Sent: Monday, February 13, 2006 11:14 PM
To: cyber@mailcl.com
Cc: Deniz Eseryel
Subject: Request for permission to reprint
Importance: High

Hello Dean,

I hope all is well. It has been quite some time, I think the last time was the TICL dinner at AERA in 2003.

I am doing considerably well.... Trying to finish my dissertation. I am almost done. As you might remember, I am extending the assessment study based on causal influence diagrams you started with Mike Spector in Norway in the domain of instructional design.

For the literature review of my dissertation, I want to use the following figures from your the conference paper entitled, "Evaluating the impact of system dynamics based learning environments: Preliminary study." that was presented at the International System Dynamics Society Meeting in Norway:

- Problem scenario for the spread of an infection
- The causal questionnaire form
- Deer population scenario
- Yeast problem scenario

Mike suggested as a first author, I should contact you for request permission to reprint. Of course, I will properly reference the figures according to APA 5th guidelines.

My dissertation is almost ready. I am planning to submit it to the graduate school within 2 weeks. Dissertation defense is set for March and, hopefully, I will be graduating in May 2006. I would be happy to send you a copy of my dissertation upon your request.

I am looking forward to hearing from you,

Greetings, Deniz.
Permission to Use Figures 23 through 29.

>>> "J. Michael Spector" <mspector@lsi.fsu.edu> 2/7/2006 8:52 AM >>>

With regard to the first, all you need is the permission of the first author – Dean Christensen – he is now in North Carolina I believe – cyber@mailclc.com:

Dean L. Christensen
Vice President
CYBER Learning Corporation
103 St. George LN
Semora, NC 27343

With regard to the second, I think technically you only need permission of the first author, but I strongly advise getting permission of both (you have mine).

In both cases, when you use the figures, you should cite the source and include the phrase ‘used with permission’.

mike

From: Deniz Eseryel [mailto:deseryel@syr.edu]
Sent: Monday, February 06, 2006 11:18 PM
To: mspector@mail.lsi.fsu.edu
Cc: Deniz Eseryel; Jerry Klein; Philip Doughty
Subject: copyright question

Hello Mike,

I have just faxed to book/journal publishers my requests for permission to reprint the figures I used in my dissertation.

However, I am not sure how to proceed with the conference paper you presented at Bergen with your colleagues and the NSF-DEEP report (references are below). So, I decided to ask you if it will be appropriate to send to you formal requests for permission to reprint. If not, who do you think I should contact? Each author/ conference organizer/NSF? I looked at APA 5th but there was no guidance beyond APA journals. I am new at this so I appreciate your help. Cheers,

Deniz.

——
Deniz Eseryel 2/13/2006 11:01 PM >>>
Dear Mike Spector & Tiffany Koszalka:

I am writing to request reprint permission of the figures you have in the research report entitled, the DEEP methodology for assessing learning in complex domains.

Specifically, the figures I would like to use are as follows:

- A screenshot of the 'Respondent Registration Form" presented by the DEEP tool
- A screenshot of the Instructions page from the DEEP tool
- A sample problem space conceptualizations page from the DEEP tool
- Sample cluster for novices on medical scenario one
- Second sample cluster for novices on medical scenario two.

I’d like to use this figure in my doctoral dissertation. My dissertation is entitled: Expert Conceptualizations of the Domain Of Instructional Design: An Investigative Study On The Deep Assessment Methodology For Complex Problem-Solving Outcomes. In chapter 2, where I am reviewing the literature on complex problem solving, I’d like to use these figures to accompany review of your work.

Of course, these figures will be properly reference as suggested by APA 5th.

My dissertation is almost ready. I am planning to submit it to the graduate school within 2 weeks. Dissertation defense is set for April 3 and, hopefully, I will be graduating in May 2006. I would be happy to send you a copy of my dissertation upon your request.

I am looking forward to hearing from you,

Sincerely,

Deniz Eseryel
REFERENCES


VITA

NAME OF AUTHOR: Deniz Eseryel

PLACE OF BIRTH: Ankara, TURKIYE

DATE OF BIRTH: January 29, 1974

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

   University of Twente, Enschede, THE NETHERLANDS
   Middle East Technical University, Ankara, TURKIYE

DEGREES AWARDED:

   Master of Science in Educational & Training Systems Design, 1998,
   University of Twente

   Bachelor of Science in Science Education/Mathematics Teaching, 1995,
   Middle East Technical University

AWARDS AND HONORS

International Scholar Honor by Alpha Sigma Chapter of Phi Beta Delta (inducted in April, 2000)

Scholarship for a Doctoral study at Syracuse University by Turkish Council of Higher Education ($125,000)

Scholarship for Master’s study at the University of Twente by Netherlands Organization for International Cooperation in Higher Education (NUFFIC) ($55,000)

PROFESSIONAL EXPERIENCE

Teaching Assistant- Syracuse University, Syracuse, NY 2001 – 2006

Instructional Designer- Syracuse University Center for Business Information Technologies (CBIT), Syracuse, NY 1999 – 2001


Teaching Assistant- University of Twente, Enschede, The Netherlands, 1997 – 1998

SELECTED PUBLICATIONS

A) JOURNAL ARTICLES


B) BOOK CHAPTERS


