Assessing the Knowledge Structure of Information Systems Learners in Experience-Based Learning

Weiqi Li
School of Management
University of Michigan - Flint
Flint, MI 48502, USA
weli@umflint.edu

Hanwen Zhang
Ping Li
FangWei Company
Nanjing, China
sdzhang@jionline.com

ABSTRACT

The fundamental goal of this study was to investigate the effects of an experience-based learning environment on information systems students' knowledge structure. The learning environment was structured in a way consistent with the problem solving approaches used by information systems experts. The focus of this paper is to report the assessment of the knowledge structure of the information systems learners in a self-managed and experience-based learning environment. The key issue here is whether information systems students can develop the necessary cognitive skills in such learning environment. To assess the knowledge structure of the learners, this study designed three research instruments that included a declarative-knowledge test, a problem-solving task, and a similarity-judgment task. The analysis results suggested that the learning outcome in this experience-based learning environment was very positive. The environment that imposed an expert-like organization both on information gathering and on problem solving activities resulted in improved problem-solving skills. The learners mastered the necessary declarative knowledge, as well as developed domain-specific basic skill and strategies.

Keywords: knowledge structure assessment, learning environment, experience-based learning

1. INTRODUCTION

The Information systems (IS) professionals are required to display a wide range of knowledge, skills and abilities, and most of these skills tend to be cognitive in nature (Blanton, LeRouge & Nohelty, 2000; Eierman & Schultz, 1995; Lee, Trauth & Farwell, 1995; Prabhaker, Litecky & Arnett, 1996; Yip & Ghafarian, 2000). Thus, IS graduates should be able to (1) understand how to acquire knowledge for problem solving, (2) understand how to apply the theory to practice, (3) have critical thinking and problem-solving ability, and (4) communicate effectively. They must be equipped with the academic knowledge and the practical skill for problem solving.

Becoming an IS expert takes substantial time and effort. This raises an interesting question: Is becoming an IS expert simply a function of time and effort, or can the path toward IS expertise be made more efficient? One of the challenges to the traditional view about the acquisition of knowledge is the view that knowledge can be constructed by the rational individuals. For example, problem-solving ability can be acquired in two ways (Lancaster & Kolodner, 1988). Individuals can obtain the knowledge required for certain problem solving through direct instruction. In this way, knowledge is merely acquired by passive absorption or by simple transfer from a teacher to a student. This type of individuals is called *students* in this paper. On the other hand, individuals can also derive the knowledge directly from their experiences with problems in the domain of interest. These individuals are called *learners* in this paper. Learners actively construct their own set of understanding during their learning process.

An educational philosophy that encourages active and meaningful learning is the constructivist philosophy. This philosophy believes that learning is a structuring process in which knowledge is derived from experience and is characterized by its viability in the natural world (Ausubel, 1963; Barba & Rubba, 1992; Driver & Oldham, 1986). Anderson (1982, 1993) proposed that individuals progress from possessing declarative knowledge to possessing procedural knowledge as they acquire cognitive skills. Since cognitive skill acquisition is an important part of IS education, assessing IS students on both declarative and procedural knowledge within skill domains is of extreme importance from a pedagogical point of view. Especially, when IS students study in a constructive learning environment, understanding their knowledge structure obviously is particularly important to the educators of IS professionals. The knowledge structure dictates what are or are not known by the learners, and will yield the most important information about their knowledge state.

The fundamental goal of this study is to investigate the effects of an experience-based learning environment on IS students' knowledge structure. The experience-based learning environment was structured in a way consistent with the problem solving approaches used by IS experts. This empirical study was a part of a project for restructuring the IS curriculum at a large university (Li & Zhang, 2001). The purpose of the restructuring project was to present IS students not only with the prerequisite mandatory knowledge of the available problem-solving techniques, but more importantly to equip IS students with the skills to use the vast collections of knowledge that are now readily available from a variety of sources, and to expand their ability to frame new problems and to think creatively. There are hosts of important educational issues that emerge in the debate about the method of knowledge acquisition in such learning environment. One of important questions is: "Is the structure of knowledge in learners parallel to the one in students?" The key issue in this study was whether IS students could develop the necessary cognitive skills through an experience-based constructive learning environment. In other words, this study tried to answer the question: "Can we make distinction between the knowledge structure constructed by learners through their own learning process and the knowledge structure obtained by students from teachers?" When learning in a constructive environment, it is equally important for the learners to master the bodies of knowledge that the scientific community regards as currently warranted. The learners would not be regarded as being scientifically educated if they did not know the publicly-recognized "funded wisdom" (Dewey, 1956).

The focus of this paper was to report the assessment of the knowledge structure of the learners. This study investigated the acquisition of a complex skill – information systems development, by a group of IS students in a self-managed and experience-based learning environment. To assess the knowledge structure of the learners, this study designed three research instruments that included a declarative-knowledge test, a problem-solving task, and a similarity-judgment task. The declarative-knowledge test was to examine whether the learners mastered basic concepts, definitions, and principles (declarative knowledge) in IS development. The problem-solving task was to measure the learners' performance on problem solving process (procedural knowledge). The similarity-judgment task was to assess the domain-general skills in the learners. In these assessments, the effectiveness of learning in the learners was compared with that of a sample of students who took traditional IS development courses in the same academic year.

The paper is organized as follows. Section 2 discusses the knowledge structure; section 3 describes the experiment methodology; section 4 summarizes the empirical analyses on the three assessments, and the final section concludes this paper. Details on the design of these assessment instruments will be reported in later papers.

2. THE KNOWLEDGE STRUCTURE

The knowledge structure is composed of knowledge items, which can be the comprehension of conceptual information as well as the ability to perform some task (Desmarais et al., 1988; Johnson, 1996). In simplistic terms, the learning of conceptual information is referred as *declarative knowledge* and the learning of skills as *procedural knowledge*. Declarative knowledge is the knowledge of facts, theories, events and objects, in a form that can be manipulated, decomposed and analyzed by its users. It is static, acquired quickly and modified easily. Procedural knowledge is the knowledge of how to do things and includes motor skills, cognitive skills and cognitive strategies. It is dynamic and acquired slowly. Individuals must practice the skills to know how their knowledge works and to understand how their strategies are implemented.

Declarative knowledge and procedural knowledge differ in the type of advantages that they have for the development of knowledge (Desmarais et al., 1988; Doignon & Falmagne, 1985; Johnson, 1996). Declarative knowledge knows that something is the case. Declarative knowledge gives the user the ability to use knowledge in a way that could not be foreseen. Procedural knowledge is the knowledge of "how-to-do". It has the advantage of being able to automate skills and makes knowledge faster to use. Procedural knowledge operates on information to transform it. People need declarative knowledge to create procedural knowledge and need procedural knowledge to enable more declarative knowledge to be generated. One cannot exist without the other. People need both so knowledge can go on being effectively used and created.

Cognitive skill acquisition theory (Anderson, 1982 & 1993; Blanton, LeRouge & Nohelty, 2000) proposes that cognitive skills are acquired through a process of moving from declarative knowledge to procedural knowledge. When an individual acquires a new cognitive skill, declarative knowledge in the form of facts and examples is stored in memory. Examples consist of problems specific to the skill domain, as well as the steps taken to solve those problems. When a novice attempts to solve problems on his/her own, he/she searches for an analogous example. He/she then uses that example's solution to arrive at his/her own solution for the problem on which he/she is currently working. Obviously this initial mode of the problem-solving process is more tedious and requires more time than the problem-solving process demonstrated by an expert. As the problems are solved, the individual is able to compile this initial declarative knowledge into procedural knowledge. Because procedural knowledge consists of psychomotor or cognitive actions, it is difficult to clearly describe procedural knowledge in verbal or written form. Verbal or written descriptions should not be equated to the procedural knowledge they describe. Procedural knowledge depends on one's experience. People must acquire the procedural knowledge through experience in performing the skill (Blanton et al. 2000).

There are three categories of procedural knowledge (Johnson, 1996): (1) domain-specific basic skills that are related to how people rapidly or accurately complete a task; (2) domain-specific strategies that are concerned with how people organize their solution to overall problems. To do this people need to recognize the problem and then choose and apply appropriate actions; and (3) domain-general skills that are thought to underlay our ability to learn, think critically and reason effectively. They are useful across a wide variety of domains and far more general than the previous categories. They include classification, logic, assertion, arguments, etc. Procedural knowledge is prescriptive knowledge. It employs declarative knowledge for an action.

Learning is an interactive experience. Declarative and procedural aspects of knowledge interact and combine in the regulation of human learning (Johnson, 1996). In most domains of knowledge, the process through which one learns to become more expert is relatively constrained. People learn the basic concepts and simple methods before they learn the more complex ones. These constraints in learning reflect the cycle of knowledge development. Simple declarative knowledge provides the starting point for proceduralization. When people convert the declarative knowledge into procedural knowledge, they have the ability to discover new information and comprehend it into working memory where methods of elaboration increase the relationship between new and prior knowledge. Learning takes place when the new information becomes part of the knowledge network. If the new knowledge is elaborated and integrated, it becomes meaningful and useful. It then becomes prior knowledge that again is used in working memory (declarative knowledge) and can be retrieved or used to construct knowledge that has never been learned (procedural knowledge).

3. THE METHODOLOGY

The Subjects of this study were students in the IS curriculum at a large university during the 1999-2000 and 2000-2001 academic years, who had completed the first year IS courses and received a grade of B or better, and participated in this study on a voluntary basis. Seventy-two IS students were involved in the study. These students had already exposed to many introductory aspects of IS area, but they were certainly not yet IS expert. Clearly the goals of IS education in this stage are the those of advanced knowledge acquisition — learning beyond the introductory stage but before the achievement of practiced expertise that comes with massive experience. Students must attain a deeper understanding of content material, reason with it, and apply it flexibly in diverse contexts.

In the regular IS curriculum at the university, students usually took the Visual Basic (VB) Programming course, Database Management Systems course, and Systems Analysis and Design course during one academic year. Each course represents a relatively unique cognitive environment, with its own conceptual structure and methodological knowledge bases. The subjects were randomly divided into two groups of 36 subjects each. The "students" group, with other regular IS students, attended those three regular courses in which they were given lectures, individual assignments, group projects, and examinations.

The "learners" group participated an experimental course that was a combination of the three IS courses. The learners were provided with an e-book on the Web (see Figure 1), which contained the same contents as the textbooks used in the regular courses, but was represented in three different ways: Textbook, Concept Map and Example Map. The Textbook was following the original order of the textbooks, course by course and chapter by chapter, but removed all questions and exercises appearing at the end of each chapter. The Concept Map and Example Map were developed based on the cognitive flexibility theory (Bednar, Cunningham, Duffy & Perry, 1991; Bransford, Franks, Vye & Sherwood, 1989) and designed to develop insights and understandings of the application of information concepts, processes, and systems in an integrated way. Concept Map considered the interconnectedness and context dependency of knowledge in the three courses and arranged the concepts to represent interconnections across knowledge components. Example Map combined declarative and procedural information in an integrated framework. It provided 187 sets of examples, each under a given conceptual structure. The learners then had the

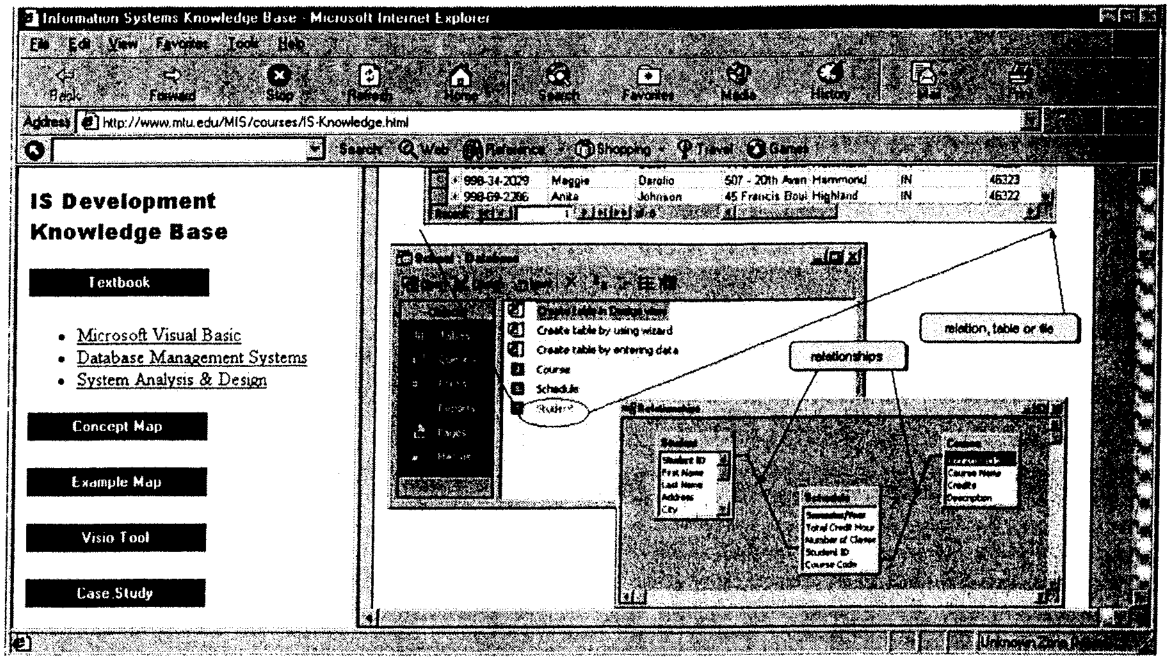

Figure 1. IS development knowledge base for the learners

option of viewing different examples in the application of a concept they chose to explore. The purpose of these two maps was to permit the learners to selectively examine the full range of uses of any selected basic concept across cases with different application features, and thus facilitate access to conceptual information in real-world contexts and foster an understanding of the different ways that a given concept has to be tailored to be practically relevant. Through this way, the learners were expected to learn the patterns of concept application.

This e-book also contained a data-mining mechanism that traced information retrieval activities and monitored the use of concepts and examples. The e-book was able to provide a rich record for analyzing when and how the learners access the information in the knowledge base.

Experience-based learning is learning strategy that uses problems as the starting point for learning and prepares students to be knowledgeable about the domain. Thus, this study provided the learners a list of real-world business application projects. Each project, containing one real-world business problem provided by a real-life small business, required the learners to develop an IS solution to the business problem. For example, one company asked for a system that could monitor and control a manufacturing process to ensure that the process was progressing on schedule and that costs were kept to a minimum. These business problems were ill-structured in nature. By *ill-structured* we not only mean that many concepts (interacting contextually) are pertinent in the typical case of knowledge application, and that their patterns of combination are inconsistent across case applications of the same nominal type (Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987), but also mean that the companies didn't provide specific requirements for their projects. The learners had to identify the objectives of the projects and define the information and operational requirements for the projects. The learners were expected to master necessary conceptual knowledge and develop high-order thinking and problem-solving skills through solving these business problems. At the end of academic year, a professional IS expert work with the company concerned to evaluate the project. The business that provided the problem would purchase the solution if the informational needs and operational requirements were met. One instructor was assigned to the learners group, working as a mentor, consultant and coordinator. The role of the instructor was to encourage participation, provide guidance, and assume the role of learner as well. The instructor was also responsible for structuring problem-solving activities for the learners to reflect his best understanding of how IS experts analyze and solve the problems. One of the authors of this paper, as an observer, participated many of learners' activities to see what processes were involved in their learning.

Before the experiment started, each subject took a pre-test that covered fundamental concepts of information technology. The result shown in Table 1 illustrates that there is no significant difference on the performance of the pre-test between the students and learners ($F(1,70)$ =

Table 1: Descriptive Statistics for Performance on Pre-Test

	Average	Standard Deviation	Median	Maximum	Minimum
Learners	71.08	15.63	74	94	42
Students	70.81	16.68	78	94	40

0.0053, $p \approx 0.9421$). At the end of academic year, each subject participated in three assessment sessions: Declarative-Knowledge Test session, Problem-Solving Task session, and Similarity-Judgment Task session. Next section reports the analysis results from these assessment sessions. The discussion also includes the author's observation about learners' learning process.

4. ASSESSMENT OF KNOWLEDGE STRUCTURE

4.1 Analysis I: Declarative-Knowledge Test

In this experiment, the learners and students studied in different learning environments. In the traditional instruction, the students acquired the body of conceptual knowledge from the instructor directly and practiced their skills through homework and group projects, while the learners were in an "unsupervised" learning environment and had to "discover" these concepts from their problem-solving experiences. It was concerned about whether these unsupervised learners mastered the body of conceptual knowledge that was represented in the experimental course. The learners might tend to learn the only knowledge that was needed to solve the given problems. In a problematic situation, if the learners could apply the interacting basic IS concepts that underlie the situation, their knowledge and skill would be improved. However, it might be difficult for the learners get to the basic IS concepts from the real-problem features, partly because of the great variability across cases in the way those concepts get instantiated.

However, research has demonstrated that novices tend to possess declarative knowledge and lack procedural knowledge, while experts possess both declarative and procedural knowledge (Anderson, 1983; Glaser & Bassok, 1989). In this study the learners assumed full responsibility for their learning. They were given real-world problems through which they were expected to develop higher-order thinking and problem-solving skills as well as necessary conceptual knowledge. It was expected that during their learning processes, the learners would experience the stages from novice to advanced learner. And at the advanced level they would solve the problems in an expert-like manner. During their problem-solving process, the learners must proceduralize declarative knowledge, i.e. transform declarative knowledge to procedural knowledge. If the problem-solving activities were designed properly, the learners should learn all necessary knowledge and skills. Thus, it was reasonable to hypothesize that there would be no significant difference between the learners and the students of declarative knowledge (H_0: $\mu_{learner} = \mu_{student}$; H_a: $\mu_{learner} \neq \mu_{student}$). In fact the learners might probably outperform the students, since the learners had more opportunities to develop procedural knowledge.

Development of the test began by surveying IS experts to determine the minimum level of knowledge and skills needed by a system developer to be able to design and develop IT systems on the job. To develop the survey, three standard textbooks on each subject (i.e. VB Programming, Database Management Systems, and System Analysis and Design) were consulted. A list of 180 items (60 on each subject) about definitions, concepts, terminology, and principles in designing and developing information systems were created. This list was then given to five IS experts. They were asked to consider the top 50 items on each subject that would be needed for an employee in an entry-level job to complete his common tasks in IS design and implementation.

It was found that 32 items on VB Programming, 45 items on System Analysis and Design, and 34 items on Database Management Systems were listed on all of five returned surveys. Based on the resulting list, the instrument was developed, which contained 111 multiple-choice-type declarative knowledge questions. The questions were presented via computers. Each computer randomly generated its own question set, thus no two question sets were in the same order. All subjects completed the test within the required 120 minutes.

The results are presented in Table 2. No significant differences were found between the performance of those learners and the students on the declarative-knowledge test ($F(1,70) = 0.0426$, $p \approx 0.8371$). It indicates that if a learning environment provides the learners sufficient learning content, necessary learning support, and properly-arranged problem solving activities, the learners can acquire the necessary conceptual knowledge.

Table 2: Descriptive Statistics for the Percentage Correct on Declarative-Knowledge Test

	Average	Standard Deviation	Median	Maximum	Minimum
Learners	79.32	8.90	82.89	95.50	61.26
Students	78.92	7.71	81.98	93.70	65.77

In fact, at the beginning of the experiment, like the students, all of the learners seemed to possess little knowledge about IS design and development. However, the learners understood that they were in self-directed learning situation. They had to work independently or in a group environment to solve a real-world problem logically and systematically. It was observed that their learning started with several brainstorming meetings. In these meetings, accompanied by opportunistic guidance by the instructor, these novices discussed their learning situation, worked out learning strategies, and structured problem-solving activities that reflected their best understanding of how solving the problems. They also decided to work in a group and formed nine groups, ranging from three to five people. Each group selected one project.

This study found that some of new knowledge was obtained through individual study, e.g. reading the e-book and searching for information online. It was observed that often a new knowledge began with an individual, and the individual made his/her personal knowledge available to other members in the group meetings. These group meetings were a knowledge intensive activity in which an individual not only shared personal knowledge with others, but also gained knowledge of an ability to implement strategies on the task from peer's experience. Learners interacted primarily for the purpose of information collection, and for most conversations, the aim of each participant was to take new information about the focal object or situation into his/her context. Sometimes, an individual came up with a few of arguments of his/her own, but during interaction he/she collected novel arguments and shifted his/her initial opinions. The overlapping portions that the participants shared in the contextual situations became larger and larger. This knowledge-sharing process resulted in organizational amplification and exponential growth of working knowledge.

It was also observed that, in the initial stage of the learning, the novice learners were primarily focussed on acquiring the necessary organization of knowledge and skills from the Textbook part of the e-book to build their knowledge base. They soon switched to the Concept Map and Examples Map to obtain necessary knowledge. They also realized the informational richness of the Internet. They assembled knowledge from different conceptual and precedent case sources to adaptively fit the situation at hand. Based on the result of the datamining in the e-book, this study found that the meaning of a concept was intimately connected to its patterns of use. The uses of the same concept had a complex and irregular distribution (i.e., concept instantiation was non-routine), reflecting the characteristics of ill-structuredness of the problems. In the complex and ill-structured problem domain, concepts were not treated by the learners as separate "chapters". Many alternative paths were established to get from one part of the overall knowledge base to any other part of the knowledge base.

The learners also benefited from group collaboration. During group meetings, a learner listened to other member's explanations of how to solve certain problems. He/she then added these explanations into his/her knowledge base. The learner sometimes realized that he/she did not know a specific piece of knowledge that was needed to solve the current problem. To find the missing knowledge, he/she would consult a reference source such as the e-book or the Internet, a more experienced peer, or an outside expert such as the instructor. The information obtained was then incorporated into his/her knowledge base and was available for use in later problem solving. The learners also learned more when they explained their ideas to other members.

It was observed that, in the initial stage, the learners were primarily engaged in adding new information to their knowledge bases; but in the later stage, they engaged in yet another type of learning: refining the knowledge base. They already knew most of the information needed to successfully solve the problems. Each time after modifying the design, or removing a bug from the program, they refined their knowledge base. In this type of learning process, a new conceptual knowledge had been taking two distinct roles. It provided a starting point for the next problem-solving session, and it became a part of the generative knowledge base for the individual learner.

This study also found that, in the early stage of learning, the learners were rank novices; and their knowledges were unorganized, scattered, and sometimes incorrect. They didn't know enough to be able to learn exclusively from their own problem-solving experiences. To them, the experience of trying to learn something by themselves seemed to be so overwhelming that learning might take a long time. At this stage, the instructor played critical role in motivating and guiding the learners. In the later learning stage, the learners had a better organization on their knowledge and some misconceptions had been corrected. They became more experienced and advanced learners, and had a much more complete knowledge base. These observations are consistent with the result of the declarative-knowledge test. It is apparent that declarative and procedural aspects of knowledge interact and combine in the regulation of human learning.

4.2 Analysis II: Problem-Solving Task

The domain of IS development is knowledge-rich and both depth of knowledge and the ability to use it are critical in solving problems. To measure the difference between the learners and students in problem-solving ability, this study constructed a problem-solving task. The task contained seven small business application problems, with increasing complexity. The subjects were working on computers to implement their solutions to these problems. No time limit was set. As reported in the Analysis I, the learners and students seemed to possess the same type of conceptual knowledge structure. However, problem-solving ability requires a fair amount of expertise on the part of the problem solver. The students, having learned how to deal with IS problems in classroom instruction and computer lab, were primarily focussed on acquiring the necessary knowledge and skill to complete homework and pass the examinations. In contrast, the learners, having engaged in a problem-solving situation, primarily focussed on acquiring the necessary knowledge and skills to solve the real-world problems. Their information resource was not confined to the textbook and computer lab, as the real-world working setting added to the variety and flexibility of learning opportunities. They had the opportunity for contextually meaningful experience through which they could set up their own learning goals, raise their own questions, search for information they wanted, and construct their own problem-solving strategies. It was believed that this kind of problem-based learning experience could promote developing problem-solving skills as well as helping learners to acquire the necessary knowledge and skills (Biggs, 1999; Boud & Feletti, 1997). Thus, this study hypothesized that the learners would have better performance on the problem-solving task than the students (H_0: $\mu_{learner} = \mu_{student}$; H_a: $\mu_{learner} > \mu_{student}$), and they would be more likely to solve problems in a way consistent with the problem solving approaches used by experts.

The completed tasks were graded independently by two professors. A score for each subject was determined by averaging the two scores given by the graders. The result is shown in Table 3. The difference in the problem-solving performance is statistically significant ($F(1,70) = 39.2925$, $p < 0.0001$). The learners also took shorter average time to complete their tasks.

It is not really a surprising result. It suggests that, the better performance for the learners was primarily due to practicing problem solving in a real-world context as well as due to performing real-world tasks. This type of learning environment enabled the learners to become active participants in the learning process, as opposed to passive recipients of information. The learners derived knowledge from their problem-solving experience and tested its viability in the real world. This result can also be understood by observing how examples were used by the learners and the students during problem solving. The students tended to follow the example verbatim, coping each solution line over to the problem, while the learners tried to solve the problem themselves, but referred to the example when they got stuck or wanted to check a step. Moreover, comparing to the students, the learners referred less often to the examples while solving problems, and they read less of the examples each time they referred to them. It seemed that the learners acquired procedural competence by storing the derivations of problem solutions and using them as analogs to guide their search for solutions to novel problems.

A prerequisite to handling real-world problems is the ability to manipulate an arsenal of problem-solving techniques that have been developed for a variety of conditions. These three regular IS courses were devoted to algorithms for problem solving and each presented an array of individual techniques. In the rush to present problem-solving techniques, each course was typically offered independently, thereby overlooking potentially important synergies between different procedures. It was tempting for students to simply look up an algorithm as they would look up recipe for a cake. When they found a solution to a problem, it was also tempting to quit. After all, the problem was solved. But this natural tendency forewent creativity; it didn't afford students the possibility of being ingenious. Instead, it forced students to fit the problem into the constraints of a particular algorithm in a certain chapter or course. Better solutions to real-world problems can often be obtained by usefully hybridizing different approaches. Effective problem solving requires more than knowledge of algorithms; it requires a devotion to determining the best combination of approaches that addresses the purpose to be achieved within the available resources. The students were taught to decompose a problem into smaller and simpler parts and treat them individually. They were spoon fed the solutions to problems, course by course, and chapter by chapter. Each chapter explained particular techniques and illustrated their applications with various examples. The problem and its solution in these chapters were By contrast, the learners in this study were trained to think about how to frame and solve complex real-world problems. They were able to internalize the approaches implicit in the problem solving, since they had way to gauge whether or not they were using the strategy and techniques appropriately. The learners learned how to organize their cognitive structures into more integrated patterns through examining the conceptual, relational

Table 3: Descriptive Statistics for Problem-Solving Performance

	Average	Standard Deviation	Median	Maximum	Minimum	Average Time (min.)
Learners	64.39	7.35	66	78	54	87
Students	48.97	12.79	53	67	25	103

and hierarchical nature of the knowledge with which they were working. In this way, the metacognitive learning strategy was promoted.

4.3 Analysis III: Similarity-Judgment Task

Novices and experts store and use domain-specific knowledge in distinctly different ways (Chase & Simon, 1973; Chi, Feltovich & Glaser, 1981; Egan & Schwartz, 1979; Kochevar & Johnson, 1988; Larkin, McDermott, Simon & Simon, 1980; Mestre & Gerace, 1986). In the problem solving process, experts perform by selecting information specifying the "deep structure" of the domain (i.e. the principles and heuristics that could be applied to solve that problem), while novices are only capable of accessing the "surface feature" (i.e. objects and descriptor terms in the problem). Since novices do not access task relevant feature relationships, they must mentally combine surface level information or "deduce" task solution. To the extent that the novice's reasoning consists of invoking processes functionally similar to environmental structures, the novice will be able to perform the task. However, experts can behave intuitively because they can access relational information from the environment. The distinction between expert and novice performance is paralleled by the nature of the knowledge underlying each.

One way to assess whether an individual follows an expert-like approach to problem solving is the similarity-judgment method in which the subject is to decide which of two comparison problem can solved most similarly to a third model problem (Hardiman, Dufresne & Mestre, 1987). To investigate whether the learners were more likely to focus on deep structure similarity as a basis for categorization, this study designed a similarity-judgment task that contained 16 task items. Each task item was composed of three simple business problems. For each item, one of the three problems was identified as the model problem, while the other two were the comparison problems. The comparison problems were paired such that only one of the two comparison problems matched the model problem in deep structure. A comparison problem can be designed that matches the model problem in (1) surface features (denoted by S), meaning that the objects and description on both problems are similar; (2) deep structure (denoted by D), meaning that the underlying principle or procedure that could be applied to solve both problems is the same; (3) both surface features and deep structure (denoted by SD); or (4) neither surface nor deep structure (denoted by N). This study designed four S-D comparison problem pairs, four S-SD pairs, four N-D pairs, and four N-SD pairs. The task protocol was tested in advance by two professors in the knowledge domain.

It was believed that the experience-based learning strategy and constructive learning environment usually encourages mastery of domain-general skills that could be used in other domains. Thus, this study hypothesized that in the similarity-judgment task the learners would be more likely to focus on deep structure than traditional students would (H_0: $\mu_{learner} = \mu_{student}$; H_a: $\mu_{learner} > \mu_{student}$). The similarity-judgment task was presented via computers. The task items were presented in random order, with no time limit to respond. The subjects were told to read carefully the model problem and two comparison problems, and indicate which of the two comparison problems they believed "would be solved most similarly to the model problem" by clicking one of two buttons. All subjects completed the task within 75 minutes.

The focal question was whether the experience-based learning strategy in a real-world working environment would promote a shift toward reliance on deep structure rather than on surface features. The analysis result shown in Table 4 provided affirmative response to this question. There were significant differences in the performance between the learners and students on the similarity-judgment task ($F(1, 70) = 13.2380$, $p \approx 0.0005$).

Learning about a domain provides the knowledge to organize and encode the features of a problem important to the structure of its solution, so that it can be retrieved later in appropriate circumstances. This study observed that in the early stage of learning, the knowledge base of both the students and learners was less structured and had fewer interconnections. When solving problems, they focused on surface feature such as descriptor terms as reminders, and then looked for the right chapter or concept that could provide an answer. But in the late stage of the learning, the learners and students stored and used their knowledge in different ways. The learners tended to store information in hierarchically structured clusters related by underlying principles or concepts. When attempting to solve a problem, they initially focused on the principles and heuristics that could be applied to solve that problem. In contrast, the students still relied on surface features as reminders. They focused on the examples that were plausible scenarios for the problem, but were unrelated to the structure of the solution.

Table 4: Descriptive Statistics for the Percentage Correct on Similarity-Judgment Task

	Average	Standard Deviation	Median	Maximum	Minimum
Learners	68.71	8.59	68.75	87.50	56.25
Students	60.26	10.95	62.50	81.25	43.75

One explanation of this difference might be the fact that the traditional instruction class didn't provide enough opportunities to let the students identify important features of the problem based on the problem solving goals. Comparing to the learners' problem-solving situation, the students always could find the solutions to the "simple problems" from the textbooks. They might never be forced to think about whether or not the problems they were facing should be solved with the techniques just described in the chapter. They learned how to apply particular methods to particular problems, but only within the context of knowing that these exact methods ought to be perfect for these particular problems. They were constrained to concentrate on the problems using the information learned in that course or chapter. They might never learn how to think about solving problems in general. Thus, in a problem-solving situation the students would be more often guided by surface characteristics than by structural characteristics.

On the learners' side, the real-world problems were much complex. The learners realized that problems were their possessions and they were purpose-driven decision-makers. When searching for a solution to a problem, they looked for the knowledge that enable effective problem solving, then tried to understand the rational of the problem-solving procedures, and finally decided what knowledge to apply to a particular state. When they were determining how best to solve the problem, the learners had to consider it in the context of "how the user's actions affect the possible solution" and "what comes next". In order to make proper judgments in problem solving, they had to know what each particular problem-solving method assumes, its informational or operational requirements, its reliability, and so forth. The learners took a lot of time and effort to obtain these types of information. It was not possible to simply peruse the textbook and obtain something that seems like it might fit the problem at hand. The learners were both physically and mentally active to understand the structure of each solution and its association with the problem at hand.

5. CONCLUSIONS

The analysis results suggest that the learning outcome in this experience-based constructive learning environment was very positive. The environment that impose an expert-like organization both on information and on problem solving activities result in improved problem solving skills. The learners not only mastered the necessary declarative knowledge, but also developed domain-specific basic skill and strategies. In these learners, the domain-specific basic skills seemed to become automated and directly produced behavior. The learners seemed to be able to organize their solutions to overall problems. When solving problems, they were able to maintain conscious control and use declarative cues. These were evidenced in the problem-solving task assessment. The students were far more ready to do the problem-solving task than the learners. Some students looked anxious and asked a lot of questions before they started. Meanwhile, the learners started the task very quickly and with a degree of confidence. The students completed the task much slower than the learners did. The learners seemed to stay a lot calmer than the students, even when some of them didn't find the right way to begin with. They took time to think rather than ask for hints. They seemed to have very little emotion attached to the task. In contrast, the students had a different reaction. They were often confused or worried about aspects of the task, asked for hints when being stuck, and felt relieved rather than happy when a problem was solved.

The informal feedback of the learners was also favorable. They found that the learning activities, such as teamwork, real-world problems solving, decision making, and critical thinking were more meaningful than the traditional approach of lecturing and taking multiple choice or short answer tests. Here are some quotes from the learners: "I learned IS design and development without much memorizing", "The project was no small challenging but had a lot of fun", "I enjoyed working in a team like this", "When I finished the project, I felt that I already became an IS expert." The learners strongly felt the relevance of knowledge and skills to their career and lives. Learners became more and more engaged in their learning. It was in fact all about learning motivation.

In the increasing complexity and magnitude of resources needed to make meaningful knowledge change, people have to assume individual responsibility for the learning process: asking relevant questions, pursuing needed knowledge, evaluating learning experiences, and so forth. Learning is moving toward a theme of self-responsibility and self-efficacy and people is taking more active role in the learning process to construct their knowledge base. Basic knowledge and skills are learned not in isolation, but in the course of undertaking, often on a collaborative basis, higher-level real-world tasks whose execution requires the integration of a number of different knowledge and skills. People access information resources at that point in time when they actually become useful in executing the particular tasks at hand. Continued experience with real-world problem solving can lead to long-term learning and provide an activity where people are involved in developing problem-solving and critical thinking skills as well as knowledge of fundamental concepts necessary for application. This problem-solving process in fact ensures that there are some meaningful connections between new and prior knowledge, theory and application, and school and society. As educators of IS professionals, it is no longer enough to teach our students whole screeds of declarative knowledge and expect them to be able to apply the knowledge in a variety of situations. More importantly it is necessary to equip our students with the skills to use the vast collections of knowledge. If students do not develop these skills, then they will not succeed in getting the most from their learning. Technology has enabled us with the ability to affect the environment to such an extent that the decisions we make today may have irrevocable future consequences. Technology also continues to expand the number of people we interact with and who are affected. By consequence, problem solving grows increasingly more difficult because there are more factors to be considered. As the interactions of these factors become ever more frequent and complex, knowledge for handling real-world problems become imperative. There is a great deal to be gained from problem-solving experiences.

It should be noted that encouraging the learners to move from a rote learning mentality to a meaningful learning mentality was not without some mental resistance. During the problem solving process, the learners realized that the real-world was opposite to something taught in classroom in which irregular was treated as regular, the nonroutine as routine, the disorderly as orderly, and the dynamic as static. They felt that the complex concepts and phenomena were inadequately covered by the regular courses. The richness of interconnection in conceptual structures and knowledge application could only be derivable from active exploration and involvement in real-world problem solving. In an ill-structured domain like IS development, knowledge could not just be handed to the students. Active learner involvement in advanced knowledge acquisition was particularly important. Early in learning, however, the learners seemed incapable of learning without guidance. Aids must be provided to help the learners manage the added complexity that came with the nature of ill-structuredness. Much of the learning at the early stage depended on the instructor to give an explanation of the procedures for solving a problem and the knowledge needed to solve it. With expert guidance and various kinds of cognitive support by the instructor, the learners could explore the complex conceptual structure, learn how to encode the features of a problem and organize them into the structure of its solution. At the later stage, the learners were able to do more and more learning by themselves.

All nine projects were successfully completed, and seven were purchased by the companies. There is one final aspect to be considered in the learners' successful experience. Their success was rooted in luck. They were lucky to get full support from the companies' executive management. They were lucky to find the right users and get the users involved early and keep open lines of communication throughout the life of the project. Their success was also rooted in failure. A process of trial and error was necessary for learning to take place. When the learners started their project, the first thing they did was to create a top-down strategy by understanding the "big picture" and breaking the project into manageable parts and then setting a time limit on project milestones. Roles and responsibilities for each member of the project team were clearly defined. The learners focused on smaller tasks with shorter timelines and less complex. Each task had a clear statement of requirements and a set of objects. The ability to accomplish smaller goals would lead to the ability to handle the larger projects. A shorter timeline placed an emphasis on the processes of design, testing and implementation. Working in small tasks was not only easier and cost effective but also was an excellent platform for making mistakes. A failure in one small task was easily identified, evaluated, and repaired. Failure at this level increased the overall quality of the projects. The learners began with failure and learned to evaluate it. The learners involved in an iterative process of designing, developing prototype, testing, correcting mistakes, and deploying small elements. One learner commented on her experience like this: "We were often frustrated when something didn't work. But we learned to succeed from our mistakes. Out of failure we gained knowledge. I think that failure really begets the knowledge."

Of curse, this study has several limitations. First, the students participated in the experience-based, self-directed learning on a voluntary basis and received no monetary incentives for their participation but with possible substantial monetary rewards for their performance on the project. Thus, these individuals might be a special group of students who were highly-motivated and hard-working people and willing to take the responsibility on their learning. They might have different personalities, psychological conditions, cognitive abilities, and learning styles from the other students. These important and sensitive factors were not considered in this study. Secondly, in this study the learners worked in a group environment where social interaction was involved. This study found that information sharing through social interaction led to better performance in learners. The knowledge structure was socially shaped. But in reality, when individuals study in a self-managed learning environment, some of them may have to learn individually and independently. They may have to build up conceptual structures for themselves. When a learner is in a non-interactive social environment, the experience-based learning setting may have different effect on personal learning and lead to different performance at both low and high experience levels. Thus, further research is required that would extend the study to other environmental conditions in order to ensure the generalisability of the present findings.

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AUTHOR BIOGRAPHIES

Weiqi Li received the B.S. degree in mechanical engineering in 1982 from Nanjing University of Aeronautics and Astronautics, China; the B.A. degree in international trade in 1986 from University of International Business and Economics, China; the M.B.A., M.S. in computer science, and Ph.D. in management information system from University of Mississippi in 1994, 1996, and 1998, respectively. He served as assistant professor in the School of Business at Michigan Technological University from 1999 to 2001. In 2001 he joined the faculty of the School of Management of the University of Michigan – Flint, where he currently is assistant professor of Management Information System. His research interests include machine learning, heuristics for the combinatorial optimization problems, and e-learning.

Hanwen Zhang received the B.S. degree in electronics from Nanjing University of Science and Technology in 1987, the M.S. degree in computer science from Mississippi State University in 1994, and the Ph.D degree in educational technology from University of Northern Colorado in 1997. His research interests include educational technology, e-learning, and knowledge management system. He found FangWei Co. in 2002 to provide e-learning products and service in market.

Ping Li received the B.A. degree in education from Nanjing Normal University in 1986, the M.A. degree in educational technology from San Diego State University in 1991, and the Ph.D degree in instructional technology from University of Tennessee in 1995. Her research interests concern e-learning and knowledge assessment. She recently joined FangWei Co. for designing products and services for knowledge assessments.