A Knowledge Assimilation Schema for Acquiring Technical Knowledge

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ABSTRACT

It has always been a challenge for business students to acquire technical knowledge. Such challenges are more pronounced at urban minority universities where many returning students often have additional obstacles that prevent them from learning as traditional students do. In response to the situation, we have developed a learning tool, called the *Knowledge Assimilation Schema* (KAS), that guides students to focus on the development of their knowledge structures rather than the collection of isolated knowledge entities. The learning tool has two major components: a knowledge representation *framework* that facilitates structural understanding and a knowledge acquisition *process* that steers deeper learning. Initial feedback and results from KAS have shown a noticeable improvement in conceptual learning of technical subjects, especially among non-traditional students.

Keywords: Conceptual Learning, Knowledge Assimilation, Knowledge Representation, Object Orientation, Ontology

1. INTRODUCTION

In response to the profound impact of information technology (IT) on virtually all aspects of an organization, business schools are constantly revising and expanding their curricula. As we endeavor to equip our students with necessary technical skills, we encounter the following challenges:

1. While the total number of credit hours offered by a business administration curriculum is relatively constant, curriculum is expanding (Tesch, Crable, & Braun, 2003).
2. Use of IT in most functional areas of a business requires our students to possess interdisciplinary knowledge in order to compete in an increasingly competitive marketplace.
3. Technology is constantly evolving. By the time our students graduate, their technology related curriculum will have changed, requiring them to have adaptive skills to deal with change.

These challenges are exacerbated at urban minority universities like ours where a high percentage of the students are returning adults. To cope with our situation, we have developed a learning tool, called the *Knowledge Assimilation Schema* (KAS), that guides students to focus on developing their knowledge structures rather than collecting isolated knowledge entities. The rest of the paper is organized as follows. Section 2 summarizes our literature review of existing teaching and learning methods. Section 3 describes the framework of KAS and Section 4 gives examples of its use in our classroom settings. The perceived effectiveness of KAS is analyzed in Section 5 and the relevance of this research is highlighted in Section 6.

2. LITERATURE REVIEW

Considerable research has been conducted in teaching and learning, some of which is relevant to the acquisition of technical knowledge.

Active learning is effective because it facilitates deeper learning. Strommen and Lincoln's research findings (1992a) indicate that learning becomes active when students acquire new knowledge using existing knowledge and experience. Sherry (1996) suggests the use of inquiry learning, stating that a teacher is no longer "the sage on the stage" or the deliverer of a fixed body of information. Fink (2003) observes that students learn more and retain their learning longer if they acquire it in an active, rather than passive, manner. He attributes the lack of knowledge retention to traditional deductive teaching methods.

Active learning can take place when students work together in teams. Welch, Gradin, and Karin (2002) discover that students become more involved in their learning and strive to assist each other in attaining course goals in a team situation. Group discussions promote inductive learning, which is considered effective in teaching technical subjects that usually demand high-order thinking and intense exploration (Quinlan, 1979).

Inductive learning activities should arrive at concept establishment. Bean (1996) suggests that at the end of a session the instructor ask students to summarize the discussion. McFarland (2003) proposes that we teach students to learn *how* to learn rather than *what* to learn.

Technology has extended the learning space by allowing dialogue and reflection to take place beyond the physical constraints of a traditional classroom. Williamson and Nodde (2002) find that a collaborative learning method that utilizes computer technology can compensate for the impersonality of distance learning.

Various hypermedia facilitations have been investigated to incorporate the principles of inductive learning. These include the use of puzzles and games (Hill et al., 2003), knowledge maps (O'Donnell, Dansereau, & Hall, 2002), rich pictures (Monk & Howard, 1998), and multimedia systems for situated learning (Tretiakov & Kinshuk, 2003). But we have observed that these tools lack both a representation ***framework*** to mimic human thinking and a development ***process*** to facilitate deeper learning. Psychologists posit that both the representation framework and the development process can significantly affect learning. Zhang (1997) emphasizes the relationships between external representation of knowledge (i.e., visual and spatial layouts of diagrams) and internal representation of knowledge (i.e., the structure in memory). He suggests that the cues in external representation can trigger a cognitive process that retrieves internal information. Gibson, in an early study (1979), concludes that external representations of knowledge can be picked up and stored in memory. While their research findings somewhat differ, both show that the external representations of knowledge, including spatial and visual layouts, play a significant role in knowledge internalization. Equally important is a knowledge development process that facilitates a structural translation from external knowledge to internal knowledge. In addition to the need for visualizing parts of a system, engineers in various disciplines often rely on various processes to analyze its behaviors (Booch, Rumbaugh, & Jacobson, 1999; Blanchard, 2003).

3. THE KAS FRAMEWORK

KAS, a Web-enabled learning tool, mainly consists of two key components: a knowledge representation ***framework*** for describing relationships among knowledge entities and a knowledge discovering ***process*** for assimilating external knowledge. The process of discovering relationships among knowledge entities elicits the *aha* experience that plays an important role in promoting active learning, while the framework that represents both internal and external knowledge in a polymorphic structure keeps the learning process manageable. We focus the description of KAS on these two components.

3.1 Concept Objects and Their Relationships

Akin to Strommen and Lincoln's suggestion (1992b), KAS facilitates conceptual learning through learning by analogy. To confine the increasing complexity of a technical subject, however, we think learning by analogy must leverage an emblematic framework and decided to build such a framework using ontology (Zúñiga, 2001). In a computational, versus philosophical, ontology, the domain-specific knowledge is represented by a set of objects and the relationships among these objects (Fox, 1998). Once the structure of a specific domain is established, concepts can be mapped to another domain with a similar structure. Knowledge acquisition takes place in search of the mappings from one ontological system to another. Nonetheless, instead of building an entire lexicon for an ontological framework, we situate KAS in a more general ontological framework, namely object orientation (Minsky, 2000). Although object-oriented models have been explored for a variety of business applications (Wand, Storey, & Weber, 1999; Wegmann & Naumenko, 2002), they have not been directly applied to shape classroom learning.

As in an object-oriented paradigm, concepts are associated in KAS through three basic relationships, i.e., IS_A, HAS_A, and RELATES_TO. IS_A enables concepts to form an hierarchy of inheritance. An aggregation of concepts is constructed through HAS_A relationship and is equivalent to a composite concept. Concepts that do not have an IS_A or HAS_A relationship may still be affiliated via a RELATES_TO relationship. Learning by analogy occurs when the internal knowledge entities are found analogous, in one of these three relationships, to those of an undertaken subject (Linn, 1995a; Davis, 2003a).

As shown in Figure 1, data communication systems and transportation systems can be considered as two related ontological systems where a computer network can be generalized as a network of nodes that mimics a transportation system. While the two may have different aggregations in terms of the HAS_A relationship, the IS_A relationship can identify both similarities and differences between them.

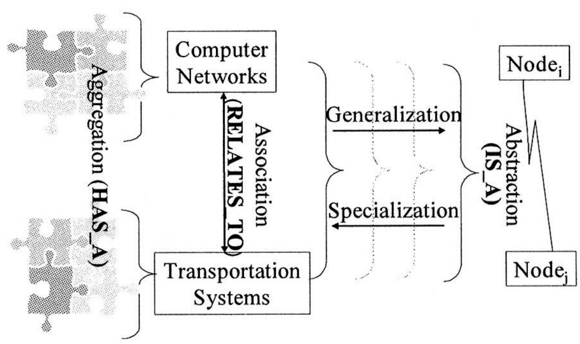

Figure 1: KAS associates ontological systems of different domains using three kinds of relationships

By adopting a simple but robust representation structure, we can examine comparable concepts using important properties of object orientation to explain knowledge entities without unmanageable details. A transportation system and a data communication system are polymorphic in nature. At an abstract level of understanding, transportation and data communication can share a variety of principles since both systems facilitate exchanges between two distant parties regardless of what is transferred. At a detailed level of understanding, although interstate freeways operate quite differently from wide-area networks, they share many operation principles such as static routes as opposed to dynamic routes. At an even more detailed level, domain experts for one system would know little about the other system. Therefore, a comparison between the protocol for delivering a package using the freeway and the protocol for sending a file over the Internet can be ill-structured if the level of comparison is not manageable. Using a hierarchy of inheritance, KAS supports an iterative and incremental approach to learning by focusing on either the depth or the breadth of the knowledge in each learning cycle. In a depth-first approach, we study selected aspects of the concept, such as how a network system works from a user point of view. In a breadth-first approach, we first understand all basic quality factors of the network system and, in the following learning cycles, gradually intensify the understanding of these factors.

As shown in Figure 2, a user interface of KAS supports navigation from a current concept to its parent concept, sibling concepts, and sub-concepts. By clicking the View link at the rightmost column, the student can then move on to study the chosen concept and its relationships with its surrounding concepts. Such knowledge exploration can proceed at various levels of abstraction. As illustrated in the figure, the concept of circuit-switched networks has a sibling relationship with the concept of packet-switched networks because both share the same parent concept, namely, wide-area networks (WAN). An examination of unique or common attributes of these related concepts is provided through hyperlinks.

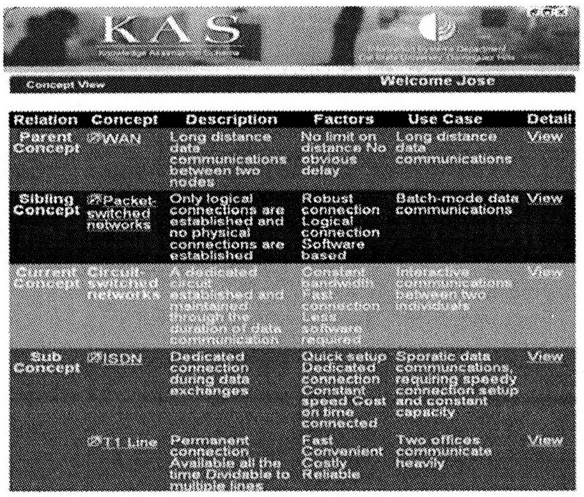

Figure 2. A Hierarchical Navigation Table the Facilitates the Comparison Among Similar Concepts

3.2 Concept Objects and Their Use Cases

Knowledge assimilation is more than knowledge representation; it relies much on discovering effective links among knowledge entities (Linn, 1995b; Davis, 2003b). In search of such links, KAS employs a ***process*** that heuristically guides students to explore the semantic relationships between internal and external knowledge entities (Bell & Davis, 1996; Clark & Linn, 2003). The more internal knowledge a student already possesses, the greater the effectiveness of learning by analogy. In this regard, the fact that the majority of our students are working adults with many viable life experiences supports the KAS rationale.

KAS takes an inductive approach by focusing on the "use cases" of a concept (Pols, 1997) that drive the development of an ontological structure (Cimolino, Kay, & Miller, 2004). A "use case" consists of all significant scenarios, both typical and atypical, in which the concept plays a central role. Starting from a specific scenario, students are encouraged to pragmatically describe how the system should behave. Once appropriate behaviors are identified, design options for implementing the behaviors can be objectively evaluated. This learning sequence encourages discovery to be explored by students rather than conducted by the instructor.

Following Figure 3, let us consider a circuit-switched network application, namely two parties converse at different speeds over the phone. In this case, we are asked to assess two design options for the phone system. Option 1 allows one party to request the other party to slow down whereas Option 2 lets either party record the phone conversation first and listen to the recording later. To make an intelligent

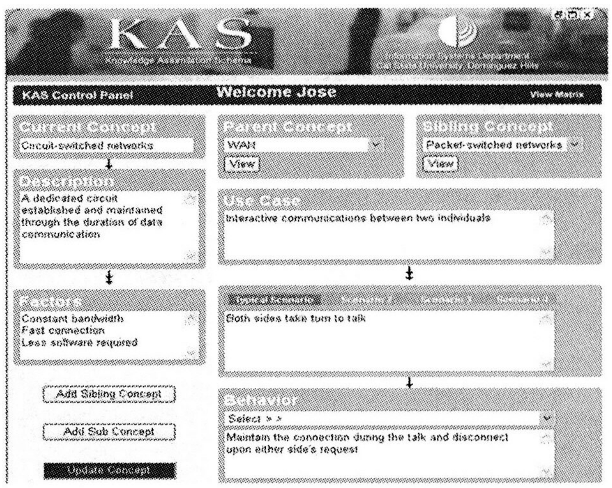

Figure 3. A Concept is Established with Relationships to Others and is Characterized by Its Use Cases That Specify Scenarios

choice, we need to think about specific scenarios so we can identify required system behaviors. Two of such exceptional scenarios are often anticipated. Scenario 1 depicts the situation that it is difficult for either party to find a mutually convenient time to talk. Scenario 2 is that one party talks much faster than the other party can comprehend. If these two scenarios totally reflect the critical use of the phone system, we in turn discuss what behavior of the phone system could best accommodate both scenarios. The desired behavior then helps us realize that Option 2 is superior than Option 1 since the former can function well in both scenarios whereas the latter fails to handle Scenario 1. The investigative process helps us not only understand the unique attributes of each design option but also pay attention to the value of each.

Although the above discussion of KAS uses the example of data communications, the descriptive power of object orientation allows KAS to describe a variety of IT concepts. For example, if the learning subject is about the modular design in a computer programming course, it is often difficult for students to comprehend the principle of functional cohesion just through instructor's explanation. They usually do not perceive the advantages of the rule that one module should implement one and exactly one function (Yourdon, 1979). An alternative approach to introducing the concept is to ask students to think about all the roles involved in a familiar business environment. For instance, the business environment could be a restaurant where cashier, waiter, and manager are distinct roles with specific responsibilities. Students can then look into the advantages and disadvantages of having employees play distinct roles, especially as the size of a restaurant increases. With such a familiar example in mind, students are better prepared to appreciate the modularization principle. By examining differences across domains, students strive to incorporate new knowledge entities into their existing knowledge structures in their familiar terms and notations. KAS facilitates such knowledge transferring, which is otherwise ill-structured, by means of organizing and developing the comparison.

4. APPLYING KAS IN OUR CLASSROOM SETTINGS

Since the fall semester of 2004, we have applied KAS to our data communications course and software development course. The data communications course is always one of the most difficult subjects for our students. In the past, they felt the subject too overwhelming to comprehend. Many of them reported that they just tried to memorize the contents for exams without a clear understanding. This challenging situation has motivated us to leverage KAS to try a three-stage learning process: stage one, exploring the ontology of a familiar concept; stage two, mapping to a new concept; and stage three, concept assimilation.

The first stage becomes necessary when students have difficulty imagining the use of a learning concept. The learning process could start directly from a general discussion of data communications. However, without being able to envision what they are learning, most students are inactive in the discussion. Apart from giving some general propositions, such as a dedicated connection between transceivers through a wired or wireless medium, most students cannot explore the concept much further. To steer the stagnant discussion forward, we switch to asking students to think about the scenarios of an analogous but familiar concept, such as common transportation systems. In parallel with classroom discussion, students use KAS to document their understandings of specific traffic situations. For example, students often consider driving to work in a shared lane as a typical scenario, and then propose several atypical scenarios, including one that people want their commuting time constant and another that people want both comfort and speed. Subsequently, they specify the functional requirements of an effective transportation system. In support of a typical scenario, system behaviors initially seem easy to describe, but as specific issues, such as safety and congestion, are raised, their descriptions become complex. Students then argue about design options. Some insist that all vehicles have the privilege of using any available lane while others defend the requirement for dedicated express lanes to ensure uninterrupted traffic flow. The discussion eventually results in a summary of pros and cons of valid design options. The key achievement of the first stage is to have students establish in KAS an ontological system of their internal knowledge.

Once a familiar but analogous system is established, the second stage of learning, namely identifying mappings to the data communication subject, should begin. For each transportation scenario students consider an analogous situation in data communications. Since the two systems do have many similar scenarios although few of them are identical, students struggle to identify similar and dissimilar features of the two systems. With an analogous system well documented, students ask each other specific questions: Do we share network connections with others as we do in a transportation system? Do we need to communicate at a constant speed? Do we need information highways as well as local surface streets? Are they different from comparable ones in the transportation system? We find that this stage of learning is best conducted in small groups so that everyone can actively participate in the discussion that usually results in a variety of useful mappings. Since at this point the instructor has not yet given a lecture on the subject but has merely guided the learning process, active learning is achieved. The emphasis on identifying mappings between a familiar domain and an unfamiliar domain motivates students to extend their internal knowledge structure rather than to collect external knowledge entities.

In the third stage, students assimilate the newly established concepts into their prior knowledge base through knowledge aggregation and generalization. For knowledge aggregation, students might compare the WAN system, learned from their initial readings, with the freeway system to see if some aspects in one do not exist in the other and vice versa. Students often discover some scenarios applicable to one concept but not to the other. In fact, they usually end up with recognizing three groups of scenarios: those that are supported by both network protocols, by neither, and by one but not the other. This exercise helps students understand the unique features of each system. For example, students see the need for adapting when driving in another country. They subsequently ask if the same situation would happen in a WAN environment. For adaptation methods in a familiar transportation environment, they can easily come up with such suggestions as replacing the driver with a local driver or loading the entire vehicle to a local tow truck. Some students have even thought about an international sign system for all road systems. Through these analogous examples, students begin to understand data communication protocols. They think of a logical system, through relating the international sign system to a common protocol on top of individual network infrastructures. The discussion then moves on to how logical systems and physical systems in data communications could operate similar to, or different from, the ones in the transportation environment.

For knowledge generalization, students conceptualize their extended knowledge structures. This step enables students to integrate knowledge entities across disciplines. In fact, students at this point already have many questions about the relationships of what they have learned and what they knew before. They ask if someone specializing in civil engineering can also quickly become an expert in data communications, and if there is a common set of rules applicable to both, namely, cars or trucks that share a single lane and multiple data transfers that share a single channel. These questions give the instructor opportunities to introduce details that differentiate data communications from transportation. As students continue to derive conceptual knowledge and to distinguish unique features of each system, they enrich and consolidate their knowledge structure. While in this paper we have given just one example of comparing WAN with freeways, in our classes we also compare WAN with local area networks (LAN) and wired LAN with wireless LAN, albeit the initial comparison that brings students to the digital world from the real world is most crucial.

In summary, the three-stage learning process first guides students to organize their knowledge of a familiar system into an ontological framework. Secondly, the process develops an analogous knowledge structure to model new knowledge entities. Finally, the process assimilates both existing and incoming concepts through aggregation and generalization.

The driving force behind learning effectiveness is the ***framework*** that forces students to find a position for a new concept in their knowledge structure, and the ***process*** that guides students to think about use cases, scenarios, behaviors, and design options for the new concept. The beauty of this approach is its simplicity and heuristics. It is simple because it offers only three kinds of relationship for binding all knowledge entities together and it is heuristic because it guides an inductive, pragmatic learning process for discovering new knowledge entities. The better students can describe a known concept, the easier they can extend their internal knowledge to incorporate a similar, new concept.

5. ASSESSING THE EFFECTIVENESS OF KAS

The initial assessment on the use of KAS, through questionnaires, interviews, and analysis of test results, yields quite encouraging findings. We summarize them as follows:

- In response to an anonymous questionnaire given to 90 students in three participating classes, eighty percent of them agree that KAS engages active learning and sixty-eight percent of them agree that KAS facilitates concept establishment. Sixty percent of the participants admit that KAS helps them manage the complexity of technical concepts while the rest believe that KAS will be more helpful once they become more familiar with it. Although nearly all students perceive the usefulness of a modeling method because they see how they can use it to depict technical concepts that otherwise seem tedious and discrete, seventy percent of them suggest that they need more guidance from the instructor in order to substantially benefit from it. When asked if they have tried KAS at home, fifty-five percent of them say they have tried, but all admit that it is more difficult to use it at home than in class.

- In random interviews, some students complain that the KAS strategy does not guarantee the coverage of the subject matter and thus challenge them to balance the depth versus breadth of their comprehension. Others report that they have relied on KAS to achieve an in-depth understanding of some difficult concepts but then still rely on traditional methods to prepare for exams. Some of the students who have a professional job point out that KAS is quite similar to the tools or methods they use at work. The students who show little interest in KAS are those younger. They complain that the KAS approach is cumbersome and make them learn the information irrelevant to the subject matter. These students are anxious to learn the technical skills specific to the course. They also complain that it is difficult to follow the KAS structure, and they are concerned about the fact that when using KAS they take longer to finish their assignments.

- We have also observed the effect of KAS on test results. For our first data communications course, two classes taught with the use of KAS scored seven percent higher in the final exam than two classes taught without. Since the students in all these classes are academically comparable, we are confident that the improvement on the exam scores is significantly attributable to the use of KAS. Notably, the students who seriously tried KAS could answer essay questions more analytically than the ones who chose not to leverage KAS. The scores on multiple-choice questions showed less obvious improvement between participating and non-participating students. In addition, the test scores on conceptual questions are improved more significantly than ones on the questions involving significant math calculations.

- Feedback from the instructors indicates that the way KAS is introduced to students matters. For example, when an instructor formally introduces the concepts of object orientation undergirding KAS, students show more frustration. In contrast, when students were given an exercise without much description of the modeling concept behind KAS but with some concrete examples, they complained less and could finish their exercises quickly.

To sum up, most participants agree that KAS help them understand the concepts that are otherwise imperceptible. They also agree that some technical concepts can be structured via KAS as a natural extension to their existing knowledge base. Overall feedback has shown consistent signs that students who perceive the usefulness of KAS are likely older and work full-time.

6. CONCLUDING REMARKS

KAS reflects the research results highlighted in Section 2. First, KAS supports an inductive learning process for knowledge assimilation. Students learn new concepts largely through their own discoveries based on their analyses. Such an inductive approach helps them achieve a higher level of comprehension. Second, because it is a scenario-based learning strategy, there can be multiple solutions or no solution. Such a form of learning requires the instructor not to give standard answers but to encourage students to discover reasonable answers on their own. Finally, KAS emphasizes the development of knowledge structure in an integrative form rather than the collection of knowledge entities in isolation. Therefore, it facilitates knowledge assimilation.

KAS differs from other approaches to knowledge assimilation in that it leverages a structured framework proven effective for describing real-world problems, and it guides students to explore new knowledge based on prior knowledge. Unlike other learning tools, KAS imposes a rigid structure for a learner to follow, which could be intimidating to some students. Therefore, we believe there should be additional bridge templates designed to be highly graphic and free from technical terms so that these students can focus on developing knowledge without having to understand a rigid structure. We envision the next version of KAS will be enhanced with latest presentation technology such as the Rich Internet Application (Wong & Sheu, 2006). KAS is a learning tool, one that we have so designed to suit our students.

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