

# An Investigation of Students' Thought Processes in Solving Business Problems with a Database Application

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*The study examined students' thinking processes when using database applications to solve an ill-structured business problem; it also investigated the effect of two computer interfaces (command language and menu selection) on the thinking processes. The findings revealed that subjects used a subgoal analysis method in solving the assigned problem. When computer problems were encountered, the working backward method was used. The computer problems that affected problem-solving processes included complex database procedures, insufficient knowledge on using the software, software errors, and undetected errors in execution results. Further, subjects in the command language group were more likely to skip the consideration of relevant factors for making decisions due to the complicated steps and difficult-to-remember commands required in using the interface. The computer interface affected the quality of the factors considered for decision making while solving ill-structured business problems.*

In today's complex and competitive businesses, the ability to organize useful information for decision making is essential. Businesses must hire employees who are capable of thinking through a process. Therefore, one of the objectives in today's business education curriculum is to prepare students to be able to manage, control, and effectively use information for problem solving (Breivik, 1998; Frueling, Kerin, & Sebastian, 1997; Secretary's Commission for Achieving Necessary Skills, 1991).

In the past, instruction in problem solving generally emphasized well-structured problems. Well-structured problems are problems for which needed information is clearly presented and an appropriate algorithm is available that guarantees a correct answer (Frederiksen, 1984; Newell & Simon, 1972). Sternberg and Spear-Swerling (1996) criticized the emphasis on well-structured problems for not preparing students to be able to solve problems outside of academic settings. Most problems faced in life are the ill-structured type of problem. The information needed for solving ill-structured problems is not explicitly identified, the goal is often not specified, and no test exists to determine whether a proposed solution is the best solution (Nickerson, 1994; Thomas & Litowitz, 1986). To solve this type of problem, individuals

must continuously search for relevant information to identify the problem, formulate hypotheses, ask for additional information, and revise hypotheses on the basis of new information until a solution is proposed (Frederiksen, 1984; Jaušovec, 1994). In many cases, problems encountered in the day-to-day world do not have a known correct best solution (Nickerson, 1994; Thomas & Litowitz, 1986). It appears that when problems are ill-structured, skill in retrieving relevant information becomes more important, along with reasoning skill which is needed in evaluating the evidence for and against each hypothesis. A problem solver, therefore, needs quick access to information that is already available in order to generate and test hypotheses.

Microcomputers can be used to provide the quick access; database applications have the capabilities to sort and search through large amounts of data, and in turn, organize data into useful information for hypotheses testing (Salomon, Perkins, & Globerson, 1991; Pea, 1993; Perkins, 1993). Salomon, Perkins, and Globerson further

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stated that using technologies as tools, “they potentially allow a learner to function at a level that transcends the limitations of his or her cognitive system” (p. 4). However, to become a truly useful tool in helping students solve complex business problems, the microcomputer system should provide an intuitive interface. Hackos and Redish (1998) defined interface as “a bridge between the world of the (computer) system and the world of the users. It is the means by which the users interact with the system to achieve their goals” (p. 5). In using a truly usable system, “the users are not encumbered by the computer” (Shneiderman, 1998, p. 10). The system becomes transparent to the work and enables users to concentrate on their work (Hackos & Redish, 1998; Shneiderman, 1998). In fact, if users cannot communicate effectively with an interactive system, its computational ability may be inaccessible.

Educators in the 21st century need to use the technology effectively in their teaching, particularly teaching students to solve ill-structured business problems. However, the general approach is to demonstrate the use of the computer, distribute exercises or homework assignments, and then grade the solutions that students produced. Little is known about how students plan, monitor, and evaluate their own problem solving. Important questions are left unanswered, such as how students came up with the solution. What problem-solving approach did students use? How effectively did students use the software application? What type of computer problems did they have (if any)? Did the computer interface help or hinder students’ problem solving? Teachers need insights into students’ current understanding and thinking processes, and then the information can provide guidance for how to assist students in improving their problem solving approach and critical thinking.

Although current technology provides a rather user-friendly graphical interface for the users to communicate with the computer, no empirical data are available on the effect of any particular computer interface on problem solving. To study the effect of interfaces on problem-solving activities and better control other variables (such as software functionality), it is necessary to use the same software with different interfaces in the

investigation. This research, therefore, used the command language version and menu-driven version of the same database application to study the effect of computer interfaces. Detailed information gathered on how the computer interface affects students’ problem solving will assist teachers in selecting the appropriate interface and developing teaching strategies that facilitate data exploration and problem solving.

## **Purpose of the Study**

This research was designed to examine students’ problem-solving processes when using a database application to solve an ill-structured business problem. It investigated students’ difficulties and needs while solving the problem and compared the effect of different computer interfaces, on students’ thinking processes. Specifically, the study focused on investigating three questions:

1. What are the problem-solving methods students employed in solving an ill-structured business problem?
2. What are the computer problems that affect the processes of solving an ill-structured problems and/or the decisions made?
3. Is a command language interface or a menu selection interface a more effective tool in assisting problem solving?

Until business teachers have a clear understanding of the thinking processes students apply while using microcomputers to solve ill-structured business problems, they are limited in helping students develop problem-solving ability and in integrating microcomputers in teaching higher-order thinking skills.

The use of protocol methods can generate detailed information in detecting students’ strengths and weaknesses in the process of solving problem (Thomas & Litowitz, 1986); therefore, this study used protocol analysis research procedures to investigate students’ problem-solving processes while using a database application to solve an ill-structured business problem.

## Review of Literature

The foundation for this research is rooted in the theoretical bases of problem solving methods, information processing, microcomputers as tools in solving problems, and human-computer interface.

### ***Problem-Solving Methods***

Researchers in their study of human problem solving have identified some generally useful problem-solving methods. The following are commonly identified problem-solving methods:

- **Algorithms**: Algorithms are specific procedures that are guaranteed to produce a solution to a problem so long as the algorithm is relevant to the problem (Anderson, 1985).
- **Means-ends analysis**: A general feature of this method involves identifying various differences between the goal state and the current problem state with operations that are likely to reduce those differences; thus the process moves the problem from the initial state successively closer to the final desired state (Anderson, 1985; Nickerson, 1994).
- **Subgoal analysis**: This approach breaks a complex problem down into a series of simpler problems, and the problem is solved by combining the solutions to the simpler sub problems (Nickerson, 1994; Sacerdoti, 1977).
- **Working backward**: The key to working backward is to start with the goal and try to change it into the givens (Bransford, Sherwood, & Sturdevant, 1987). This method is useful when there is a single, clearly, and completely specified goal stated in the problem.

It is not suggested that any of these strategies is adequate to ensure effective problem solving by itself. They can be used in many combinations. In solving a complex problem, for example, subgoal analysis can be combined with any other strategy (Nickerson, 1994).

## ***Information Processing***

Research has led to the development of a general theory of problem solving that assumes that humans operate as information processing systems when they carry out the processes involved in problem solving (Dominowski & Bourne, 1994). Memory is basic to any theory of information processing. Most cognitive psychologists distinguish at least three kinds of memory: a sensory buffer, a long-term memory, and a short-term or working memory. The various senses first bring environmental information to the sensory buffer (Anderson, 1985; Atkinson & Shiffrin, 1968; Norman & Rumelhart, 1970). Long-term memory is a virtually limitless repository of permanent knowledge and skills, and information must be activated in order to be recalled or retrieved from long-term memory. Information that is active at a given moment is contained in short-term memory (Feigenbaum, 1970). Therefore, the short-term memory contains the information that is actively being used from both the sensory buffer and the long-term memory. In other words, short-term memory maintains an internal representation of the current situation, but its capacity is limited to five to seven items of information (Miller, 1956; Simon, 1974). Based on the assumption that the processes and information compete for a shared limited capacity, a task that has heavy processing requirements should decrease the amount of information that can be maintained. Therefore, the limited capacity of short-term memory represents a fundamental limitation of human mental capacity (Anderson, 1985; Miller, 1956).

### ***Microcomputers and Problem Solving***

Historically, there have been extensions of human intelligence through the use of cognitive technologies to combat this human limitation (Pea, 1993). Sternberg, Baskin, and Hofer (1986) conducted a study on problem solving that used the kind of problems that needed the storage of large amounts of information and required problem-solving strategies. The results indicated that using computers as a tool to store and organize information was a helpful aid to problem solving. In addition to reducing memory requirements for

solving problems, microcomputers can also be used to remove mechanical operations from students, such as tedious calculations, recalculations, sequencing, or organizations. Instead, they permit higher-order thinking, such as problem formulation, problem analysis, and solution interpretation (Pea, 1986; Perkins, 1985; Schoenfeld, 1988).

### ***Human-Computer Interface***

Using microcomputers as tools for problem solving requires familiarity with the interactive system (Fischer, 1989). Therefore, the success of an interactive system should be determined more by its ability to communicate with general users and less by its processing speed and memory size. If the computer cannot communicate effectively with the user, the user will not be able to access the system's computational ability (Fischer, 1989; Hix, 1989).

The two metaphors that describe interaction styles are conversational and model environment. In the conversational environment, the user describes the intention with a command language. On the other hand, the model environment requires the user to show the intention by manipulating visual representations of operations (Hartson, 1989), which include selecting options from menus and directly pointing at visual representation of objects and actions to instruct the machine such as graphical user interface (Sneiderman, 1998). A command language interactive system typically responds only to commands phrased with total accuracy. This type of system often fails to understand the user's intention and is unable to explain the nature of the misunderstanding to the user (Hayes, Ball, & Reddy, 1982). Olson (1987) also commented that with less on-screen information to indicate the next action from the system, the more the user must depend on long-term memory recall of the commands. On the other hand, Norman (1984, 1987) argued that there is no perfect design, only tradeoffs. He explained that command language applications offer the expert great versatility; experts can specify their operations, parameters, files, or other required options directly with commands. Users of a menu selection system, however, will need to have a comprehensive understanding of all of the options displayed in the menu. Without this knowledge, it

will be difficult for the user to select the appropriate option before exploring several options that might seem to have the same functionality.

From the literature review, it is clear that teaching business problem solving with computers as tools is a complex issue. In business education, however, not much attention has been given to "how" to teach students to use the technology effectively (Lambrech, 1999). In order to answer the questions of how effectively students use the software application in their problem solving, what problem-solving approaches they use, and what computer problems emerge when they solve problems, the protocol analysis research method was used. This research method requires students verbalize what comes to their minds as they solve problems. Verbal protocols offer a rich description of thinking processes of each student and make it possible for researchers to compare the thinking processes of different students who are solving the same problem (Ericsson & Hastie, 1994).

### **Method**

This section describes research procedures and subjects used in the study.

### ***Research Procedures***

Newell and Simon (1972) pointed out that it is essential to identify the information processing function and used verbal reports as data to understand information processing and problem solving. Verbal reports provide a nearly complete record of the thought processes (Ericsson & Simon, 1993) and make it possible to compare thought sequences of two individuals solving the same problem (Ericsson & Hastie, 1994). This research used the think aloud approach to gather qualitative data for analysis.

**Software Selection.** To investigate the effects of computer interfaces in problem-solving activities, it is essential to select one application that provides different interfaces for users to manipulate data. This criterion allows tight control on the application's capability and functionality. Yet, none of the more commonly used software meets the criteria. For example, Microsoft Access is a more commonly used database application with a

graphical user interface, but it does not provide an alternative user interface that is needed for this research. Although Visual Basic (which requires using commands) can be used in Access, it is a programming language designed for creating applications, not an application that users can use to manipulate business data. Therefore, this study used dBASEIII+ in the command language group and dBASEIV in the menu selection group. These two applications were produced by the same software company, and essentially are the same database application with different user interfaces.

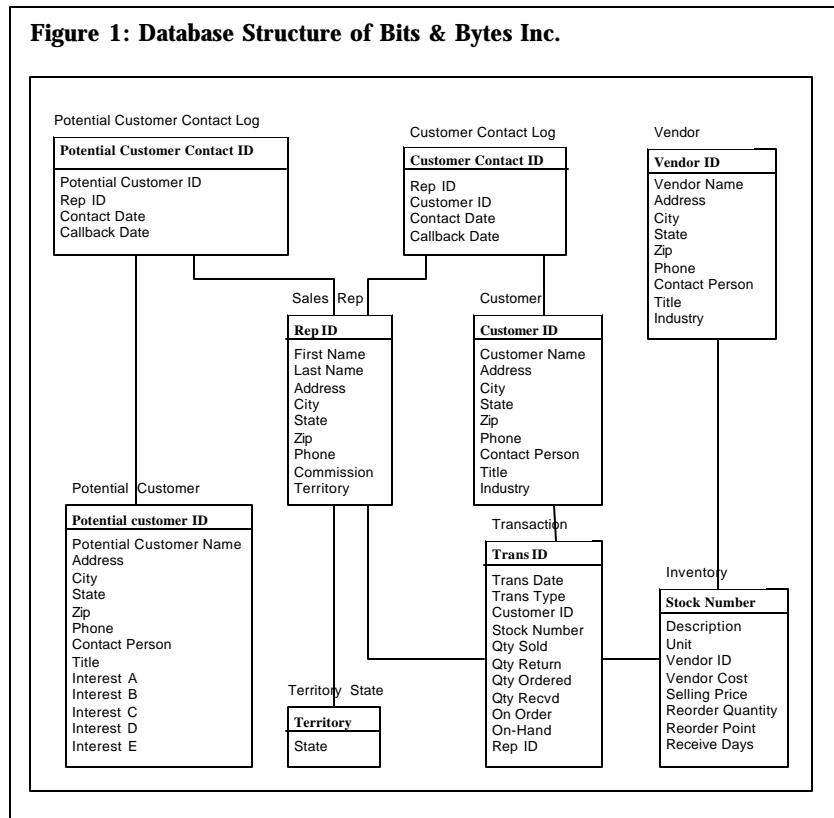
**Generation of the Business Problem and Database files.** It was essential to select problems that met the following criteria: (a) an ill-defined business problem for which there was no single solution and correct answer; (b) a business problem that required the use of large volume of computerized data; (c) a typical business problem that a college graduate could be expected to solve. To gather problems, a questionnaire was sent to 201 members of the Organizational System Research Association (OSRA), asking assistance in identifying business problems appropriate for instructional use. Second, visits were paid to two small businesses to gather business problems. Information gathered from these businesses and the problems obtained from the mailing responses were then compiled to form 14 ill-structured business problems. These problems were ranked according to their complexity and the use of database application procedures. Two of the more complex problems were reserved for the pilot study and lower- and intermediate-complexity problems were used in the later part of the instruction.

A fictitious corporation (Bits & Bytes Inc.) was created to simulate the database environment of a real business. A consultant with five years of experience managing a microcomputer system department provided assistance in creating the fictitious corporation, the database model, and the database files used in

this study. Based on the database design theory presented in *Designing Quality Databases with IDEF1X Information Models* (Bruce, 1992), a database model was developed with nine database files (see Figure 1). In the process of generating the database files for Bits & Bytes Inc., every effort was made to ensure that the data closely resembled that of a real business. For example, the database file with transaction records contained large numbers of records (13,000 records), and the employee file contained only a few records. Computer programs were written to generate most of the data. Since the majority of the data generated were random data, the database files were manipulated to reflect the problem situation that occurred in the problem selected for the study.

**Pilot Tests.** Two complex business problems were used in two pilot studies. The first pilot tested the nature and length of the problem-solving activity, the database model, the format for audiotaping, and the procedures for encouraging subjects to think aloud during the problem-solving interview. Adjustments were made before the second pilot was conducted with a community

**Figure 1: Database Structure of Bits & Bytes Inc.**



college teacher who taught microcomputer applications and business subjects. This individual confirmed the appropriateness of the problem, the database model, and the database files. Both individuals recommended using only the first business problem. The problem selected for this research stated that sales representative John was complaining that he was over-loaded. The problem asked subjects to gather evidence on his performance and compare that of other sales representatives. If John's claim was evident, the problem asked to make recommendations on regrouping states in territories. This problem was ill structured; neither did it provide solutions or steps to research a solution, nor did it provide criteria for subjects to decide when the problem was solved.

Data Gathering Technique. Thornburg and Pea (1991) commented that people choose logical alternatives and use more effective procedures on problems with familiar data. Due to the complexity of the database model of Bits & Bytes Inc. and the large volume of computerized data used in this study, it was important that students have the opportunity to become familiar with the database model and files. A commercial workbook for business problem solving using microcomputer database applications was used in the first five weeks of the course. At the sixth week, business problems (described in the Generation of the Business Problem and Database Files section) with lower complexity were given to students with two database files. Gradually, students were given less structured problems with higher complexity and more database files to solve. Students were also required to provide rationale for their decisions to encourage their awareness of problem solving processes. However, various problem-solving methods were not part of the course content.

Three approaches were used to gather the data needed to address the intent of this study. At the beginning of the problem-solving interview, a demographic questionnaire was administered to gather background information, including subjects' education and work-related experience in both business employment and on computers. Then, the 12 subjects were asked to "think aloud" while solving the ill-structured business problem using the microcomputer database application. The problem-solving interviews were audio taped. When subjects

were performing the problem solving task, commands used and the computer responses displayed on the screen were recorded as supplemental materials to verify procedures used in the problem-solving activity.

The Problem-solving Interview. The problem-solving activities for this study were conducted after students had finished the final exam. A vacant academic office was used for the interviews. A personal computer with dBASEIII+ and dBASEIV applications and a LaserJetIIP printer were set up with a calculator, reference books for dBASEIII+ and users' manuals for dBASEIV. Notepads, pencils, and a tape recorder were placed on the desk next to the computer. All 12 interviews took place in the same office with the same setting.

Each subject completed a demographic questionnaire before beginning the problem-solving activity. Subjects were then given a printed description of the business problem and a paper model of the database structure. They were told that they could have as much time as they needed to solve the problem to their own satisfaction, and that they would be required to orally verbalize their thoughts as they worked. They were also told that they had to solve the problem on their own, and the researcher was not able to answer any question. The tape recorder microphone was then clipped to the individual.

Before the command language interviews, a text file in dBASEIII+ was opened to record the keystrokes that subjects would key. Since the text file feature was not available in dBASEIV, the researcher observed and recorded the options that subjects in the menu selection group used and the responses displayed on the screen.

The protocols of the problem-solving interviews were analyzed using protocol analysis procedures developed by Ericsson and Simon (1993). The verbal protocols were transcribed, segmented, and coded. Segments consisting of discrete thoughts or phrases were coded according to the categories presented in the Computer Aided Problem-Solving Analysis Model (Chen, 1999). The model was developed by combining a problem-solving control structure developed by Voss et al. (1983) for their protocol analysis on problem-solving skills in the social sciences and the human-computer interaction model developed by Norman (1984). Chen's

model presented eight categories for coding protocols generated by students who use computers to solve business problems. The model and the eight categories are illustrated in Figure 2.

This framework provided an explanation of a subject's thinking processes. The text files containing the keystroke records and the researcher's observation records were used as supplemental materials to validate subjects' operations. In addition, the coded protocols were then diagrammed into flowcharts of thinking processes.

To investigate the effects of different computer interfaces in students' problem solving, some statistical procedures were conducted. According to Potter (1996), the use of numbers in qualitative research is not the problem. Being criticized is "the translation of concepts of qualities into numerals so that they can be analyzed using statistical procedures" (p. 91). Marshall and Rossman (1989) maintained that enumeration can be used for dealing with frequency distributions. This research used frequency count when dealing with the number of certain computer procedures used, the number of unnecessary commands used, and the number of factors considered by subjects when they solve the problem.

The Mann-Whitney rank sum test was used in this research to analyze the effect of computer interface on problem solving. The Mann-Whitney test is one of the most powerful nonparametric tests that can be used to test the difference between two independent samples. It is a most useful alternative to the *t* test when samples are small and of unequal sizes (Minium, 1978; Siegel, 1956).

## Subjects

Protocol analysis research procedures are complex and time-consuming, and therefore studies usually involve a small number of subjects. Voss, Blais, Means, Greene, and Ahwesh (1989) had only five subjects in each of the six groups in their study on informal reasoning and knowledge base of economics of naive and novice individuals. In their book, *Education Research: An Introduction*, Gall, Borg, and Gall (1996) cited a qualitative research study involving protocol analysis conducted by Samuel Wineburg on the knowledge structures of

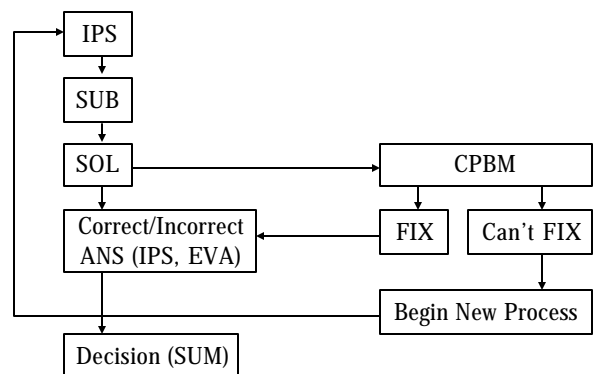
experts and novices. Wineburg used four historians in the specific area, four historians with specializations in other area, and eight high school students (Gall, Borg, & Gall, 1996).

As Potter (1996) stated, the selection of subjects in a qualitative research was more concerned with "why" the subjects were selected than "how." For this study, the problem solvers need to have business knowledge and familiarity with database applications to solve an ill-structured business problem with database applications. Potential subjects had to have: (a) formal education or working experience in business; (b) hands-on experience on the use of microcomputers; (c) hands-on experience on using dBASEIII+ or dBASEIV application; and (d) experience in solving ill-structured business problems with large volumes of computerized data.

Subjects for this research were recruited from a higher-division database applications class at a four-year university. Students enrolled in the database application class generally have finished several business courses and have business experience (criterion a). Students enrolled in this class also had finished an introduction to

**Figure 2: Computer-Aided Problem-Solving Analysis Model**

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Key: IPS—Interpret problem statement, data, or answers  
 SUB—State subproblem  
 SOL—State solution  
 ANS—State computer's response  
 CPBM—State computer problem  
 FIX—Solve the computer problem  
 EVA—Evaluate solution or answers  
 SUM—Summarize the decision

microcomputers course. The content of both the introductory course and the database applications course emphasized theory and hands-on experience (criterion b). Both dBASEIII+ and dBASEIV were used in the instruction and problem-solving projects in the database applications class (criterion c). In this class, simple problems with small database files were used, and gradually ill-structured problems with large database files were provided for the problem-solving activities (criterion d). Twelve of 19 students enrolled in the class volunteered to participate in the study; six subjects were randomly assigned to the command language group, and six

subjects were randomly assigned to the menu selection group.

For easy reference, subject codes were assigned to all. Subjects who used dBASEIII+ (command language interface) were assigned III.1, III.2, III.3, III.4, III.5, and III.6; subjects who used dBASEIV (menu selection interface) were assigned IV.1, IV.2, IV.3, IV.4, IV.5, and IV.6.

Age, Gender, GPA. Data gathered from the questionnaire administered at the beginning of the problem-solving activity are listed in Table 1. There were nine female and three male students who participated in the study. All six of the

**Table 1: Background Information on Subjects**

Sbjct	Gndr	Age	GPA	Status	Education				Experience	
					Dg	Mjr	Bus	Cmptr	Bus	Cmptr
III.1	F	32	4	G	BA	BUS ED	BLAW, MTG, FNC, MGT, ACT, OFF MGT, RDS MGT, BUS COMM.	Intro, 123, HG, DP, dBASE	Secretary	Appleworks, PM, HG, WP, VT, 123, WORD, dBASE
III.2	F	32	4	G	BA	ACT	108 Credits, Licentiate in ACT	FORTTRAN, BASIC, 123, ACCPAC, CRCA, dBASE	Auditor—4 yrs Lecturer in Auditing	Review ACT Sys., Implementation of ACCPAC
III.3	F	29	3.5	G	MED	CISY	ECON, ACT, BUS COMM.	123, dBASE, WP		Assisting use of WP
III.4	F	25	3.9	G	BA	ECON	ECON, ACT, CAD, Int'l FNC	dBASE, 123	Off. Mgr, Sales Rep	123
III.5	F	37	4	U	AS	BUS MGT	ACT, MTG, MGT, BLAW, Ins., Human Rel., Int'l Bus	SS, DB, WP, dBASE	Secretary, Comm. Coordinator, Advertising, Personnel Mgr, Purchasing	WP, EMail, DB
III.6	F	47	2.9	U		SP ED	ACT, MGT, MTG	123, dBASE, WP	None	None
IV.1	M	30	2.9	U			ACT	5 cmptr languages, dBASE	Adm. Clerk, Library Assistant	Created database sys., Used numerous WP & SS
IV.2	F	46	4	G	BA	BUS ED	ECON, FNC, BLAW, Stats.	123, DP, dBASE, WP	Teacher—10 yrs, Mkg rep for IBM—4 yrs, Secretary	WP, DP, others
IV.3	M	23	3	U		BUS ED	ECON, MGT, MTG, Info Sys., Stats.	Intro, 123, HG, dBASE	Data Processor	WP, 123, dBASE
IV.4	M	30	3.6	G	MA	BUS ADM	ACT, MGT, ECON	WP, dBASE, 123	Staff in Shipping Co.	WP
IV.5	F	34	3.4	U			BLAW, T&D, MTG, ORD, Int'l Bus,	Intro, dBASE	Legal secretary—2 1/2 yrs Personnel Coordinator— 5 yrs	123, Q&A, WP, Paradox, dBASE, HG
IV.6	F	21	3.1	U	AA		ACT, MGT, MTG, BUS, Writing, Human Res.	Intro, WP, 123, dBASE	Secretary, Interns in T&D	WP, 123, Windows

subjects in the command language group were female students; three of the subjects in the menu selection group were female students, and another three subjects in this group were male students. The average age in the command language group was 33, and the average age in the menu selection group was 30. The average grade point average (GPA) in the command language group was 3.71, and the average GPA in the menu selection group was 3.3.

Four of the subjects in the command language group were in graduate programs, and two were undergraduate students. In the menu selection group, two subjects were graduate students and four were undergraduate students.

Education. In the command language group, three subjects had earned a degree in business and one had earned a degree in instructional design. Two subjects in the menu selection group had earned a business degree. As listed in Table 2, all of the subjects in both groups had completed at least one course in business.

It is important to note that the same number of subjects, three of six, in both groups had completed courses in management and marketing. Due to the nature of the problem used in the study, management and marketing courses should have provided subjects the business knowledge needed for solving the problem.

Table 3 illustrates the number of microcomputer and programming language courses subjects had completed. All subjects in the command language group had completed at least two microcomputer application courses.

All but one of the subjects in the menu selection group had also finished at least two microcomputer application courses, and the subject who had completed only one microcomputer application course had extensive training in programming languages.

Business Experience. Subjects participating in this study had various degrees of working experience in a wide variety of occupations. In the command language group, two subjects had no business

**Table 2: Number of Subjects Who Had Completed Business Courses**

Interface	Accounting	Management	Marketing	Finance	Economics
Command Language	6	3	3	2	2
Menu Selection	3	3	3	1	3

experience; one subject had experience in secretarial duties; one subject had auditing experience; one subject had been a sales representative and an office manager; and one subject had been a secretary, coordinator, and manager. However, the two subjects who had no business experience had three to four courses in accounting, economics, management, or marketing.

Subjects in the menu selection group also had a variety of business experience: one subject had been an administrative clerk and library assistant; one subject had been a data processor; one subject had experience in secretarial duties and training and development; one subject had working experience in a shipping company; one subject had experience as a legal secretary and personnel coordinator; and one subject had teaching experience and business experience as a secretary and marketing representative. In short, subjects in the command language group and subjects in the menu selection group received similar education on microcomputer applications and business subjects. The subjects in these two groups also had much the same working experience in business.

Results of the Interview. One of the 12 subjects did not complete the problem solving due to software errors. One subject in the command language group arrived at an unreasonable solution

**Table 3: Number of Microcomputer Applications and Programming Language Courses Completed by Subjects**

Microcomputer Courses	Command Language						Menu Selection					
	III1	III2	III3	III4	III5	III6	IV1	IV2	IV3	IV4	IV5	IV6
Applications	5	4	3	2	4	3	1	4	4	3	2	4
Programming Languages		2					5					

because she did not detect errors in the results presented by the software. Two subjects, one in command language group and one in menu selection group, arrived at the same solutions. Eight subjects had reasonable solutions supported by their search of information. The emphasis of the study was to investigate subjects' thought processes, their strengths and weaknesses in using the software, and the effects of computer interfaces in the problem-solving processes. The quality of subjects' solutions, therefore, was not the focus here.

## Findings

Similarity and differences were found between groups of subjects using the command language interface and the menu selection interface.

### **Question 1: Problem Solving Methods**

What are the problem solving methods students employed in solving ill-structured business problem?

For the purpose of answering Question 1, the flow charts of students' problem solving processes were simplified to diagrams, in which lower-level details were eliminated to illustrate a higher-level thinking process.

Although subjects were not taught any specific problem-solving method, all subjects in both the command language group and the menu selection group used the subgoal analysis approach to solve the business problem. After reading the problem, all subjects decomposed the problem into subproblems. However, only subject 2 in the menu selection group appeared to have an overall plan for solving the problem. Most subjects employed a "plan as you go" approach. Subjects identified a subproblem, solved that subproblem, occasionally interpreted the results, evaluated the results to support or reject a point in relation to a decision, and then identified another subproblem. This cycle continued until a decision was made; yet, this was not a cycle without interruptions. In searching for a solution to reach a subgoal or solving technical problems, all of the subjects demonstrated interruptions to interpret the problem, data, or

database application procedures, and to evaluate the appropriateness of using a particular procedure.

One important factor that altered the "train of thought" was computer execution time. When subjects executed a time-consuming procedure and were waiting for the computer to respond, subjects' attention was shifted to other elements. As one of the subjects indicated,

When I notice the screen indicating 'processing query'.... to better use my time, I would look back at the problem and figure out the next step, so that I will be ready when the machine is ready for me.

Subjects shifted their attention among interpretation of the problem or database files, evaluation of the results obtained previously, evaluation of the computer procedures used for the current subproblem, and identifying more subproblems.

If a subproblem was identified but not solved immediately, subjects tended to forget solving that subproblem. In four of the seven incidents, however, subjects returned to the subproblem after one or two other subproblems were identified and solved.

This working forward, subgoal analysis problem solving approach was shifted to a working backward approach when subjects encountered software problems or detected errors in computer execution results. When they encountered computer problems, subjects traced back the steps and identified the specific step that led to the current computer problem.

In terms of problem-solving methods employed, no differences were found in the methods used between the command language group and the menu selection group. Subjects in both groups used a subgoal analysis approach in solving ill-structured business problems. All subjects frequently paused to interpret the problem, database files, and application procedures. While waiting for the computer to generate results, all subjects took the opportunity to identify more subproblems, evaluate results obtained, or check the relevance of database files.

If errors were detected in execution results or software errors were encountered, subjects in both interfaces traced the procedures used and worked backward to obtain the correct results for the subproblem.

### **Question 2: Computer Problems**

What are the computer problems that affect the processes of solving ill-structured problems and/or the decisions made?

When using database application to solve problems, different procedures can be used to accomplish the same task. However, some procedures are more efficient than others. Inefficient procedures are those that take longer time to process or unnecessarily use up more hard disk space. The procedures used in the problem-solving interview were recorded.

Four computer-related problems that affected problem-solving processes were identified: complex database procedures, insufficient knowledge in using the software, software errors, and undetected errors in execution results. An examination of all 12 verbal protocols revealed that four of six subjects in the command language group decided not to consider some relevant factors in making decisions due to (1) the need to use complex database procedures; (2) abortion of an operation because of the use of inefficient procedures; or (3) failure to recognize that the information was available. None of the subjects in the menu selection group excluded the consideration of a factor in decision making. Significant difference was found at the  $\alpha = .1$  level using the Mann-Whitney rank-sum test ( $R_{xcalc.} = 51, n = 6$ ).

### **Question 3: Computers as Cognitive Tools**

Is a command language interface or menu selection interface a more effective tool in assisting problem solving?

To examine the quality of subjects' problem solving, the nature and numbers of factors that were considered in their problem-solving processes were recorded. Those factors that could be verified by organizing data in the database files (such as

number of customers, number of transactions, etc.) and other factors that the subjects mentioned but had no data available to verify (such as why John has Missouri in his territory) were also recorded.

To answer research question number 3, both the quality and quantity of factors all subjects considered were examined and discussed. In addition, an analysis of the factors skipped, the use of wasteful commands (commands that served no purpose), inefficient procedures, and incorrect procedures are discussed in combination with the quality of factors checked to reveal the qualitative differences on the overall problem-solving processes. Table 4 lists the number of factors verified and other factors considered by subjects.

The Mann-Whitney rank-sum tests revealed that no differences existed between groups in terms of the number of verifiable factors checked and the number of other factors considered at the  $\alpha = .1$  level ( $R_{xcalc.} = 33.5, n = 6$  for both the verifiable factor variable and the other factor variable). A close examination of the verified factors revealed that fewer subjects in the command language group used large files. As a result, fewer subjects in the command language group had the chance to commit inefficient procedures. Nevertheless, subjects in the command language group used a considerably higher number of inefficient procedures than subjects in the menu selection group (11 to 6). An overall examination of the occurrences of typographic errors and syntax

**Table 4: Number of Factors Verified and Other Factors Considered by Subjects**

Subject		Factors verified	Other Factors Mentioned
Command Language	III.1	5	5
	III.2	4	3
	III.3	4	0
	III.4	5	10
	III.5	6	3
	III.6	2	4
Menu Selection	IV.1	5	2
	IV.2	4	6
	IV.3	6	5
	IV.4	5	8
	IV.5	4	4
	IV.6	7	5

errors, the use of wasteful commands, and the use of inefficient and incorrect procedures suggested that subjects in the command language group appeared to be less “on the task.” The difference in the interface appeared to affect the focus of subjects’ attention. The findings on the errors made and the wasteful and incorrect procedures used suggested that computer problems occupied more of subjects’ attention in the command language group than in the menu selection group.

## **Conclusions**

This section describes the conclusions in relation to the three research questions: problem-solving method, computer problems, and computers as cognitive tools.

### ***Problem-Solving Method***

Subjects used a subgoal analysis strategy in solving the ill-structured business problem. The problem was decomposed into smaller subproblems, and then subproblems were sequentially solved. When computer problems were encountered, however, subjects used working backward methods to trace the source of the problem. This confirmed that when problems are complex, problem solvers decompose the problem into simpler subproblems and multiple problem-solving strategies are combined to solve problems (Nickerson, 1994). The research also revealed that if subproblems were not solved immediately, the subjects were likely to forget about solving the subproblems. This evidence is consistent with the literature review, which indicated that humans have limited working memory (Anderson, 1985; Miller, 1956; Simon, 1974).

Subjects in both the command language group and the menu selection group used the same problem-solving methods and demonstrated the same problem-solving characteristics. The reason could be that the use of computers as tools did not come into play until subjects started the process of searching for solutions to solve subproblems. Since the steps of identifying subproblems and searching for solutions could be overlapped or simultaneous, the interface affected only the quality and complexity of the identified subproblems.

### ***Computer Problems***

It was clear that software errors affected problem-solving processes and the decisions made. A software error can be an unsolvable computer problem, and the user is not at fault. This caused much confusion and frustration after a few unsuccessful attempts to locate the error.

When software errors (bugs in the software) prevented a subject from solving a subproblem, the subject examined the syntax used in the procedures and re-tried them. After several attempts, the subject decided to abort the operation and found an alternative procedure, which provided an approximate indication for making a decision.

Undetected errors in answers severely affected the decisions made. In using a computer application for problem solving, particularly with a database application, the computer might accept inappropriate syntax and respond with incorrect answers without warning; it is up to the user to judge if the answers given are without errors.

In solving ill-structured business problems, the ability to detect errors in the answers obtained by any means is essential to making the right decision. All but one subject used cross-references to confirm that the answers obtained were correct. The subject who did not detect errors in computer results made unreasonable decisions based upon the incorrect answers.

### ***Computers as Cognitive Tools***

Findings revealed that subjects in the command language group were less likely to use complex procedures to solve subproblems, and as a result, subjects in this group were more likely to skip the consideration of relevant factors for decision making. Only two subjects in the command language group created relations between files and used large files. On the contrary, subjects in the menu selection group were more likely to use large files and create relations for complex procedures. The differences found in the use of wasteful commands, inefficient procedures, and incorrect procedures also indicated that the command language interface distracted from the problem-solving processes by requiring complicated steps and difficult-to-remember syntax. Consequently,

these detailed, rule-based procedural requirements in using the interface prevented the subjects from examining the data freely and more comprehensively. This is an example of an ineffective interface that "encumbers" users (Shneiderman, 1998). On the other hand, the menu selection interface enabled subjects to link files more often and gather information from a more detailed and complex perspective. This confirmed that microcomputers can facilitate higher-order thinking (Pea, 1986; Perkins, 1985; Schoenfeld, 1988).

Subjects in the command language group and subjects in the menu selection group received similar education on business subjects and had much the same working experience in business. These similarities might explain why the difference in the interfaces used did not affect the quantity of the factors considered by subjects; however, it did affect the quality of the factors considered.

## **Implications and Recommendations**

From the study results, three areas have implications for educational practice. The description of these implications is followed by recommendations for further research or for instruction in problem solving.

### **Problem-solving Method**

This research revealed an interesting theme: students used subgoal analysis strategy to solve ill-structured business problems although they were not taught to use the method. Throughout the 10-week instruction, the use of the database applications was demonstrated and students were given business problems and data in various levels of complexity and size, but problem-solving methods per se were not part of the course content. However, all subjects used the same method to solve the business problem.

*Further research is needed to investigate the most appropriate problem-solving methods when solving ill-structured business problems. Students should be taught various problem-solving methods, and then experimental research should be conducted to investigate the relationship between the problem-*

*solving methods used and the quality of the solution in solving ill-structured business problems.*

### **Choice of Interface**

Another area with important implications for education is the area of using microcomputers in enhancing students' mental functioning. The results showed that subjects in the menu selection group were able to examine data more freely and ask questions in a more comprehensive fashion. The differences found in the insufficient procedural knowledge possessed and the number of factors excluded from consideration indicate that the command language interface hindered subjects' intentions in exploring data, gathering relevant information, and examining data from a higher-level perspective. Subjects using this interface seemed to be restricted by the syntax requirements and were unable to free themselves to examine data from various perspectives. Although command language is no longer a commonly used interface, the principles revealed can assist instructors to select an appropriate computer interface.

*It is recommended that when integrating microcomputer application in teaching higher-order thinking skills, the interface selected should allow students to communicate intuitively with the computer so that it can facilitate exploration and problem solving.*

### **Error Detection**

This study indicated that software errors caused confusions and frustrations; however, it is beyond the teacher's control to guarantee "bug-free" software for instruction. Therefore, teachers need to teach students to recognize software errors. Students need to realize that commercial software may have errors and learn how to deal with the error problems.

Execution errors substantially affected the quality of decisions. The accuracy of information is the foundation of sound decisions. With large amounts of data, it is difficult (if not impossible) to manually perform the operation to confirm the answers obtained from the computer. The findings of this study showed that undetected errors in results led to unreasonable decisions. Therefore, it

is essential to help students develop strategies to check the correctness of execution results. As students are assisted in developing strategies in detecting errors, they may also simultaneously improve their awareness of the accuracy of computer answers.

*It is recommended that instructional approaches be developed that teach students to detect errors and make judgments on the usefulness of information gathered.*

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