Analyses of Information Systems Students' Applications of Two Holistic Problem Solving Methodologies

Philip F. Musa
Vickie Cox Edmondson
George Munchus
UAB School of Business
Birmingham, AL 35294-4460
musa@uab.edu coxedmon@uab.edu munchus@uab.edu

ABSTRACT

The importance of task analysis skills in the fast changing world of Information Systems cannot be over-emphasized. One of the objectives in this research was to analyze how effectively students could learn and apply two problem-solving methodologies in the analyses of two types of tasks to enhance effective decision making. The reference or tested methodology chosen was Systems Thinking, since it has been applied in a variety of settings or domains for many decades already. The second methodology (Goldratt's thinking processes) is relatively new, but has been applied in the analysis of constraint problems, especially in manufacturing, banking, healthcare, etc. After receiving the appropriate trainings, the subjects in the study were assigned two types of tasks or problems in information systems. The first task was verified by a group of experts to be dynamic, while the other was less complex (more static) in nature. The subjects in the study were master's degree students in Information Systems at a major university. The students were divided into four groups; with two professors administering the training to the groups in a format that sought to minimize confounding. Several hypotheses were generated and tested. It is believed that educators and managers could enhance their understanding of the dynamics of the two methodologies in the analyses of tasks of varying degrees of complexity.

Keywords: Systems Thinking, Goldratt's thinking Processes, Theory of constraints, Tukey multiple comparisons, Causal loops, Systems archetypes, Content analysis, Inter-rater reliability.

1. INTRODUCTION

This study seeks to farther advance the contributions of problem solving in the greater scope of knowledge management research stream by analyzing the effectiveness of two methodologies in the articulation of solutions to two classes of problems that could be of interest to organizations.

Since organizations are often made of workgroups or teams, and workgroups are, in turn, made up of individuals, when we speak of organizational learning or knowledge management, aggregation necessarily has to be preceded by analysis at the individual level (Marquardt, 1996; Liebowitz and Beckman, 1998).
The study focuses on problem solving, rather than knowledge management. More specifically, the study was conducted to expose Information Systems graduate students, and also evaluate graduate students' abilities to apply two holistic problem solving methodologies. The two methodologies are: systems thinking and Goldratt's thinking processes. As will be reported more fully later in this study, there were four groups of students involved, and two professors conducted the training of the subjects in such a way that reduces the negative effects of confounding. Confounding may lead to the over-estimation or under-estimation between exposure and outcome (Hoffman, 2005). Before we present a literature overview of various problem solving methodologies that have been applied in analyzing problems over the years, we make note of our rationale for choosing to study the two methods discussed in this study: both methodologies take a holistic approach in analyzing tasks or problems (Caspari and Caspari, 2004; Ptak and Schragenheim 2003). Thus, while philosophies such as Total Quality Management and Just-in-Time are rooted in the concept that improvement anywhere in the system, improves the performance of the whole system, the two methods in this study take a holistic approach. As pointed out in the analogy by Umble and Spoede (1991), if a link other than the weakest link in a chain is strengthened, the strength of the whole chain is not increased (Umble and Spoede, 1991; Motwani, et al., 1996).

While Systems Thinking has been applied to gain insight in many organizational settings (including IS) over several decades, Goldratt's Thinking Processes has continued to gain attention since the publication of Goldratt's first book on the subject, *The Goal* (Goldratt 1986). Initially, much of the

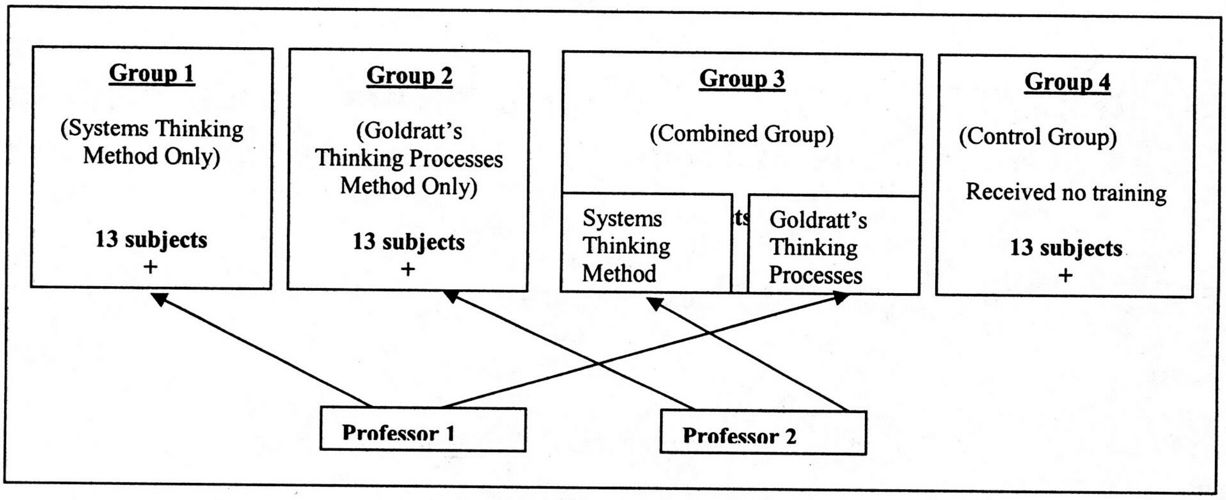


Figure 1: Design of Study to Minimize Confounding Effect

applications of thinking processes were in manufacturing, but it has also been applied in the service and even not-for-profit settings (Bramorski, et al., 1997; Motwani, et al., 1996). One of the objectives in this study was to extend its application to IS settings. For comparative purposes, we used the more established systems thinking methodology as a reference methodology. In addition to testing the suitability of each problem solving method to two types of problem classes, we also investigated possible synergies between the two methodologies.

The study is outlined as follows. In the literature review section (section 2), we give a brief review of problem solving methodologies that have evolved over the years. In the section after that, we present the research methodology that we used. Subsequent to that, we present a conceptualization of the research model in section 4, under which we introduce the basic components of both systems thinking and Goldratt's thinking processes. The hypotheses generated and tested in the study are also discussed under this major section. Then in section 5, we discuss the validation of the research model. In this section, we reiterate the composition of the four groups in the study, the basic outline of the study, a description of how all subjects were required to report their analyses of the two tasks they each analyzed or solved using either of the two methodologies. We also give a brief overview of the coding process used in the study. In section 6, we present the results of the study, starting with the pilot study results, and then the dynamic task, followed by the static task results. The need to employ multiple comparison method to investigate differences in performance between groups is also presented in this section. In section 7, we discuss the implications of the study for management. The conclusion and plans for future research are also presented in the same section. As noted in the appropriate sections, some materials are presented in appendixes at the end of this paper.

2. LITERATURE REVIEW

The literature acknowledges that the ability of individuals in an organization to recognize problems and articulate solutions to the ever-changing opportunities and threats faced by their organization is a basic element for knowledge building (Liebowitz and Beckman, 1998; Rubenstein-Montano, et al., 2001).

Past research show how constructs such as software self-efficacy are affected by various factors (Chung, et al., 2002; Havelka, 2003; Harrison and Rainer, 1992). In this study, we explore how the subjects' performances in applying problem solving methodologies in which they are trained depend on the factors presented in the study. The basic design of the study and choice of sample size are consistent with other studies that have appeared in IS journals such as Journal of Information Systems Education (Beard and Peterson, 2003).

There have been various problem-solving methodologies applied to enhance decision making (and knowledge management) in organizations, including IS settings over the decades (Couger, 1995; Couger, 1996; Liebowitz and Beckman, 1998; Sanchez and Heene, 1997; Simon, 1977; Simon, 1981; Smith, 1998). The general and heuristic problem solving methods of Newell and Simon have been widely adapted and used by researchers and practitioners (Newell and Simon, 1972).
In addition to the above, other types of specific problem solving methods such as the phase theorem have been proposed (Bales and Strodtbeck, 1951; Lipshitz and Bar-Ilan, 1996; Witte, 1972). The literature on phase-theorem approach offers numerous models. These models differ in their emphasis on the descriptive or prescriptive facets of the phase theorem, as well as in the number and nature of their phases. While some models have only two steps or phases, others have as many as eight.

Another group of researchers has proposed the creativity and innovative techniques (Couger, 1988; Couger, et al., 1993;

Couger, 1995). Creative techniques in problem solving were developed to address the need to place more emphasis on creativity. More recently, Smith has authored a text in which he offers a list of problem solving methods (which include the ones mentioned above), and domains of suitable applications to enhance organizational knowledge management (Smith, 1998 pp. 32-33).
Although the Smith (1998) text does not mention Systems thinking, the methodology has been embraced as an effective holistic method of analyzing problems (among other applications) for many decades already because it takes a dynamic perspective (Checkland and Holwell, 1998; Checkland, 1999; Checkland and Scholes, 1999; Flood and Jackson, 1991; Goodman, 1995; Senge, 1990; Senge et al., 1994). Systems thinking has found various applications in the IS discipline in settings such as decision support systems, systems analysis and design, joint application development, etc. (Courtney, 2001; Holsapple and Whinston, 1996).

More recently, Goldratt's thinking processes has been used to study constraints in business settings such as manufacturing, banks, healthcare, pipeline, not-for-profit settings, project management, etc. (Schragenheim, 1998; Caspari and Caspari, 2004; Ptak and Schragenheim 2003; Gattiker and Boyd, 1999; Cooper and Loe, 2000). Systems thinking and Goldratt's thinking processes have different foundations. Systems thinking evolved from system dynamics many decades ago, while Goldratt's thinking processes emerged out of the more recently conceived Theory of constraints that was developed to study bottlenecks in manufacturing settings (Goldratt, 1997; Goldratt, 1999). However, the two have a major commonality, and that is our main reason for choosing to study Goldratt's thinking processes relative to systems thinking in an IS education setting. The two methods rely heavily on the inter-relatedness of parts in a given system. In other words, they both take a holistic perspective to studying a system. The contention here that employing systems thinking and Goldratt's thinking processes as problem solving methods not only add to our tool kit, but that we could gain some synergistic benefits, considering the fact that both methodologies take a holistic perspective in analyzing situations (Checkland, 1999; Senge, 1990; Goldratt, 1999; Kendall, 1998; McMullen, 1998; Schragenheim, 1998; Sterman, 2000). Another motivation is to expose Information Systems students to the use of these methodologies. We note that there is at least one consulting group out there that uses these methodologies to improve the performance of their client organizations (WORXZ, 2005). Thus, exposing our students to these problem solving methodologies could lead to entrepreneurial ventures.

3. RESEARCH METHODOLOGY

The study was designed to expose four groups of students enrolled in a masters degree in IS program to the two problem solving methodologies. Each group was made up of 13 students. Additionally, there was a pilot study conducted on one subject per group to help fine-tune the final study and coding. Further details of the composition of the four groups and format used in delivering the trainings are given below.

3.1 Description of the Setup of the Study

As depicted in Figure 1, the 52 graduate students pursuing master's degrees in Information Systems who participated in the study were divided into four groups (13 students per group). Additionally, there were four pilot study subjects (one per group) used to fine tune the study and train two independent coders on how to code the data from the study. The first group of 13 subjects received training in systems thinking methodology, while the second group received training in Goldratt's thinking processes. The third group (the combined group) was trained in both systems thinking and Goldratt's thinking process. Subjects in the control group (group four) were drawn from a pre-requisite class in which neither of the two concepts or methodologies was discussed. Subjects in the control group were asked to analyze the tasks or problems assigned using whatever heuristics or methodologies they might already have been exposed to. Assignment to each group depended on the course in which the subjects were enrolled. As outlined in Figure 1, the training of subjects was conducted by two professors to reduce the effects of confounding that could have results if only one professor conducted training across the groups.

3.2 Composition of the Four Groups in the Study

The systems thinking group (group 1) was made up of 7 males and 6 females, while the Goldratt's thinking processes group consisted of 11 males and 2 females. The combined group (group 3) consisted of 8 males and 5 females. Finally, the control group had 6 males and 7 females. Thus, there were a total of 32 males and 20 female students in the actual study. Of the 4 students in the pilot study, there were 2 males and 2 females.

3.3 Brief Outline of Tasks and Responses

After the training sessions, each subject was given two tasks to analyze individually. Based on consultation with experts, the first task was deemed to be relatively more dynamic in nature, while the second task was considered to be static. A description of the tasks is given later in this study (in the validation of research model section - section 5). As discussed in section 5, the responses from all 52 subjects in the actual study were analyzed to determine each subject's ability to identify the key variables in each task, as well as their ability to identify and apply the appropriate tools to analyze each task. All the subjects in the study were asked to provide as much feedback as possible on their analyses of the two tasks assigned. They were asked to think out loud and write down their thoughts as they analyzed the tasks. Thus, there were both quantitative and qualitative aspects to each student's responses. What we gleaned from the responses is discussed later in this paper.

In addition to the primary investigator, two independent coders were trained to code all responses. Inter-rater reliabilities across the coders are discussed later in section 6 (results of study). In the next section, we present overviews of systems thinking and Goldratt's thinking processes, as well as the hypotheses that were tested in the study.

4. CONCEPTUALIZATION OF THE RESEARCH MODEL

As mentioned earlier, the research model is as given in Figure 1. Also, the make-up of the participants in the four groups in the study is as given above in section 3 above.

While an extensive discussion of the systems thinking and Goldratt's thinking processes methodologies used in this research is beyond the scope of this paper, a brief outline of the two is given in the next two sub-sections. The referenced cited provide ample discussions of the two methodologies.

4.1 An Overview of Systems Thinking

Systems thinking is a conceptual framework that considers problems in their entirety (Hall, 2004; Senge, 1990; Rubenstein et al., 2001, Checkland, 1999). It offers a method of reflecting about "organizational processes" rather than "snapshots" which is pervasive in reductionism (Senge, 1990). The approach of systems thinking is fundamentally different from that of traditional forms of analysis. Traditional analysis focuses on the separating the individual pieces of what is being studied; in fact, the word "analysis" actually comes from the root meaning "to break into constituent parts" (Aronson, 2004; Senge, 1990). Systems thinking, in contrast, focuses on how the thing being studied interacts with the other constituents of the system—a set of elements that interact to produce behavior—of which it is a part. This means that instead of isolating smaller and smaller parts of the system being studied, systems thinking works by expanding its view to take into account larger and larger numbers of interactions as an issue is being studied. This results in sometimes strikingly different conclusions than those generated by traditional forms of analysis, especially when what is being studied is dynamically complex or has a great deal of feedback from other sources, internal or external (Aronson, 2004; Checkland, 1999; Senge, 1990).
Thus, the character of systems thinking makes it extremely effective on the most difficult types of problems to solve: those involving complex issues, those that depend a great deal dependence on the past or on the actions of others, and those stemming from ineffective coordination among those involved. Over the past several decades, systems thinking has been utilized in the analyses of various tasks in IS and other types of organizations. Given this appeal and prior research validations, systems thinking was chosen as the reference or tested methodology for this study.

Some of the tools used in systems thinking to solve problems include the following: (a) causal loop and stock-and-flow diagrams, (b) behavior-over-time diagrams, (c) systems archetypes, (d) structural diagrams, and (e) simulations (Goodman, 1995).

"Causal loop" and "stock-and-flow diagrams" provide a useful way to represent dynamic interrelationships. They convey one's comprehension of a system's structure; it provides a visual representation to help communicate that understanding in a succinct form (Goodman, 1995).

"Behavior-Over-Time Diagrams" capture the dynamic relationship among variables (not just simple line projections). For example, this tool could be applied to yield a better projection of the relationship between user involvement (or a lack thereof) in systems design or joint application development and eventual adoption or resistance to adoption. It could also be used to study the interaction between sales, inventory management, and production. By sketching the behavior over time of different variables, a better insight of the interrelationships could be achieved. Dynamic time concepts regarding changes in both the environment and organization are stressed (Kolarik, 1999).
"Systems archetypes" is the name given to certain common dynamics that seem to reoccur in many different organizational settings. These archetypes consist of various combinations of balancing and reinforcing loops. They could be applied in articulating a problem. The following are examples of systems archetypes, and are briefly described in Appendix A: (a) balancing process with delay, (b) limits to growth or success, (c) shifting the burden, (d) shifting the burden to the intervenor, (e) eroding goals, (f) escalation, (g) success to the successful, (h) tragedy of the commons, (i) fixes that fail or backfire, and (j) growth and under-investment (Goodman, 1995; Senge, 1990; Senge et al. 1994).

"Structural diagrams" are high level diagrams useful for clarifying relationships between variables (Goodman, 1995; Senge, 1990; Senge et al. 1994). They are particularly helpful for quantifying the effects of variables that are difficult to measure (e.g., employee morale or time pressure).

4.2 An Overview of Goldratt's Thinking Processes

The thinking processes as postulated by Eliyahu Goldratt are really sub-components of his larger discipline: The Theory of Constraints. Areas in which the theory has been much applied include: day-to-day factory scheduling, project management, process improvement, constraints analyses in banks, etc. (McMullen, 1998; Schragenheim, 1998; Goldratt, 1999; Kendal, 1998). Unlike the well established systems thinking that has been around for many decades, Goldratt's thinking processes were developed less than 20 years ago, and is yet to find wide-spread application in pure IS settings.

Theory of constraints is based on five focusing steps. The steps are: (a) identify the system's constraint, (b) decide how to exploit the constraint, (c) subordinate everything to that decision, (d) elevate the system's constraint, and (e) return to the first step, and don't let inertia become the new constraint (Goldratt, 1986; Kendall, 1998; McMullen, 1998).

The thinking processes address following three questions: (a) what to change?, (b) what to change to?, and (c) how to effect or cause the change? (Goldratt, 1994; Kendall, 1998; Mabin and Balderstone, 2000; McMullen, 1998; Schragenheim, 1998; Smith, 2000; Cooper and Loe, 2000)

The questions posed in the previous paragraph could be answered by a careful use of a set of tools that have been developed as a part of Goldratt's thinking processes. The tools comprise of the following five logic trees, and were

applied in this Information Systems study to help solve some problems to enhance decision making. After summarizing the logic trees, we provide a list of references that give further discussion of the material.
(1) Current Reality Tree: A process to separate symptoms from their underlying causes and identify a core problem -- the focus of the improvement effort.

(2) Conflict Resolution Diagram (or Evaporating Cloud): A technique that shows why the core problem was never solved; it fosters a new, breakthrough idea.

(3) Future Reality Tree: The strategic solution to the core problem, identifying the minimum projects and ideas necessary to cause improvement.

(4) Prerequisite Tree: The detailed plan of all obstacles in the Future Reality Tree.

(5) Transition Tree: The actions that need to be implemented to fulfill the plan.

Detailed discussions of the logic trees, and indeed theory of constraints, and Goldratt's thinking processes are available in the following references: (Goldratt, 1994; Kendall, 1998; Mabin and Balderstone, 2000; McMullen, 1998; Schragenheim, 1998; Smith, 2000).

It should be noted that, while the two methods problem solving methodologies used in this study are similar in some respects, they are different in others. For example, systems thinking has been tested to be suitable for analyzing and solving problems in dynamically complex situations, while the relatively new Goldratt's thinking process is has gotten more exposure in constraint analyses settings as mentioned earlier. These settings are thought to be less dynamic (or more static) in nature. However, the two methods have an underlying similarity, in that they both take into account the interrelatedness of a given system's parts when the system is analyzed. We posit that the holistic perspective as a main element of Goldratt's thinking process warrants investigating it suitability for various Information Systems applications. When one considers the inherently short life cycles in Information Technology, it seems reasonable to apply holistic problem solving methods to enhance decision making and knowledge management. Furthermore, we were interested in verifying possible synergistic benefits from using the two methods.

Although there is no clear demarcation between dynamic and static problems in real life, (since the two exist along a continuum) it is safe to think of dynamic situations or problems as those that exhibit some discontinuity in time and space -- there tend to be some significant time delay (lag) between when a proposed solution is embarked upon and when the solution is finally realized or completed. Possible examples include new software development in a fiercely competitive world, or an initiative to address urban housing shortage in the midst of migration to suburbs. Examples of static problems could be a decision to purchase a home or the investigation of a bottleneck in a manufacturing setting (Schragenheim, 1998; Sterman, 2000).

The tasks that were assigned to the students were designed to test for these differences in orientation (or focus) between the two methodologies. Based on the assessment of a group of experts, one of the two tasks was deemed to be dynamic in nature, while the other was more static. All subjects in all four groups were assigned the same two tasks to analyze within a total of eighty minutes. The following hypotheses were designed based on our beliefs about the two methodologies being investigated. The hypotheses will be revised in section 6 when we present the results of the study.

4.3 The Hypotheses in the Research

The conjectures or hypotheses about the two task analysis methods that were used to assess the students' competency in applying the skills gained from exposure to the said methods are presented in this sub-section. The hypotheses were tested by collecting and analyzing each student's responses to the two problems or tasks assigned.

Based on the research design presented earlier, the following ten hypotheses were developed. The data from the study were coded, and the content analysis was conducted to test the various hypotheses. At the end, decisions were made (based on results) whether to accept or reject the hypotheses--a deductive process. The decisions are presented in the implications section (section 7).

Note: Hypotheses H01 and H02 are to test if training in a particular methodology helps subjects achieve better results when solving tasks of a given domain (either dynamic or static).

H01: *If the task is dynamic in nature, the performance of subjects trained in the use of the systems thinking methodology will, on average, be similar with those that received training in other methodologies or received no training.*

H02: *If the task is static in nature, the performance of subjects trained in the use of the Goldratt's thinking processes methodology will, on average, be similar with those that received training in other methodologies or received no training.*

Note: Hypotheses H03, H04, H05, and H06 would reveal the effect of receiving training (as measured by performance) in a particular methodology regardless of task domain (across domain tests).

H03: *Regardless of the task domain, subjects trained in the use of the systems thinking methodology will, on average, achieve results that are of similar quality as those trained in other methodologies or received no training.*

H04: *Regardless of the task domain, subjects trained in the use of Goldratt's thinking processes methodology will, on average, achieve results that are of similar quality as those trained in other methodologies or received no training.*

H05: *Regardless of the task domain, subjects trained in the use of both systems thinking and Goldratt's thinking processes methodologies will, on average, achieve results that are of similar quality as those trained in other methodologies or received no training.*
H06: *Regardless of the task domain, subjects that received no training in any task analysis methodology will, on average, achieve results that are of similar quality as those trained in the use of either or both methodologies.*

Note: Hypothesis H07 seeks to investigate possible synergistic benefits of receiving training in both systems thinking and Goldratt's thinking processes methods, regardless of task domain.
H07: *Regardless of the task domain, subjects trained in both systems thinking and Goldratt's thinking processes will, on average, achieve results that are of similar quality with those that were trained in the use of either methodology or those that received no training.*

Note: Hypotheses H08 and H09 are meant to test the extent to which subjects that received training in both methodologies would use a specific method when solving tasks that are perceived to be of a specific domain.

H08: *Subjects trained in both systems thinking and Goldratt's thinking processes will be just as likely to use systems thinking tools as they would Goldratt's thinking processes tools to solve tasks that they perceive to be dynamic in nature.*

H09: *Subjects trained in both systems thinking and Goldratt's thinking processes will be just as likely to use Goldratt's thinking processes tools as they would systems thinking tools to solve tasks that they perceive to be static or less dynamic in nature.*

Note: Hypothesis H10 is meant to test the similarity in performance of subjects that received training a given methodology or methodologies when solving tasks that are of different domains.

H10: *Subjects trained in a particular method will, on average, achieve results that are of similar quality, regardless of task domain.*

The discussion as to whether to accept or reject the various null hypotheses listed above is presented later in this report. In the next section, we present how the research model was validated.

5. VALIDATION OF THE RESEARCH MODEL

Attempts were made to have the groups and subjects as homogeneous as possible. To this end, masters degree students at the same university were used in the study. In addition to the 52 graduate students in the master of information systems program who participated in this study, there were 4 other students used in the pilot study (1 per group) to fine-tune the study and train the two independent coders and primary investigator. As depicted in Figure 1, there were 13 students in each of the four groups. The decision to have a sample size of thirteen is consistent with other studies that have been done using content analysis (Ford et al., 1989; Lohse and Johnson, 1996; Russo et al., 1989; Beard and Peterson, 2003). The gender composition of the groups is as given in section 3.2 above.

All the participants in the study were required to fill out a consent form. As expected in studies that call for the participation of human subjects, protection of the human subjects is an important consideration. With this in mind, all the appropriate procedures to protect human safety, privacy, and dignity were observed. Consent from the committee for the Protection of Human Subjects at the university was obtained prior to beginning the experimentation.
Participation in the study was on a voluntary basis. Those who did not want to participate were given the option to work on alternative projects. All those who agreed to participate in the study or other projects were rewarded with extra credit points based on performance.
Students were guaranteed that their responses would be anonymous and that they had the right to withdraw from the study at any time without penalty. As mentioned above, those who chose not to participate in the study were assigned other tasks for which they received equal reward as those who participated. We now present the basic outline of the study, the description of how the students were asked to present their analyses of the two tasks assigned, and a description of the coding process used.

5.1 Basic Outline of the Tasks in the Study
After the training sessions were completed, each student solved two tasks (one dynamic and one static, as determined by a group of experts). Each student was allowed 80 minutes to solve both tasks. They were also encouraged to do their very best in analyzing each of the two tasks using the methodology that they felt was most appropriate for each task. All subjects were asked to write down or sketch all thoughts, diagrams, etc. that they thought was relevant to the analysis of each task. The two tasks used in the study, as well as the instructions for the study are given in Appendix B.

5.2 Choice of Task-Analysis Reporting Format
All subjects were asked to "think out-loud" as they analyzed the tasks or problems. Each subject wrote down his or her thoughts about the analysis from start to finish. Also, the subjects were encouraged to sketch any diagram they felt contributed to the richness of the solutions to the tasks. The responses were later graded (coded) by two independent coders and the primary investigator using the guideline outlined in Appendix C. Each student was required to identify all relevant variables and how they applied the appropriate tools to analyze each task. There are various types of recording subjects' responses in students. For example, verbal protocol (Curley, et al., 1995; Ford et al., 1989), computer mouse, eye-ball movement on computer screen (Abelson and Levi, 1985; Lohse and Johnson, 1996), eye-ball movement on document, written words and/or sketches (Ramesh and Browne, 1999), etc. We instructed each student to use written words and sketches to convey

ANOVA: Single Factor. Independent Coder's Report on Dynamic Task (α = 0.05)						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Systems Thinking	13	963.7	74.13	62.08		
Goldratt's Thinking. Proc.	13	616.1	47.39	186.27		
Combined Group	13	836.6	64.35	249.32		
Control Group	13	273.4	21.03	44.44		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21091.39	3	7030.46	51.87	4E-15	2.80
Within Groups	6505.42	48	135.53			
Total	27596.80	51				

Table 1: Summary of Independent Coder's Report of Dynamic Task

their mastery of the method they used to analyze each task. The choice was due, in part, to the fact that this method has been used and validated in other studies as pointed out above. After the subjects submitted their written responses, the next phase of the validation process was to code the responses. The coding process is the subject of the next sub-section. The two professors who conducted the training had also emphasized this fact during the training sessions held prior to conducting the actual study.

5.3 Overview of the Coding Process

The research entailed coding and analyzing the contents of the subjects' responses. Coding can be defined as the analytic processes through which data are fractured, conceptualized, and integrated to form a theory (Strauss and Corbin, 1998). It is a method that has been used (along with content analysis) extensively in the humanities and social sciences disciplines. This method of research was originally developed by two sociologists (Barney Glaser and Anselm Strauss), but has gained much application in Information Systems research over the years (Curley et al., 1995; Strauss, 1978; Glaser and Strauss, 1967; Strauss, 1987).

The responses from all 52 students were analyzed by two independent coders and the primary investigator or experimenter in this study. The bases for the coding for both tasks are outlined in Appendix C. Each coder coded each student's response independently. This was to measure the student's ability to identify variables and effective use of appropriate tools used to analyze each of the two tasks assigned. The grade assigned to each subject by each coder across the various items listed in Appendix C was compared against other coders' grades for that given subject, and the overall inter-rater reliability as well as Cohen's Kappa calculated. These measures capture the extent of agreement between coders as to the performance of the students in the various groups. As mentioned earlier, pilot study using one subject per group was used to facilitate the training of the coders and to refine the study. The results from pilot study and the actual study are presented in the next section.

6. RESULTS AND DISCUSSIONS

The data gathered and analyzed in the experiment were in two parts: pilot and full studies. The data gathered from the pilot study was used to fine-tune the coding scheme, to train the coders, and to codify the full study. As mentioned earlier, the first task was designed to be more dynamic in nature, while the second task was more static in nature. The coders were trained to analyze or interpret each subject's response to both questions using two levels of grading. To accomplish this, each of the two tasks was broken into two parts (as far as the coding process was concerned). The coding scheme of the first part measured the subjects' understanding of the variables or forces at play in the task at hand, while the second part sought to evaluate the subjects' use of the tools employed in analyzing the task. Each of the subjects' responses to a given task was graded by each coder independently on a scale of zero to 100 percent.

6.1 Pilot Study Results

The pilot study consisted of a total of four subjects. Each subject analyzed two tasks and the first task (the dynamic one) had a total of 22 items while the second task (static) had a total of 19 items, it means each subject was graded on a total of 41 items across the two problems. This implies that any two coders could agree on a maximum of 41*4 =164 items in the pilot study. Based on this, the following inter-rater reliability and Cohen's Kappa figures were calculated. The inter-rater reliability numbers obtained were: Coders #1 and #3 = 87.2%, Coders #1 and #2 = 72.6%, and Coders #2 and #3 = 81.1%.

Inter-rater reliability of 70% has come to be the accepted standard in studies of this nature since the publication of Krippendorff's (1980) book on content analysis (Krippendorff, 1980; Weber, 1990). It should be mentioned here that the inter-rater reliability between coders #1 and #3 in the pilot study is higher than the other reliability numbers because it was driven by the fact these two coders assigned similar grades to the control group pilot subject. The Cohen's Kappa obtained were as follow: Coders #1 and #3 = 68.4%, Coders #1 and #2 = 67.1%, and Coders #2 and #3 = 68.0%.

6.2 Results of the Study

The results obtained in the full study that comprised of the 52 subjects will be presented in this sub-section. The interpretation and implications of the results will be presented as well, so will the tests and the acceptance or rejection of the various hypotheses listed in the previous section.

As would be recalled, there were two independent coders utilized in this study. The inter-rater reliability between the independent coders and the experimenter were similar. For the rest of the discussion, data from only one of the independent coders will be reported. The inter-rater reliability between this particular coder and the experimenter for the full study was 76.17%, which, as already pointed out, is acceptable for studies of this nature. Cohen's Kappa for the full study between he coder and the experimenter was calculated to be 0.66.

6.3 Dynamic Task Performances of the Four Groups

We start the presentation of the analyses with the first task, the dynamic task. As could be seen from Table 1, the analysis of variance (ANOVA) indicates that the performance of the systems thinking group subjects was judged to be superior relative to that of the other three groups. The second best is the combined group, followed by the Goldratt's thinking processes group, and then the control group. As indicated by the p-value in Table 1, there is a very significant difference in the performance of the various groups at the normal alpha level of 0.05. However, it is not obvious where the significance lies. This is why multiple comparisons tests (pair-wise comparisons) were done. The results of the pair-wise comparisons will be presented in the next sub-section.

6.3.1 Choice of Multiple Comparisons Method for Dynamic Task

Theoretically, the investigation of the source or sources of the significance reported in Table 1 entails doing pair-wise comparisons between all possible combinations of treatments (groups), although in practice, the comparisons are usually necessary only for the treatments that are suspected to have some significant differences. In this report, all the possible combinations are considered (Neter, Wasserman, and Kutner, 1985; Winer, et al., 1991). Since there are four groups, there are (n-1)! = 6 possible multiple comparisons.
There are numerous methods of doing multiple comparisons. These include Bechhofer-Dunenett, Dunn-Bonferroni, Scheffe, etc. (Neter, et al., 1985; Winer, et al., 1991). In this study, we selected the Tukey multiple comparison method. The Tukey method was chosen over the others because research has shown that if all factor level sample sizes are the same, the Tukey method is more conservative than the others. Also, if only pair-wise comparisons are to be made, the Tukey method gives narrower confidence limits, and is therefore the preferred method (Neter, et al., 1985). It should be pointed out that the Microsoft Excel method of doing multiple comparisons was not used here because it has an inherent drawback in that type 1 error (i.e., α) is not fixed. This could lead to a wrong conclusion or observation, especially if the difference in the particular pair being investigated is only marginally significant or insignificant. On the other hand, although the Tukey method is more tedious, in that it involves manual calculations and consulting statistical tables, its type 1 error is fixed. With fixed alpha level, the risk of making the wrong conclusions is minimized.

6.3.2 Dynamic Task Multiple Comparisons

Using a fixed level of significance of 0.05, the Tukey method was used to investigate the source or sources of the significant effects reported in Table 1. To do this, we need to get F(0.95, 3, 48) = 2.78 from a statistical table of "Critical value of the F distribution for $\alpha = 0.05$". The F(0.95, 3, 48) is based on the fact that we are doing the calculations for 95% confidence level, with four groups (r-1 = 4-1 = 3), the degrees of freedom (df = nr - r = 13*4 - 4 = 48). Next, we make note of the fact that F = 51.87 (from Table 1) or from F* = MSTR/MSE = 7030.46/135.53 = 51.87. Since 51.87 > 2.78, we know that the means of the treatments (groups' performances) differ significantly.

Next, from a statistical table of "Critical Value of Studentized Range Distribution for $\alpha = 0.05$", the Tukey multiple comparisons for a family confidence coefficient of 0.95, with four groups and 48 degrees of freedom, we find q(0.95, 4, 48) ≅ 3.76. Now the value of T (the Tukey adjustment factor) can be calculated from the formula T = 0.707(q). Thus, T = 0.707(3.76) = 2.66. Further, since equal sample sizes were employed in the research, we need to calculate the value of MSE(1/n + 1/n) = 135.53(1/13 + 1/13) = 20.85, which yields an Sx of 4.56. Thus, we obtain TSx = 2.66(4.56) ≅ 12.13.

The pair-wise confidence intervals with 95 percent family confidence coefficient therefore can be calculated from the general equation for confidence interval ($\bar{X}$ – TSx to $\bar{X}$ + TSx). A summary of the 6 multiple comparisons is given next in Table 2. From the ranges indicated, it is easy to determine which pair or pairs of groups have significant differences in analyzing the dynamic task. Note that for convenience, the group means or averages for systems thinking, Goldratt's thinking processes, combined group, and the control group reported in Table 1 are reported in Table 2 as $\mu 1$, $\mu 2$, $\mu 3$, and $\mu 4$ respectively. This format of reporting confidence intervals is common in research methods and statistics (Neter, et al., 1985; Siegel, 2000).

As reported in Table 2, there were significant differences in the performance of the groups in terms of their performance

Pair Being Compared	Significant?
Systems Thinking versus Goldratt's Thinking Process: $\underline{-38.83} = (47.4 - 74.1) - 12.13 \leq \mu 2 - \mu 1 \leq (47.4 - 74.1) + 12.13 = \underline{-14.57}$	**YES,** Systems thinking group did better.
Systems Thinking versus Combined Group: $\underline{-21.83} = (64.4 - 74.1) - 12.13 \leq \mu 3 - \mu 1 \leq (64.4 - 74.1) + 12.13 = \underline{2.43}$	NO
Systems Thinking versus Control Group: $\underline{-65.23} = (21.0 - 74.1) - 12.13 \leq \mu 4 - \mu 1 \leq (21.0 - 74.1) + 12.13 = \underline{-40.97}$	**YES,** Systems thinking group did better.
Goldratt's Thinking Processes versus Combined Group: $\underline{-29.13} = (47.4 - 64.4) - 12.13 \leq \mu 2 - \mu 3 \leq (47.4 - 64.4) + 12.13 = \underline{-4.87}$	**YES,** Combined group did better.
Goldratt's Thinking Processes versus Control Group: $\underline{14.27} = (47.4 - 21.0) - 12.13 \leq \mu 2 - \mu 4 \leq (47.4 - 21.0) + 12.13 = \underline{38.53}$	**YES,** Goldratt's TP group did better
Combined Group versus Control Group: $\underline{31.27} = (64.4 - 21.0) - 12.13 \leq \mu 3 - \mu 4 \leq (64.4 - 21.0) + 12.13 = \underline{55.53}$	**YES,** Combined group did better.

Table 2: Summary of Dynamic Task Multiple Comparisons Using Tukey

in the analysis of the dynamic task. The difference between the systems thinking and the combined group was not significant at alpha level of 0.05.

The reason for the differences between the control group and the other three groups is more or less obvious. Since the control group subjects were not exposed to any of the methods, they lacked the experience to analyze tasks assigned in this study. The observed difference between the systems thinking and the Goldratt's thinking processes groups is also expected.

As other studies in the IS discipline (and elsewhere) suggest, the systems thinking methodology is suitable for solving tasks that are more dynamic in nature (Checkland, 1999; Senge, 1994; Aronson, 2004). The fact that there was no significant difference between the systems thinking and the combined group could be due to the fact that the combined group had enough systems thinking trained subjects in it to make the overall combined group's score approach that of the systems thinking group.

6.4 Static Task Performances of the Four Groups

In comparing the performance of the four groups across the two tasks, it was realized that there were significant differences between some of the groups. The ANOVA analysis from which this conclusion was drawn is summarized in Table 3. The p-value (3.3E-10 or approximately zero) reported calls for further investigations of the source or sources of the differences, similar to what was done with the data from the analysis of the first task. Without repeating the calculations, the multiple comparisons for the static task are presented in the next sub-section.

6.4.1 Static Task Multiple Comparisons using Tukey

Multiple comparisons of the groups' performances on the static task using the Tukey method are summarized in Table 4. As reported in Table 4, there were significant differences at the traditional 95 percent confidence level in the performance of some of the groups in terms of their performance in the analysis of the static task. The significant differences in the averages of the control group and the other three groups could be attributed to the fact that the control group subjects had no formal training in any task analysis method.

The failure to have significance in the averages achieved by the combined group versus the systems thinking group could be attributed to the fact that there were enough subjects in the combined group who were able to extend their skills in analyzing dynamic tasks to the much less dynamic (static) case. Furthermore, the combined group was made up of subjects who were trained in both task analysis methods. The group benefited from synergistic effects of the dual methods training.

6.4.2 Analysis of Group Performances across Task Domains

It is of interest to compare the performance of the four groups with respect to the two task domains investigated in the study. Is the average performance of a given group similar across task domains? This question was answered by doing multiple t-tests within groups across the two task domains.

As would be recalled from previous sub-sections of this section, the variances in the performance of the groups were unequal. The results of the "t-test: Two-Sample Assuming Unequal Variances" are summarized in Table 5.

ANOVA: Single Factor. Independent Coder's Report on Static Task (α = 0.05)						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Systems Thinking	13	845.8	65.06	240.57		
Goldratt's Thinking. Proc.	13	759.1	58.39	78.71		
Combined Group	13	944.7	72.67	202.22		
Control Group	13	416	32.00	96.15		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit.*
Between Groups	12186.8	3	4062.27	26.31	3.3E-10	2.80
Within Groups	7411.73	48	154.41			
Total	19598.6	51				

Table 3: Summary of Independent Coder's Report of Static Task

From Table 5, we notice that although the systems thinking group achieved a better average in analyzing the dynamic task, the group did well enough in analyzing the less dynamic (static) task to make the difference in the group's average across the two tasks were (marginally) insignificant at the 95 percent confidence level. The group's higher average score in analyzing the dynamic task is in line with what we predicted earlier.

Also as predicted, the average achieved by the Goldratt's thinking processes group is higher for the static task. While the group's average was not as high as expected, the group did perform significantly better in analyzing the task that was of static domain. The combined group achieved average scores that were not significantly different across task domains. As explained earlier, the generally superior performance by the combined group may be due to the benefits of the synergistic benefits of having received training in both methodologies.

While, as expected, the control group did not do very well, the group's average score on the static task is significantly better than its score on the more dynamic task. This result makes sense. The static task has less number of variables, therefore, less complex. Thus, even someone with no formal training in task analysis methods would do better analyzing such a task relative to a dynamic task.

Pair Being Compared	**Significant?**
Systems Thinking versus Goldratt's Thinking Process: ***-19.62*** = (58.39 – 65.06) –12.95 ≤ μ2 - μ1 ≤ (58.39 – 65.06) + 12.95 = ***6.28***	NO
Systems Thinking versus Combined Group: ***-5.34*** = (72.67 – 65.06) – 12.95 ≤ μ3 - μ1 ≤ (72.67 – 65.06) + 12.95 = ***20.56***	NO
Systems Thinking versus Control Group: ***-46.01*** = (32.0 – 65.06) – 12.95 ≤ μ4 - μ1 ≤ (32.0 – 65.06) + 12.95 = ***-20.11***	**YES,** Systems thinking group did better.
Goldratt's Thinking Processes versus Combined Group: ***-27.23*** = (58.39 – 72.67) –12.95 ≤ μ2 - μ3 ≤ (58.39 – 72.67) + 12.95 = ***- 1.33***	**YES,** Combined group did better.
Goldratt's Thinking Processes versus Control Group: ***13.44*** = (58.39 – 32.0) – 12.95 ≤ μ2 - μ4 ≤ (58.39 – 32.0) + 12.95 = ***39.34***	**YES,** Goldratt's TP group did better.
Combined Group versus Control Group: ***27.72*** = (72.67 – 32.0) – 12.95 ≤ μ3 - μ4 ≤ (72.67 – 32.0) + 12.95 = ***53.62***	**YES,** Combined group did better.

Table 4: Summary of static Task Multiple Comparisons Using Tukey

Group	Dynamic task Mean	Static Task Mean	t Stat	two-tail p-value	two-tail t-crit.	Significant?
Systems Thinking Group	74.13	65.06	1.88	0.08	2.10	NO
Goldratt's Thinking Proc.	47.39	58.39	-2.44	0.02	2.08	YES
Combined Group	64.35	72.67	-1.41	0.17	2.06	NO
Control Group	21.03	32.00	-3.34	0.003	2.08	YES

Table 5: Independent Coder's Comparison of Task Domains

7. CONCLUSION, IMPLICATIONS TO MANAGEMENT AND FUTURE RESEARCH

The view that problem solving processes and skills are vehicles for connecting knowledge and performance in IS organizations and elsewhere has been established (Gray and Chan, 2000; Gray, 2001; Barney, 1991; Cohen and Levinthal, 1990; Prahalad and Hamel, 1990; Rubenstein et al., 2001). As pointed out earlier, while the thrust of this study was not knowledge management, problem-solving or task analysis is a component of the first phase of knowledge management (the building or creation of new knowledge) and has been identified as a critical aspect of the knowledge management effort (Liebowitz and Beckman, 1998; Rubenstein et al., 2001).

Other researchers have explained that methodologies which embody holistic perspectives have some inherent benefits in today's environment (Bellefeuille, 2002). Since both methodologies used in this study have that in common, we plan on pursuing multiple studies to assess their viabilities in various domains to:

(a) bolster our ability to think holistically about what is happening, and to seek structural solutions to problems,

(b) increase our capability to look at a situation from multiple points of view, hence enabling us to determine the highest leverage actions and opportunities,

(c) strengthen our ability to capitalize on learning opportunities,

(d) augment our understanding of assumptions in our goal-seeking efforts,

(e) identify and avoid unintended consequences,

(f) sensitizes us to the crucial role that productive conservation and high-quality interactions play in the process of team-building and continuous learning,

(g) provide a practice field to test various strategies against alternative future scenarios, etc.

Based on the data and discussions presented in the previous section, the following decisions were made with regards to the ten hypotheses presented earlier. The null hypotheses that were rejected were: H01, H02, H04, H06, H07, H08, H09, and H10 (thus, were found to be significant). The two that we failed to reject were H03 and H05 (found to have no significance). Our explanations of the results have already been presented.

Although this study was conducted in a classroom setting, it should make significant contributions to the general efforts of educators and information technology managers in the area of task analyses to enhance effective decision making in the management of knowledge in organizations. The results from the research serve to substantiate past research findings with regards to systems thinking, and sheds some light as to the suitability of Goldratt's thinking processes in the analysis of Information Systems tasks. The research also points to the existence of synergistic benefits of receiving training in both methodologies.

Furthermore, the method of analyses employed could help IS managers, educators, and others in making decisions related to training employees in certain task analysis methods. The method of verifying the validity of hypotheses in the study using content analyses, ANOVA, and Tukey multiple comparison methods could provide some benefits to others that are envisioning embarking on similar studies in educational or actual organizational setting. Content analysis has been used in the social sciences disciplines extensively, and this study further demonstrates the applicability of the method in IS studies of this nature. The study also makes some contribution to the body of knowledge by providing the justifications for analyzing the relative effectiveness (relative to problem or task type) of the two methodologies chosen for the study. We also reported the underlying similarities and differences in focus between the two methodologies. Furthermore, the method presented in this study could be used to evaluate the effectiveness of two or more task analyses methodologies or the effectiveness of other methods of performing certain tasks in an organization.

We also hope that the study provides a springboard for further investigation as to the suitability of the methodologies used to investigate various types of problems in Information Systems discipline and elsewhere. We believe that the methodologies would have great relevance in Systems Analyses, Design, Joint Application Development, and other business endeavors that require a global/holistic perspective.

8. REFERENCES

Abelson, R. P., and Levi, A., (1985). *Decision Making and Decision Theory,* Edited by G. Lindsay and E. Aronson in The Handbook of Social Psychology, 3rd Edition, 231-309.

Aronson, D, *The Thinking Page* (2004). Website URL at: http://www.thinking.net

Bales, R. F., and Strodtbeck, F. L., (1951). "Phases in Group Problem-solving", *Journal of Abnormal and Social Psychology*, vol. 46, 485-495.

Barney, J., (1991). "Firm Resources and Sustained Competitive Advantage", *Journal of Management*, vol. 17 (1), 99-120.

Beard, J.W., and Peterson, T.O., (2003). Coming to Grips with the Management of Information: A Classroom Exercise." *Journal of Information Systems Education,* Volume 14, No.1, 15-30

Bellefeuille, J. H., (2001). "Systems Thinking", *IEEE Engineering Management Society Newsletter,* vol. 51, 4th Quarter 2001, 3.

Bramorski, T., Madan, M.S., and Motwani, J., (1997), "Application of Theory of Constraints in Banks," *The Bankers Magazine*, Volume 180, No 1, pp. 53-59.

Caspari, J. and Caspari, P., (2004), *Management Dynamics: Merging Constraints Accounting to Drive Improvement,* John Wiley & Sons, New Jersey.

Checkland, P., and Holwell, S., (1998). *Information, Systems and Information Systems,* John Wiley & Sons, Chichester, U.K.

Checkland, P., and Scholes, J., (1999). *Soft Systems methodology in Action*, John Wiley & Sons, Chichester, U.K.

Checkland, P., (1999). *Soft Systems methodology: A 30-year Retrospective*, John Wiley & Sons, Chichester, U.K.

Chung, S. H., and Schwager, P. H. (2002). "An Empirical Study of Students' Self-efficacy: Differences among Four Academic Disciplines at a large university." *Journal of Computer Information Systems*: 1-6

Cohen, W. M., and Levinthal, D.A., (1990). "Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly* vol. 35, 128-152.

Cooper, M. J., and Loe, T. W., (2000). "Using the Theory of Constraints' Thinking Processes to Improve Problem-Solving Skills in Marketing", *Journal of Marketing Education* vol. 22, No. 2, 137-146.

Couger, J. D., (1988). "Key Human Resource Issues in 1990s: Views of IS Executives", *Information & Management* (14:4), April, 161-174.

Couger, J. D., (1995). *Creative Problem Solving and Opportunity Finding*, Boyd & Fraser Publishing, Danvers, MA.

Couger, J. D., (1996). *Creativity and Innovation in Information Systems organizations,* Boyd and Fraser Publishing Co., Danvers, MA.

Couger, J. D., Higgins, L. F., McIntyre, S. C., (1993). "(Un)Structured Creativity in Information Systems Organizations", *MIS Quarterly*, December, 375-397.

Courtney, J. F., (2001), "Decision Making and Knowledge Management in Inquiring Organizations: Toward a New Decision-Making Paradigm for DSS", *Decision Support Systems*, vol. 31, 17-38.

Curley, S. P., Browne, G. J., Smith, G. F., and Benson, P. G., (1995), "Arguments in the Practical Reasoning Underlying Constructed Probability Responses", *Journal of Behavioral Decision Making,* vol. 8, 1-20.

Flood, R. L., and Jackson, M. C., Editors (1991), *Critical Systems Thinking: Directed Readings*, John Wiley & Sons, Chichester, U.K.

Ford, J. K., Schmitt, N., Schechtman, S. L., Hults B. M., and Doherty, M. L., (1989), "Process Tracing Methods: Contributions, Problems, and Neglected Research Questions", *Organizational Behavior and Human decision Processes*, vol.43, 75-117.

Gattiker, T. F., and Boyd, L. H., (1999). "A Cause-and effect Approach to Analyzing Continuous Improvement at an Electronics Manufacturing Facility", *Production and Inventory Management Journal*, vol. 40 (2), 26-31.

Glaser, B. and Strauss, A., (1967). *Discovery of Grounded Theory*, Aldine Press, Chicago, IL.

Goldratt, E. M., (1986). *The Goal,* The North River Press, Great Barrington, MA.

Goldratt, E. M., (1994). *It's Not Luck*, The North River Press, Great Barrington, MA.

Goldratt, E. M., (1997). *Critical Chain*, The North River Press, Great Barrington, MA.

Goldratt, E. M., (1999). *Theory of Constraints*, The North River Press, Great Barrington, MA.

Goodman, M. R., (1995). *Systems Thinking as a Language*, Systems Thinking Tools: A User's Reference Guide, Edited by Kim, D. H., Pegasus Communications, Cambridge, MA.

Gray, P. H., (2001). "A Problem Solving Perspective on Knowledge Management Practices", *Decision Support Systems*, vol. 31, 87-102.

Gray, P. H., and Chan, Y. E., (2000). "Integrating Knowledge Management Practices Through Problem-Solving Framework", *Communications of the AIS*, vol. 4 (12).

Hall, M. L. W., (2004). *Systems Thinking and Human Values: Towards Understanding Performance in Organizations,* Website active as of fall 2004: http:/ / sysval.org/chapter3.html

Harrison, A.W. and Rainer, R.K., Jr. (1992). "The Influence of Individual Differences on Skill in end-user Computing," *Journal of Management Information Systems*, 9(1): 93-111

Havelka, D. (2003). "Predicting Software Self-efficacy among Business Students: A Preliminary Assessment." *Journal of Information Systems Education*, vol.14, No. 2, 145-152.

Hoffman, H.S., (2005). "Confounding Factor", Web site Accessed in May 2005: http://www.animatedsoftware.com/statglos/sgconfnd.htm

Holsapple, C. W., and Whinston, A. B., (1996). *Decision Support Systems: A Knowledge-Based Approach*, West Publishing, St. Paul, MN.

Kendall, G. I., (1998). *Securing the Future: Strategies for Exponential Growth Using the Theory of Constraints*, The St. Lucie Press, Boca Raton, FL.

Kolarik, W. J., (1999). *Creating Quality: Process Design for Results*, McGraw Hill, Boston, MA.

Krippendorff, K., (1980). *Content Analysis: An Introduction to Its Methodology*, SAGE Publications, Newberry Park, CA.

Liebowitz, J., and Beckman, T., (1998). *Knowledge Organizations: What Every Manager Should Know*, St. Lucie Press, Boca Raton, 49-51.

Lipshitz, R. and Bar-Ilan, O., (1996). "How Problems are Solved: Reconsidering the Phase Theorem", *Organizational Behavior and Human Decision Processes*, vol. 65, No. 1, January, 48-60.

Lohse, G. L., and Johnson, E. J., (1996). "A Comparison of Two Process Tracing Methods for Choice Tasks", *Organizational Behavior and Human Decision Processes*, 28-43.

Mabin, V. J., and Balderstone, S. J., (2000). *The World of the Theory of Constraints: A Review of the International Literature*, The St. Lucie Press, Boca Raton, FL.

Marquardt, M., (1996). *Building the Learning Organization*, McGraw-Hill, Chicago, 121-124.

McMullen, T. B., (1998). *Introduction to The Theory of Constraints Management System*, The St. Lucie Press, Boca Raton, FL.

Motwani, J., Klein, D., and Harowitz, R., (1996), "The Theory of Constraints in Services," *Managing Service Quality*, Vol 6 No 1, pp. 53-56.

Neter, J., Wasserman, W., and Kutner, M. H., (1985). *Applied Linear Statistical Models: Regression, Analysis of Variance, and Experimental Designs*, Irwin, Homewood, IL.

Newell, A., and Simon, H. A., (1972). *Human Problem Solving*, Prentice-Hall, Englewood Cliffs, NJ.

Ptak, C. and Schragenheim, E., (2003), *ERP: Tools, Techniques, and Applications for Integrating the Supply Chain*, 2nd Ed., CRC Press, Florida.

Prahaland, C. K., and Hamel, G., (1990). "The Core Competence of the Corporation", *Harvard Business Review*, May-June, 79-91.

Ramesh, V., and Browne, G. J., (1999). "Expressing Causal Relationship in Conceptual Database Schemas", *The Journal of Systems and Software*, vol.45, 225-232.

Rubenstein-Montano, B., Liebowitz, J., Buchwalter, J., McCaw, D., Newman, B., and Rebeck, K., (2001). "A Systems Thinking Framework for Knowledge Management", *Decision Support Systems*, vol.31, 5-16.

Russo, J. E., Johnson, E. J., and Stephens, D. L., (1989). "The Validity of Verbal Protocols." *Memory and Cognition, 17*(6), 759-769

Sanchez, R. and Heene, A., (1997). *Strategic Learning and Knowledge Management*, John Wiley and Sons, New York, NY.

Schragenheim, E., (1998). *Management Dilemmas: The Theory of Constraints Approach to Problem Identification and Solutions*, The St. Lucie Press.

Senge, P. M., (1990). *The Fifth Discipline: The Art and Practice of The Learning Organization*, Currency Doubleday.

Senge, P. M., Kleiner, A., Roberts, C., Ross, R. B., and Smith, B. J., (1994). *The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization*, Currency Doubleday, New York, NY.

Siegel, A. F., *Practical Business Statistics, 4th Ed.*, Irwin/McGraw-Hill, Boston, MA, 2000.

Simon, H. A., (1977). *The New Science of Management*, Prentice-Hall, Inc, Englewood Cliffs, NJ.

Simon, H. A., (1981). *The Science of the Artificial*, The MIT Press, Cambridge, MA.

Smith, D., (2000). *The Measurement Nightmare: How the Theory of Constraints Can Resolve Conflicting Strategies, Policies, and Measure*, The St. Lucie Press, Boca Raton, FL.

Smith, G. F., (1998). *Quality Problem Solving*, ASQ Quality Press, Milwaukee, WI.

Sterman, J.D., (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Irwin/McGraw-Hill, Boston, MA.

Strauss, A., (1978). *Negotiations: Varieties, Contexts, Processes, and Social Order*, Jossey-Bass Publishers, San Francisco, CA.

Strauss, A., (1987). *Qualitative Analysis for Social Scientists*, University of Cambridge Press, Cambridge, UK.

Strauss, A., and Corbin, J., (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, SAGE Publications, Thousand Oaks, CA.

Umble, M. M., and Spoede, C.W., (1991), "Making Sense of Management's Alphabet Soup," *Baylor Business Review*, Fall Edition, pp. 26-27.

Weber, R. P., (1990). Basic Content Analysis, 2nd Edition, SAGE Publications, Newberry Park, CA.

Winer, B. J., Brown, D. B., and Michels, K. M., (1991). *Statistical Principles in Experimental Design*, McGraw-Hill, New York, NY.

Witte, E., (1972). "Field Research on Complex Decision-Making Processes: The Phase Theorem", *Management and Organization*, vol. 2, 156-182.

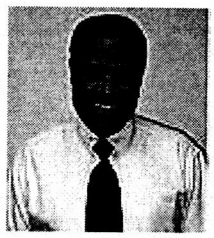
WOKRXZ, (2005), "Combining Systems Thinking and Goldratt's Thinking process to move Toward Improvement" Web site Accessed in May 2005: http://www.worxz.com/systemsthinking.html

AUTHOR BIOGRAPHIES

Philip F. Musa is an Assistant Professor of Management and Information Systems in the School of Business at The University of Alabama at Birmingham. He holds a B.S.E.E., M.S.E.E., M.B.A., and a Ph.D. in Information Systems and Quantitative Sciences, all from Texas Tech University. He is a licensed professional engineer with process and test engineering experiences in the semiconductor industry. He has published research in the areas of Entrepreneurship, Systems Thinking/System Dynamics, and Information Technology and Systems Issues in Developing Countries in journals such as *The Communications of the ACM*, *Journal of Global Information Management, Information Systems Journal, CAIS,* etc. He has also published proceedings of various national and international conferences. Dr. Musa is a senior member of IEEE and a lifetime member of Phi Kappa Phi honor society.

Vickie Cox Edmondson is an Associate Professor of Management at the University of Alabama at Birmingham. She holds a B.A. (English) from Spelman College, an MBA from Mercer University and a Ph.D. in strategic management from the University of Georgia. Her research interests include strategic management, entrepreneurship, corporate social responsibility, business ethics, and ethnic business enterprises. She has published in the Journal of Developmental Entrepreneurship, Journal of Business and Entrepreneurship, the Journal of Business Ethics, and others. She serves on the board of directors for Follow Me Foundation, a nonprofit community based organization. Dr. Cox Edmondson has more than 10 years of professional experience at NBI, INC., Procter and Gamble, and United Airlines.

George Munchus is Professor of Management at the University of Alabama at Birmingham. He earned a B.B.A. in Business Administration an M.B.A. in Management, and a Ph.D. in Management, all from the University of North Texas. His background includes military experience in inventory control and operations scheduling with the General Dynamics Corporation. His current research is focused on human resource utilization, project management, employee-employer relations and inequality management theory. He has published numerous articles and presented seminars on management and has served as a consultant to individuals, industry, government, labor and educational organizations in the areas of human resources, organizational development, business, and economic development, etc.



APPENDIX A: Brief Description of some Systems Archetypes

Systems Archetype	Description
Balancing process with delay	Overcorrecting a process that has a delayed feedback (e.g., seen in Real Estate boom and bust cycles).
Limits to growth or success	When a process feeds on itself to produce a period of accelerating success or growth. Then the growth begins to slow (often inexplicably to the participants in the system), and may even reverse itself and collapse.
Shifting the burden	When a short-term "band aid" solution is employed. This practice takes attention away from more fundamental, enduring solutions. Over time, the ability to apply a fundamental solution may decrease, resulting in more and more reliance on the symptomatic solution (e.g., drug and alcohol dependency).
Shifting the burden to the entervenor	Reliance on outsiders to a point that insiders do not learn how to solve own problems.
Eroding goals	A situation in which the short-term solution compromises long-term goals.
Escalation	When two parties compete for advantage in an arena. As one party's actions put it ahead, the other party "retaliates" by increasing its actions. The result is a continual ratcheting up of activity on both sides (e.g., price battles).
Success to the successful	When much of a limited resource is allocated to a more successful activity, thereby starving the other(s).
Tragedy of the commons	When a shared resource becomes overburdened as each person in the system uses more and more of the resource for individual gain.
Fixes that fail or backfire	A solution that yields positive results at first, but due to unforeseen dynamics worsens the problem in the long-run.
Growth and under-investment	A situation in which resource investments in a growing area are not made, owing to short-term pressures. As growth begins to stall because of lack of resources, there is less incentive for adding capacity, and growth slows even further.

Adapted from Goodman, 1995; Senge, 1990; Senge et al., 1994

APPENDIX B: The Two Tasks Analyzed by all Students in Study

Instructions: In order to earn the extra credit points, you must put in your very best effort in completing all requirements in this study. The requirements include answering the survey questionnaire, filling out the consent form and analyzing two problems as in-depth as you can.

Outline of Study Session:

Session Item	*Approx. Time*
Introduction	5 minutes
Filling out Consent Form	5 minutes
Filling out Pre-test Survey	5 minutes
Analyzing two tasks	80 minutes (about 40 minutes per task)
Filling out Post-test Survey	5 minutes

Analyze each of the two problems using what you feel is the most appropriate task analysis method with which you are familiar. The task analysis method of choice could be: Systems Thinking/System Dynamics, Goldratt's Thinking Processes, or some other task analysis method or heuristic. You do not need to use the same task analysis or problem-solving method to answer both problems. You are encouraged to use one task analysis or problem-solving method for a given task or problem.

Task #1

Being a graduate student, you must balance classes and assignments with outside activities, a personal life, sleep, etc. During the semester you attend classes, do the readings, prepare for and take the tests, and hand in assignments and projects as they are due, at least occasionally. You probably try to work harder if you think your grades are lower than you desire and take more time off when you are sleep-deprived and your energy level falls.

The real problem is the work pressure that builds up. Certainly, a larger assignment backlog contributes to more work pressure, but there are other contributors as well. These include time remaining to complete the work (or just "time remaining"). Note that "time remaining" is the difference between the current calendar date and the due date of the assignments, projects, or test dates.

You might try to cope with this work pressure in at least one of two ways. By working longer hours (more hours per week), you can increase the work completion rate. Doing a skimpier job by taking short cuts on the assignments, test preparations, and projects also speeds up the work completion rate as effort devoted to each assignment is reduced. Both of these strategies have some down sides. Can you think of any other strategies for coping with this problem?

Consider the strategy of working longer hours. This deprives you of sleep, resulting in burnout and a drop in productivity. A drop in productivity, in turn, reduces the work completion rate.

On the other hand, consider the second strategy (the strategy of reduced effort) in which you take short cuts. Reduced effort strategy results in reduced grades and reduced GPA, which are also undesirable, as they lead to dissatisfaction with grades. Actually, what happens is that reduced effort reduces the quality of your work, which in turn results in reduced grades. This often leads you to ask your professors for extension in due dates for assignments, projects and test dates. There are many variables already mentioned in this problem statement to help you analyze the situation more adequately.

Analyze this problem using the most appropriate task analysis method (systems thinking/system dynamics, Goldratt's thinking processes, or some other task analysis method with which you are familiar). The quality of your response will be judged by how well (detail) you analyze the problem.

Please identify and discuss as many of the following concepts related to the particular task analysis method of your choice as possible: Causal Loop Diagrams; Variables and Edges, Cycles of Influence, Stock and Flow Diagrams; Behavior Over Time Charts; Systems Archetypes; Simulations; What to Change; What to Change to; How to Cause the Change; Current Reality Tree, UnDesirable Effects (UDE's), Evaporating Cloud or Conflict Resolution diagram, Injection(s), Future Reality Tree, PreRequisite Tree (PT), Transition Tree, etc.

(a) List all the variables or forces at play in this problem.

(b) What are the tools (or concepts) you used in analyzing this situation? Analyze fully the situation described in this problem, using tools and concepts that you believe are the most appropriate for the situation. If you do not know of any tool, please use any method or heuristic with which you are familiar.

Task #2

You are a young "Assistant Manager for Quality Assurance" for a publicly-held desk and floor lamps manufacturing company. You are of the opinion that in order to stay competitive, your company should continually work on improving internal procedures, product design, features, etc. Your 60-year old immediate boss, on the other hand, believes that implementing frequent changes is disruptive, and that the company should strive to maintain its current (albeit eroding) advantages in the desk and floor lamps industry.

The primary problem your company is faced with is that it is not making enough profit. In a recent brainstorming session, your management has identified some problems that might be behind your company's current precarious position. Both you and your boss are interested in how to increase market demand and/or increase the perceived value of your products in the eyes of more customers in order to boost profits. Some things that have come to mind as having negative effect on the market demand for your products are:

(1) too many models being offered, you might need to streamline the desk and floor lamp models you offer,

(2) the lead times for your products are too long, this leads to reduced market share, which in turn leads to eroding profitability,

(3) your deliveries are often unreliable,

(4) the quality of your products need improvement,

(5) your high costs prevent you from selling to certain segments of the market without losing money,

(6) some of your product designs have been characterized as "too European" in taste, and therefore "not appealing" to American consumers,

(7) fierce competition from other manufacturers, etc.

You have recently attended a seminar on lot sizes, inventories, and their benefits if reduced. It is known that small lot sizes improve product quality. This is true because even if a lot is incorrectly processed, the loss is smaller (due to small lot size). Reduced inventory shrinks cycle time. The two solutions together (i.e., small lot size and reduced inventory) lead to better reliability of deliveries of better quality products at reduced costs.

Analyze this problem using the most appropriate task analysis method (systems thinking/system dynamics, Goldratt's thinking processes, or some other task analysis method with which you are familiar). The quality of your response will be judged by how well (detail) you analyze the problem.

Please identify and discuss as many of the following concepts related to the particular task analysis method of your choice as possible: Causal Loop Diagrams; Stock and Flow Diagrams; Variables and Edges, Cycles of Influence, Behavior Over Time Charts; Systems Archetypes; Simulations; What to Change; What to Change to; How to Cause the Change; Current Reality Tree, UnDesirable Effects (UDE's), Evaporating Cloud or Conflict Resolution diagram, Injection(s), Future Reality Tree, PreRequisite Tree (PT), Transition Tree, etc.

(a) List all the variables or forces at play in this problem.

(b) What are the tools (or concepts) you used in analyzing this situation? Analyze fully the situation described in this problem, using the tools and concepts that you feel are most appropriate for the situation. If you do not know of any tool, please use any method or heuristic with which you are familiar.

APPENDIX C: Coding Schemes Used for the Two Tasks in Study

Coding Scheme for Task #1 (Dynamic Task)

Part (A): Evaluation of Subject's Ability to Identify Variables

Item	*Variable*	*Wrong or None = 0 pt.*	*Partial = 1pt.*	*Full = 2pts.*
1	Assignment backlog			
2	Assignment rate			
3	Work pressure			
4	Workweek rate			
5	Work completion rate			
6	Calendar time			
7	Due date			
8	Time remaining			
9	Effort devoted to assignment			
10	Energy level			
11	Requests for extension			
12	Productivity			
13	Quality of work			
14	Grades (actual)			
15	Desired grades or Desired GPA			
16	Pressure for achievement			
17	Satisfaction with grades or achievement			
18	Other (Listed by subject, but invalid)			
19	Causal loop diagram			
20	Stock and Flow diagram			
21	Conflict Resolution Diagram (i.e., Evaporating Cloud)			
22	Current Reality Tree (CRT)			
23	Future Reality Tree (FRT)			
Totals				

Coding Scheme for Task #1, continued

Part (B): Evaluation of Subject's Use of Tools

Item	*Variable*	*Wrong* or *None = 0pt.*	*Partial =1pt.*	Full *=2pts.*
1	# of models or designs			
2	Market demand			
3	Operating expenses			
4	Production costs			
5	Product price			
6	Reliability of delivery			
7	Lead time			
8	Lot or batch size			
9	Inventory level			
10	Product quality			
11	Level or extent of European design			
12	Competitive pressure			
13	Market perception of products			
14	Profit or Profitability			
15	Other (Listed by subject, but invalid)			
16	Causal loop diagram			
17	Stock and Flow diagram			
18	Conflict Resolution Diagram (i.e., Evaporating Cloud)			
19	Current Reality Tree (CRT)			
20	Future Reality Tree (FRT)			
Totals				

Coding Scheme for Task #2 (Static Task)

Part (A): Evaluation of Subject's Ability to Identify Variables

Item	*Variable*	*Wrong or None = 0pt.*	*Partial =1pt.*	*Full = 2pts.*
1	Assignment backlog			
2	Assignment rate			
3	Work pressure			
4	Workweek rate			
5	Work completion rate			
6	Calendar time			
7	Due date			
8	Time remaining			
9	Effort devoted to assignment			
10	Energy level			
11	Requests for extension			
12	Productivity			
13	Quality of work			
14	Grades (actual)			
15	Desired grades or Desired GPA			
16	Pressure for achievement			
17	Satisfaction with grades or achievement			
18	Other (Listed by subject, but invalid)			
19	Causal loop diagram			
20	Stock and Flow diagram			
21	Conflict Resolution Diagram (i.e., Evaporating Cloud)			
22	Current Reality Tree (CRT)			
23	Future Reality Tree (FRT)			
Totals				

Coding Scheme for Task #2, continued

Part (B): Evaluation of Subject's use of Tools

Item	*Variable*	*Wrong* or *None = 0pt.*	Partial =*1pt.*	Full = *2pts.*
1	# of models or designs			
2	Market demand			
3	Operating expenses			
4	Production costs			
5	Product price			
6	Reliability of delivery			
7	Lead time			
8	Lot or batch size			
9	Inventory level			
10	Product quality			
11	Level or extent of European design			
12	Competitive pressure			
13	Market perception of products			
14	Profit or Profitability			
15	Other (Listed by subject, but invalid)			
16	Causal loop diagram			
17	Stock and Flow diagram			
18	Conflict Resolution Diagram (i.e., Evaporating Cloud)			
19	Current Reality Tree (CRT)			
20	Future Reality Tree (FRT)			
Totals				

Information Systems & Computing
Academic Professionals

EDSIG
Serving Information Systems Educators

STATEMENT OF PEER REVIEW INTEGRITY

All papers published in the Journal of Information Systems Education have undergone rigorous peer review. This includes an initial editor screening and double-blind refereeing by three or more expert referees.

ISSN 1055-3096