Real-World Problem Solving as a Means of Promoting IS Expertise

Weiqi Li, University of Michigan-Flint, United States of America
Hanwen Zhang, Nanjing, China
Ping Li, Nanjing, China
Ming Li, Tongji University, China

Abstract: The fundamental goal of this study was to investigate the effects of an experience-based learning environment on information systems (IS) students' learning process, knowledge acquisition and knowledge structure. The learning environment was structured in a way consistent with the problem solving approaches used by IS experts. 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 from 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: Learning Environment, Knowledge Structure Assessment, Experience-Based Learning, Learning Technology

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 [6], [22], [27], [28]. 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.

Problem-solving ability can be acquired in two ways [21]. 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. On the other hand, individuals can also derive the knowledge directly from their experiences with problems in the domain of interest. They 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 [3], [14]. Anderson [1], [2] suggests that people progress from possessing declarative knowledge to possessing procedural knowledge as they acquire cognitive skills. The fundamental goal of this study was to investigate the effects of an experience-based learning environment on IS students' learning process, knowledge acquisition and 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. 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.

This study investigated the acquisition of a complex skill — information systems development, by a group of IS students in a self-managed, experience-based learning environment. The focus of this paper is to report the settings of the experiment, observations on the students' learning process, and the assessment of the learners' knowledge structure. 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 learning process and knowledge structure obviously is particularly important to the educators of IS professionals.

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The paper is organized as follows. Section 2 describes the experiment setting, the learning environments for the students involved in this study, and observed learning behaviour; Section 3 discusses the knowledge structure and presents the empirical analyses on the assessment of knowledge structure for the study subjects, and the final discussion section concludes this paper.

The Learning Environment

The Experiment Setting

The subjects of this study were students in the IS curriculum at a large university in U.S.A. during the 1999-2000 and 2000-2001 academic years, who had completed the first-year IS courses and received grades of B and better. Seventy-two IS students were involved in the study. They participated on a voluntary basis. 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 Programming course, Database Management Systems course, and Systems Analysis and Design course during their second 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 students each. One group, called "students" group, with other regular IS students, attended those three regular IS courses in which they were given lectures, individual assignments, group projects, and examinations.

The other group, called "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 [4], [8] 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 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.

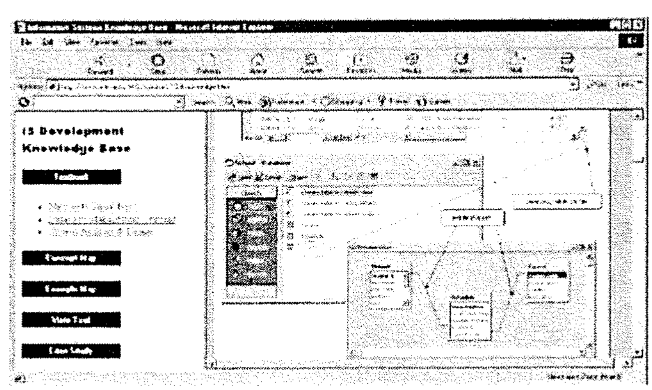

Figure 1: IS development knowledge base for the learners

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

One challenge in design of the learning environment in this study was to not only provide training on the technology but also to be able to do that from a business perspective. IS students need to be educated not only about the technology *per se*, but also about its applications in business. They should understand and aware of the role of IS in organizations, and truly understand the full potential of information technology.

Experience-based learning is a learning strategy that uses problems as the starting points for learning and prepares students to be knowledgeable about the domain. Thus, this study provided the learners a selected list of real-world business application projects. Each project, containing one real-world business application 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 [26], 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 information needs and operational requirements were met. One of the authors of this paper was assigned to the learners group, working as a mentor, consultant and coordinator. The role of the mentor was to encourage participation, provide guidance, and assume the role of learner as well. The mentor was also responsible for structuring problem-solving activities for the learners to reflect his best understanding of how IS experts analyse and solve the problems. Another author of this paper, as an observer, participated many of learners' activities to see what learning activities were involved in their learning processes, analysed the output of datamining in the e-book to understand how the learners obtain the declarative knowledge, and interviewed the learners to identify the learning process and factors involved in their learning experiences. The observer did not give any advice on learner's learning.

The Learning Environment

The basic goals of education are deceptively simple: the retention, understanding, and active use of knowledge and skills. The trouble with this trio of simple-sounding aspirations is that they have proven remarkable difficult to achieve [25].

Advances in learning theories and technologies enable us to create a range of educational environments, from traditional instruction environment to constructive learning environment in order to improve learning at all levels and for all learners. The central theme of learning environment is learning and thinking without limit. In the learning environment, knowledge is viewed as the development of increasingly complex cognitive structures and learning is viewed as the recursive process through which learners actively use current knowledge to construct new knowledge. Learning environment must provide the mechanism to support learners moving from an instructivist mode to a more constructivist one as they obtain more knowledge and develop attributes of information literacy, critical thinking, teamwork, problem solving and other higher-order, metacognitive skills.

In this experiment, the learners and students studied in different learning environments. Figure 2 illustrates the difference between students' learning environment and the learners' learning environment. The students studied in the traditional instruction environment, where the students acquired the body of conceptual knowledge from the instructor directly and practiced their skills through homework and group projects. In the students' learning environment, learning is general, passive, structured, and content-centered. This environment, using explicit and careful guidance, introduces the basic concepts and knowledge, and forms a mental map of various conceptual objects. Instructors control student's learning process.

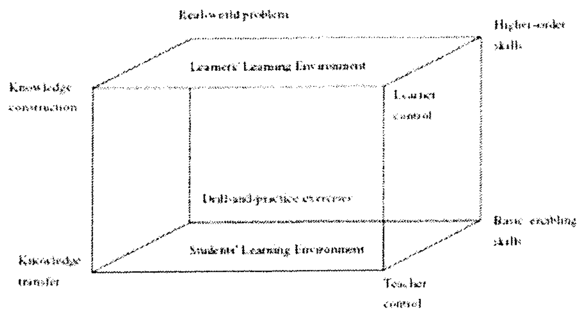

Figure 2: The difference between students' learning environment and learners' learning environment

On the other hand, the learners studied in a constructive learning environment. This learning environment was concerned with providing the kinds of learning activities that might best allow significant engagement and meaningful learning. The fundamental goal of the learning environment was to make a strong impact on learning by providing new type of educational service, by giving learners more controls on their learning process, and by improving relationships between learners, instructors, learning contents and activities, and society. This learning environment should integrate information technology with effective learning models to provide the learners with options and choices that are not found in the classroom settings.

E-learning technology was used in this study to help us create a learning environment better in terms of flexibility, communication potential and exploratory power. This study realized that e-learning technology is just part of the solution to learning requirements. Successful learning improvement requires that e-learning technology be couple with a careful rethinking of the targeted learners and processes. In addition to meeting the accessibility, scalability, and reliability requirements, improvements are needed in the education methods and learning environment to enable knowledge construction and support higher-order thinking and problem-solving skills. Before we developed the learning environment, we asked ourselves the questions "What problem is the learning environment really trying to solve?" and "Whose problem is it?"

In the classroom, teaching practices remain largely uncritical to the ways in which we approach the issue of knowledge, its production and reproduction. The teaching objectives and assessment criteria are established by the instructors in the belief that they are able to discern the properties of knowledge with which education should equip students and which will prove of value to students' future lives and work. Students have little possibility or responsibility of setting up their learning goals. However, the relationship between the goals of teaching and the assessment criteria is not a straightforward for all involved. In many cases the goals of teaching appears equally confusing to teachers who may not be quite clear about the kinds of support structures that would best enable students to fulfil their learning obligations. The danger with this situation is that the teaching objectives established and the assessment criteria applied will function more as limits of knowledge than as a springboard for all involved to seek out innovation and new perspectives.

This study tried to create a learning environment that combine learning tools, learning contents and learning services that allows learners to obtain useful and timely information and knowledge, to undertake substantial and authentic tasks and activities in a realistic context, and to actively construct their own knowledge and understanding. We wanted to give the learners an environment that starts with the power of the learners and enables learners to develop confidence in their own powers. This study believes that the dynamic mechanism of a learning environment is a function of the learner's previous experience and its interaction with the new challenges that the learner encounters in the process of learning, rather than a function of teacher's engagement in the teaching process itself. The environment responds to the continually changing demands from the learner, and critically reassesses the enriching opportunities that it offers to the learner. The environment must improve effectiveness and productivity of *learning*.

Therefore, there were three major players in the learning environment. The *learners* were the students who acquired, constructed, and produced knowledge through the learning environment. The *learning content and tool provider* was the company which provided the e-learning platform and solutions, and learning materials. The university instructor acted as a *learning service provider* (LSP) who provided the learners with supportive services in their learning process. He provided learners with ongoing mentoring and consultative support to help them to familiarize with available learning content and tools. He also provided meta-level guidance for optimizing each learner's learning process. With the help from the LSP, the learners quickly transformed themselves from a passive learner to active learner. An *active learner* is defined here as a participant in learning process whose mental and/or social activities generate new engagements with an environment. He/she assumes responsibility on his/her own learning and shapes his/her own knowledge structure.

When changing to the constructive learning environment from the instructive learning environment, the learners assumed a central role as the active architect of their own knowledge and skills, rather than passively absorbing information proffered by the instructor. They gave greater attention to the acquisition of higher-order thinking and problems-solving skills, with less emphasis on the assimilation of a large body of isolated facts. Skills were learned not in the isolated drill-and-practice exercise, but in the course of undertaking higher-level, real-world tasks whose execution required the integration of a number of such skills. Focus of learning activities was more about context than content. There were a lot of windows that let them glimpse questions and contradictions and entice them to go deeper and deeper into their own understanding of the subject matter. The learning resources were accessed at that point in time when they actually become needed and useful in executing the particular tasks at hand.

The Learning Process

At the beginning of the experiment, the learners were rank novices, possessing little knowledge about IS design and development. They didn't know enough to be able to learn exclusively from their own problem-solving experiences. They had little experience in studying in a "self-regulated" learning environment in which they had to "discover" the knowledge and skill from their problem-solving experience. To them, the experience of trying to learn something by themselves seemed to be so overwhelming that learning might take a long time. At the first meeting, many learners expressed their concerns about the learning situation and learning outcomes.

At this stage, the LSP played critical role in motivating and guiding the learners. The LSP acted as a facilitator whose main function was to help the learners become active participants in their learning processes. He offered the learners cognitive apprenticeship, calibrating the learners' behaviour by offering support. This support offered a bridge between present and future task components that might be too difficult for the learners to undertake alone, and helped them gradually develop their ability to self-motive, self-manage, and self-assess their learning. The LSP also helped the learners to recognize destructive patterns in their lives and develop practical steps for changing bad mental habits.

The learners were challenged by complex problem-solving situations. They had to work independently or in a group to solve a real-world problem logically and systematically. Their learning started with several brainstorming meetings. In these meetings, accompanied by opportunistic guidance by the LSP, the learners discussed their learning situation, worked out learning strategies, and structured problem-solving activities. They also decided to work in a group and formed nine groups, ranging from three to five people. Each group selected a different project.

It was observed that, in the early stage of the learning, the novice learners were primarily focussing on acquiring the necessary organization of knowledge from the Textbook part of the e-book to build their knowledge bases. They then gradually switched to the Concept Map and Examples Map to enrich their 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 use of the same concept had a complex and irregular distribution, reflecting the characteristics of ill-structuredness of the problems. In the complex and ill-structured problem domain, the concepts were no longer treated by the learners as separate "chapters". Many alternative paths were established by the learners to get from one part of the overall knowledge base to any other part of the knowledge base.

The learners' group meeting were really 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. The 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. Often a new knowledge began with an individual who made his/her personal knowledge available to other members in the group meetings. During the 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 piece of the 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 LSP. The information obtained was then incorporated into his/her knowledge base and was available for use in later problem solving. Through this way, the overlapping portions that the participants shared in the contextual situations became larger and larger, which results in organizational amplification and exponential growth of working knowledge.

The learners benefited from group collaboration, especially when they explained their ideas to other members and other members asked questions. The collaboration created the condition for learning where a learner has a right to a point of view and where this view has a status. In contrast, although the instructor-centered traditional teaching provided the group project in the hope of encouraging collaborative learning, it seemed that the students did not want to participate in spite of the fact that they were assessed on their participation and the quality of the project. They didn't share or didn't feel to collaborate. The practice that the teachers set up the project requirements and assessed the students based on the requirements seemed to deny the very virtue of collaboration as fundamentally based in a shared need to discover, explore, discuss, evaluate, and exchange. A meaningful learning often begins with a question that makes sense to the learner, not the teacher [23].

It was observed that, in the later stage of learning, the learners engaged in a different type of learning: refining the knowledge base. The learners had a better organization on their knowledge. They already knew most of the information needed to successfully solve the problem. Each time after modifying the design, or removing a bug from the program, they refined their knowledge base. In this stage, a new conceptual knowledge had been taking two distinct roles. It became a part of the generative knowledge base for the individual learner, and it also provided a starting point for the next problem-solving session. The learners became more experienced and advanced learners, and had a much more complete knowledge base.

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 an analogous example that could provide an answer. They then used that example's solution to arrive at their own solution for the problem at hand. Obviously this initial mode of the problem-solving process was more tedious and required more time than the problem-solving process demonstrated by an expert. But in the later stage, the learners and students stored and used their knowledge in different ways. The students still relied on surface features as reminders. They continued focusing on the examples that were plausible scenarios for the problem, but were sometimes unrelated to the structure of the solution. In contrast, 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. As the problem was solved, the learners were able to compile this initial declarative knowledge into procedural knowledge. Most learners felt that the procedures they obtained from their experiences were different from ones described in the textbook. One reason to explain that difference is that procedural knowledge also consists of psychomotor or cognitive actions, it is difficult to clearly describe procedural knowledge in verbal or written form. Thus, 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 [6].

When dealing with their projects, the learners automatically learned how to apply a top-down strategy to their problems. They studied the whole project in attempts to understand the "big picture". They then broke the project into manageable tasks, clearly defined a set of requirements for each task, and set a time limit on each task. Roles and responsibilities for each member of the team were also clearly defined. The learners focused on smaller tasks with shorter timelines and less complex. A shorter timeline forced the learners to place an emphasis on the processes of design, testing and implementation. The ability to accomplish smaller goals would lead to the ability to handle the larger projects. Working in small tasks was not only easier and cost effective but also was an excellent platform for making mistakes. A mistake in one small task was easily identified, evaluated, and repaired. Mistakes at this level increased the overall quality of the project. In contrast, the students had no chance to practice the top-down strategy, mainly because their homework and project were too small or too simple to apply the strategy.

Today, IS specialists play a change-agent role in organizations. One dimension of effective change agentry is the interpersonal skill. One positive side-effect the learners obtained from their learning experience was this type of "soft skill". There was no formal interpersonal effectiveness training in the IS curricula at the university. The real-world problem solving provided opportunities for the learners to practice different role behaviours in circumstances where they could get constructive feedback about the effects of their behaviour on others. The learners often described their experiences about how they dealt with user-related situations, such as the situation in which user insisted the learners build a system with specific features, but the learners knew that the intended hands-on users would find the system too hard to learn, or the situation in which users resisted using a system because of the way it changed familiar tasks and redistributed some important political resources. This type of learning environment was the best way to foster affective and behavioural learning and personal development. This learning experience also set the stage for further behavioural and affective growth in the learners' career.

Assessment of Knowledge Structure

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 [11]. 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 analysed 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. 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 [11], [13].

Cognitive skill acquisition theory [1], [2], [6] suggests 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. There are three categories of procedural knowledge: (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 solutions 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 [18]. 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.

Research has demonstrated that novices tend to possess declarative knowledge and lack procedural knowledge, while experts posses both declarative and procedural knowledge [1], [16]. Learning is an interactive experience. Declarative and procedural aspects of knowledge interact and combine in the regulation of human learning [18]. 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 never been learned (procedural knowledge).

Assessment of Knowledge Structure

Before the experiment started, each subject took a pre-test that covered fundamental concepts of information technology. There was no significant difference on the performance between the students and learners, as shown in Table 1. 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.

Table 1: Descriptive Statistics for Performance on Pre-Test and Three Assessment Sessions

Session		Average	Standard Deviation	Median	Max	Min	p-value
Pre-test	Learners Students	71.08 70.81	15.63 16.68	74 78	94 94	42 40	0.9421
Declarative-Knowledge Test	Learners Students	79.32 78.92	8.90 7.71	82.89 81.98	95.50 93.70	61.26 65.77	0.8371
Problem-Solving task	Learners Students	64.39 48.97	7.35 12.79	66 53	78 67	54 25	<0.0001
Similarity-Judgment Task	Learners Students	68.71 60.26	8.59 10.95	68.75 62.50	87.50 81.25	56.25 43.75	0.0005

Declarative-Knowledge Test

In this study the learners learned in a constructive environment and 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 the body of conceptual knowledge that the scientific community regards as currently warranted. It was concerned about whether these self-regulated 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 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. The learners would not be regarded as being scientifically educated if they did not know the publicly-recognized "funded wisdom" [12].

This study expected that, during their learning processes, the learners would experience the stages from novice to advanced learner. 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 declarative knowledge. To test this hypothesis $(H_0: \mu_{learner}=\mu_{student}; H_a: \mu_{learner}\neq\mu_{student})$, this study designed a Declarative-Knowledge Test.

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 to complete his/her 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, containing 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 1. No significant differences were found between the performance of the learners and the students on the declarative-knowledge test. This result is consistent with the observation. It is apparent that declarative and procedural aspects of knowledge interact and combine in the regulation of human learning. The result also indicates that if a learning environment provides the learners sufficient learning content, necessary learning support, and properly-designed problem solving activities, the learners can acquire the necessary conceptual knowledge.

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. Problem-solving ability requires a fair amount of expertise on the part of the problem solver. 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.

The student, 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 resources were 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 is 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 [5], [7]. Thus, this study hypothesized that the learners would have better performance on the problem-solving task than the students $(H_0: \mu_{learner}=\mu_{student}; H_a: \mu_{learner}\neq\mu_{student})$. The learners 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 in Table 1 indicates that the difference in the problem-solving performance is statistically significant. The learners also took shorter average time to complete their tasks. This result 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 constructive 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 had acquired procedural competence by storing the derivations of problem solutions and using them as analogys to guide their search for solutions to novel problems.

A prerequisite to handling real-world problem 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 explains particular techniques and illustrated their applications with various examples. The problem and its solution in these chapters were never far apart. The relationship between a problem and a method was discussed from the perspective of a method, not the problem. The students knew that, to solve the problem, they could use something that was discussed in the same chapter. It seems, however, that this was not the right way to learn. What is interesting here is the fact that all problems in the problem-solving task were selected from the textbooks used by the students. These problems were easy to solve when placed at the end of the appropriate chapters. But when they removed from the context of their chapters, it could be quite difficult. What was missing in the students was a development of problem-solving skills. They might have difficulties in solving real-world problems because complex real-world problems are not found in chapters and cannot be often decomposed easily or meaningfully. 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 had learned how to organize their cognitive structures into more integrated patterns through examining the conceptual, relational and hierarchical nature of the knowledge with which they were working. In this way, the metacognitive learning strategy was promoted.

Similarity-Judgment Task

Novices and experts store and use domain-specific knowledge in distinctly different ways [9], [10], [15], [19], [20], [24]. 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 be solved most similarly to a third model problem [17]. 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 task 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, it was expected 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: $\mu_{learner} \neq \mu_{student}$).

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 that task within 75 minutes. The result, shown in Table 1, indicates significant differences in the performance between the learners and students on the similarity-judgment task, which implies that the experience-based learning strategy in a real-world working environment would promote a shift toward reliance on deep structure rather than surface features.

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 their "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 problem 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 more 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 such as "how the systems user's action 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.

Discussion and Conclusion

The assessment results in this study suggest that the learning outcome in this experience-based, constructive learning environment is very positive. The environment that imposes an expert-like organization both on information and on problem solving activities results 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 behaviour. They 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 less ready to do the problem-solving task than the learners were. 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 did, even when some learners didn't find the right way to begin with. They took time to think rather than asked 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 favourable. 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 has a lot of fun"; "I enjoyed working in a team like this"; "When I finished the project, I felt that I already became as 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.

It should be noted that encouraging the students 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 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 learners' involvement in advanced knowledge acquisition is particularly important. At early stage 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 LSP 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 LSP, 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 independently.

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. 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, academic and practice, 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 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.

All nine projects were successfully completed, and seven were purchased by the companies. There is one important 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. The learners began with many failures and learned to evaluate them. The learners involved in an iterative process of designing, developing prototype, testing, correcting mistakes, and deploying the working 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."

Computers have been used in education for many years. Although the popularity and utility of the learning technology has begun to reveal the power of e-learning, the full potential of e-learning system to support learners has not yet been realized. Much attention today is focused on providing widespread access to current curriculum and courses. Providing access is necessary for education but not sufficient to achieve improved IT-enhanced learning and education. Learning technology is just part of the solution to e-learning requirements. Successful e-learning improvement requires that information technology be couple with a careful rethinking of the targeted customers and processes. In addition to meeting the accessibility, scalability, and reliability requirements for e-learning infrastructure, improvements are needed in the education methods and learning environment to enable knowledge construction and support higher-order thinking and problem-solving skills. Increased attention need to be paid to integrating technology into the process of learning.

The assumptions about learners and the task of learning that is embedded within the learning environment shape individual and institutional perceptions of the goals and methods by which learning should proceed. These perceptions are formed in the contexts of social interactions and ultimately become a new model of how learners should look and be. Learning technology providers, teachers, and learners form a strategic source, support and partnership relationship. They will work together to model and monitor the processes that would affect the activity of the education, wherever those processes are occurring, up and down the learning pipeline. This pipeline contains components that would be pushed out to all learners as well as components that individual learners could pull from to meet their specific needs. It supports learning in a variety of channels, contents, tools and services, provides a variety of learning opportunities, and allows learners to best meet the needs of their learning objectives. This type of learning pipeline will produce the well-educated, information-literate, more motivated, and highly skilled workforce the nation needs.

The design of learning environment is not about using information technology to teach in traditional ways. It is about people and about using technology to support human learning and social interactions. The technology is viewed not just as a tool for improving the efficiency of traditional instruction based largely on the unidirectional transmission of isolated facts and skills from teacher to students, but as one by which learners actively construct their own knowledge bases and skill set. Learning technology should satisfy the need for rearranged knowledge sequences, for multiple dimensions of knowledge representation, for multiple interconnections across knowledge and skill components, for multiple data codings, and for multiple linkages among content and activity elements. In such way, learning technology could play a major role in improving the quality of people's learning experiences and ultimately offer the most fertile ground for the application of technology to education. The future of learning technology will depend on who controls the technology and learning process. The challenge to e-learning designers is not only how to embed the learning environment into the learning system, but also how to put the learning system into the learners' hands and let them use it.

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. Therefore, learning system developers must create new vision of education, not a new version of traditional education. The nature and quality of the learning depend upon the extent to which the learning environment emerges, evolves, and supports progressive levels of understanding.

Of course, 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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About the Authors

Dr. Weiqi Li

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 systems 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 Systems. His research interests include machine learning, heuristics for the combinatorial optimization problems, and e-learning.

Hanwen Zhang

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

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.

Ming Li

Ming Li received the B.A. degree in English language and culture from Zhengzhou University, China, and M.A. degree in English literature from Shanghai International Studies University, China. She recently works as an education and learning facilitator in the Department of International Education Program at Tongji University, China.