Case-based Reasoning:

Case Libraries and Analogical Reasoning

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Support for teaching with cases comes from a number of areas of research in cognitive science. Situated cognition, for example, emphasizes the importance of the context in which knowledge is used. Thus, learning should be situated in the culture of the practitioners (Brown, Collins, & Dugid, 1989). From this perspective, cases, consisting of setting, actors, goals, and a sequence of events (Kolodner & Guzia, 2000), are useful in instruction because they can involve learners in analyzing specific problems presented in a realistic scenario. The instructional purposes of such a case study approach, especially in legal and medical education, tend to provide an authentic context for learners to apply principles, theories or techniques, or to help learners to acquire principles and rules abstracted from their analysis of cases. The effects of such a case study approach have been claimed to be beneficial (Spizizen & Hart, 1985; Kreck, 1992).

In higher education, problem-based learning (PBL), another form of case study approach first developed in medical education at McMaster University, has been adopted during the past three decades in a variety of other professional schools, including architecture, business, law, engineering, forestry, political science, social work, and education (Camp, 1996). In the PBL environment, a case describing a problem situation establishes a context of learning. The power of this approach lies in its creation of a problem-anchored learning environment for learners to take up the natural process of inquiry to pursue and use knowledge. On the other hand, case-based reasoning (CBR), which originated from the field of artificial intelligence, also promotes learning through cases. CBR derives its theoretical support from memory organization and reminding in
cognitive science (Shank, 1982; 1990). CBR uses prior experiences in the process of problem solving. CBR, as a learning model, argues that the acquisition of expertise is to accumulate experiences with a succession of real cases and to properly index these experiences for later retrieval (Koschmann et al, 1997). The power of the reasoning activities through the access to old cases provides a potential instructional practice in problem solving. In fact, Kolodner, Hmelo, and Narayanan (1996) proposed to incorporate CBR with PBL to enhance learning. They suggested that a library of cases that cover an adequate variety of the problem solving experiences from others should be presented at the moment when the cases are needed. It is expected that the case library, providing the experiences that human learners lack, will be able to augment learners’ memory and thus enhance learners’ problem solving and reasoning skills.

However, the value of a case library is not widely assessed. Most of the studies on the use of a case library in teaching focus on the issues of the interface design and indexing (Shank, 1991; Edelson, 1993; Maher, Balachnadran, & Zhang, 1995). Other research, such as the studies conducted by Brown (1992) and Kerany (1995), shows the effectiveness of the use of concrete stories on inducing conceptual changes and on attitude change; but both studies present stories to the subjects before the problem solving task rather than at the moment when the subjects are engaging in a problem solving task. Therefore, this study intends to examine whether the implementation of a case library in a problem-based learning environment, provided as an available resource during the process of inquiry to the solutions, has any effects on the learners’ problem solving skills, especially in terms of organizational structure of the cases in their memory.
Moreover, the theoretical support for the learning strength in CBR is derived from the ability of reasoning the old problem solving episodes to navigate the new ones. A problem solver or a case-based reasoner demonstrates reasoning ability in the process of interpreting and adapting the solution through analyzing the similarities and differences of similar cases. However, the research on analogical reasoning indicates that novices, without explicit suggestions or without undertaking self-generated solution processes, were not able to see the connection between the provided examples and the target problem (Gick & Holyoak, 1980). Hence, a number of questions, based on the suggestions from Chi et al. (1989) and Leake (1996a), will be developed to foster learners’ self-explanation skills and to guide them to be aware of their reasoning process. Since learning is generated by the interpretation and adaptation of the past problem solving experience to the present one, the ultimate goal of such guidance is to enhance learners’ ability of analogical reasoning so that they can store a new case linked to prior instances for future use. Accordingly, this study will also look into the influence of those guided questions on the analogical reasoning, provided during the process of adapting the prior case to the new situation.

Literature Review

Case-based reasoning and learning

Case-based reasoning is a computational model that uses prior experiences to understand and solve new problems. The foundation of the CBR system is laid on Schank’s arguments on the role of reminding (1982), which coordinates past events with current events to enable generalization and prediction. The assumption is that when a case is indexed to a place where another experience is already indexed, a reminding
happens and the potential for generalization exists (Kolodner & Kolodner, 1987). Different from expert systems, which store past experience as generalized rules and objects, CBR systems store past experiences as individual problem solving episodes (Kolodner, 1992; Maher, Balachandran, & Zhang, 1995). CBR systems also attempt to generate solutions to a new problem based on the use of these experiences from previously solved problems. The underlying principle of such a system is that people solve new problems by remembering similar experiences about similar situations.

According to Schank (1990), human memory is story-based. What people know is stored in memory as stories. People are reminded of past experiences by current ones, and we use those past experiences as a guide to help us process new experiences.

Thus, in the CBR paradigm, problem solving is viewed as a process of remembering a specific problem-solving episode, adapting the solution to fit the current situation, and storing the adapted solution in the memory. With this problem solving process, the solved problems with the adapted solutions can be indexed as new cases into learners’ memory for future use. It is exactly the accumulation of the cases that demonstrates the acquisition of the expertise. Put simply, learning occurs when people process new experiences in light of old ones (Shank, 1990). Similarly, Kolodner et al. (1996) stated that learning means extending one’s knowledge by incorporating new experiences into memory, by re-indexing old experiences to make them more accessible, and by abstracting out generalizations from experiences.

Moreover, studies on the nature of expertise all show that experts differ from novices in the amount of their knowledge, the organization and accessibility of the knowledge, and the methods used to apply the knowledge (Chase & Simon, 1973; Chi,
According to the knowledge representation in the CBR systems, the critical factor that sets experts apart from novices is the ability of experts to deal effectively with new situations by recalling and reusing the relevant experience. Therefore, it is thought to be valuable to use the CBR system to teach novices, who do not have much problem solving experience, by presenting stories of others in the problem-solving context. Based on such a premise, the Institute of the Learning Science at Northwestern University developed four examples of case-based teaching software (Shank, 1991). However, the studies from those programs do not look into the educational effectiveness. Instead, they explore mainly the technical issues involved in the case-based teaching architecture, especially the issue of indexing, i.e., when and how a case should be told. Thus, the empirical verification of the impact of such teaching invention on learning is worthy of investigation.

Integrating CBR with PBL

The underlying principle of the case-based teaching architecture of the programs is to use old experiences to understand and solve new problems. The case-based teaching architecture consists of two independent components of the system: the task environment and the storyteller (Edelson, 1993). The task environment has to provide learners with an engaging task, and the storyteller has to monitor the learner’s interaction with the task environment, looking for opportunities to present instructive cases. To complement the case-based teaching architecture, the initial problem scenario in the PBL environment provides an authentic task context acting as a stimulus for students to start the learning process.
The underlying development and design principles of PBL reflect how people solve problems in their everyday lives. When learners confront a problem, they analyze the situation, identify what the problem is, inquire about the information that they need to know, and come up with hypotheses and solutions. One of the critical processes in PBL calls upon learners to identify important issues and relevant subgoals. A case library, a storyteller’s systematic collection and organization of experiences, is meant to help learners to be an effective case-based reasoner. Through access to the case library, it is assumed that the learners would be able to draw on enough understanding from the old experience to evaluate a case’s relevance to a specific situation (Edelson, 1993). As a consequence, they would be able to identify learning issues that need to be addressed in order solve the problem task they are facing. CBR argues that people solve problems, construct plans, and understand new situations by making reference to similar previous experiences. From the perspective of problem solving, CBR supports the practice of learning from problem solving activity in the PBL environment. Besides a case library as a learning resource, Kolodner, Hmelo and Narayanan (1996) also claim that CBR can contribute learning in PBL by providing suggestions about what makes a good problem, and the range of the problems that students should solve.

Analogical reasoning in case-based reasoning

In order to assist learning from prior problem-solving episodes, the CBR systems should be able to execute a basic process: retrieving, adapting and storing. Montazemi & Gupta (1997), although focusing on the system’s decision making about how to retrieve a similar case, elaborate the process between adapting and storing, i.e., evaluating the adapted solution, and predicting success or failure of the solution. Incorporated with
Leake’s concept of analogy (1996b), a process model of the CBR system is proposed below (Figure 1).

The proposed CBR process emphasizes the performance of analogical reasoning and the feedback of evaluation in order for a case-based reasoner to learn its lessons while adding a new experiential episode of success or failure to its memory. As Leake (1996) pointed out, case-base reasoning can be viewed as fundamentally analogical. Didierjean and Cauzinille-Marmeche (1998) discussed that there are two processes underlying reasoning by analogy: one is to use abstract knowledge; the other is to use case-based reasoning. Previous psychological experiments show that human reasoners do use both processes of reasoning by analogy simultaneously (Goldin-Meadow et al., 1993; Didierjean & Canzinille-Marmeche, 1998).

In case-based reasoning, the degree of relevance of the retrieved case to the new situation is a crucial element to the reasoning process. Thus, the research on CBR is more concerned with the issue of indexing to form correspondence between the new experience episode and a previous one. The index is important because an index for a case allows a reminding strategy to recognize situations in which the case is relevant. Kolodner (1993) made a very clear statement about the importance of such indexing. She defined a case as “a contextualized piece of knowledge representing an experience that teaches a lesson fundamental to achieving the goal of the reasoner” (p. 15). The key element for learners to remember in applying the previous cases is how much information an index is able to capture about those cases so that the situations to which the cases apply can be identified. Thus, in the CBR approach, solving a problem consists of searching out the nearest case and then adapting it without mediation of a more abstract knowledge structure.
Figure 1. A process model of the CBR system
(Hammond, 1990). From this perspective, this case based analogical reasoning contrasts with rule-based learning.

According to Anderson’s ACT theory of learning, in order to become truly expert in a field, a learner must learn the abstract principles in the domain and how those principles apply in practice. But, if CBR uses a representation of specific episodes of problem solving to learn to solve a new problem, can such analogical reasoning support expertise? The answer to the question may lie in the exploration of what the analogical reasoning is about. Carbonell (1986) distinguished two types of analogical reasoning. Transformational analogy works on the basis of representations of past solutions, where the solutions can come from one’s own problem solving or are provided in the form of examples. Derivational analogy is much richer in its specification about why a certain solution is taken and why the solution is better than the alternatives. Maher, Balachandran, and Zhang (1995) interpreted such distinctions in the CBR paradigm: transformation analogy learns from the solution for the previous experience, and derivation analogy learns from the problem solving process performed in the previous experience. From the perspective of machine learning, Reinmann and Schult (1996) found that to foster derivialational analogical reasoning in learners through cases is promising. The strength of the analogical reasoning depends on the study process of representing and using cases. Simply copying the steps from the past solutions, such as the system based on trasnformational analogy, is not enough. A more reconstructive approach is needed.

Another issue about learning through cases is that people are not necessarily reminded of the most relevant prior cases and may fail to notice important similarities
between old and new cases. Gick and Holyoak (1980) found out that not until the participants provided their own solutions to the military problem were they able to generate an analogous solution to the medical radiation problem. Also, not until the participants were encouraged to use one of the problems as an analogous solution could they transfer the solution in the military problem to the medical radiation problem.

Moreover, research on the novice-expert differences also shows that novices concentrate mainly on the salient feature whereas experts concentrate on the inferred attributes of a problem description (Chi, Feltovich, & Glaser, 1981). In other words, novices rely more on surface features while experts look into the underlying problem solving structures. Novices have difficulties in interpreting examples and problem-solving episodes because of their lack of knowledge to come up with inferences. It seems that the learners as novices need to be guided to reason from the provided case to the current problem situation they are involved in. Therefore, how we can help students to reason through the problem situation they are facing while retrieving a case can be an instructional design issue.

To refine the expertise in retrieving and adapting stored cases, Leake (1996) proposed to use introspective learning. Learners have to be aware of their own problem-solving process in order to become successful case-based reasoners. Also, Chi et al. (1989) observed that students who explain to themselves problematic aspects of worked example show superior problem solving. Better learners learn by constructing explanations to help understand the presented examples. Reimann and Schult (1996) suggested that a problem solver to take into account the rationale to the example solution when trying to relate it to a new problem-solving task. In other words, in order to learn
successfully from examples, one must identify operator-goal relations, i.e. the problem solution steps to each other and to the goals those steps serve. On the basis of those suggestions as well as the research findings of the self-explanation, guided questions for students to reflect their own thinking process and to explain the rationale to their decision-making would be beneficial. The guided questions will be developed based on the content of self-explanation found in Chi et al.’s research (1989), and on the conditions of analogical reasoning suggested by Vosniado and Ortony (1989). Overall, the guided questions would ask students to elaborate the conditions of the applications of action, the consequences of actions, and the relationship of actions to goals. Also the guided questions would encourage students to monitor their thinking process. The sample examples of these questions would be like the questions, such as: In what ways, is the retrieved case similar to the problem you are solving? In what ways, is the retrieved case different from the problem you are solving? What can you learn from the retrieved case? What will be the results if you use the same solution in the retrieved case to the problem you are solving?

Purpose

The present study has two major objectives. One is to assess the effect of a case library implemented in a problem-based learning environment on the learners’ problem solving skills. The other is to examine the influence of a set of guided questions for self-explanation provided during the inquiry about solutions to a problem on the learners’ analogical reasoning ability. An underlying assumption is that a group of novice learners with access to a case library while solving a problem will be able to index design cases more like experts and to identify better the similarities between cases than the control
group of novice learners without access to the case library. Also, the case library group equipped with the guided questions for self-explanation will be able to assess better the similarities and differences between the previous problem and the present one, and be able to articulate better their reasons to support their solution than the case library group without the guided questions. Two specific research questions will be investigated:

1. Does access to a case library have stronger effects on the learners’ organizational structures of knowledge in terms of indexing ability?
2. Do the guided questions for self-explanation enhance learners’ analogical reasoning ability?

Method

Subjects

This study will implement a case library as an instructional intervention in an information technology design course. The reason for choosing information technology design as the subject matter is a pragmatic one. Designers have been seen making extensive use of cases (Domeshek & Kolodner, 1993; Maher, Balachandran, & Zhang, 1995). The resource for cases and the guidelines of indexing would be more readily available. Students in the course will be randomly assigned into three groups: one control group and two experimental groups. The two experimental groups differ from the control group in that the former will have access to a case library. The difference between two experimental groups is the presence of a set of questions guiding their reading of the retrieved cases. The control group is given articles related to design topics similar to the case library, but not in case formats and not indexed.
Howard Barrows (1996) lists the six original characteristics for the problem-based learning model employed in the medical school as follows: (1) learning is student-centered, (2) learning occurs in small student groups, (3) teachers are facilitators or guides, (4) problems form the original focus and stimulus for learning, (5) problems are vehicles for the development of clinical problem solving skills, and (6) new information is acquired through self-directed learning. In this study, the PBL environment will be set up on the basis of these characteristics. However, the small groups have to be divided within the control group and the experimental groups themselves to control the external validity on treatment diffusion.

**Materials**

For the purposes of this study, the different types of learning resources are the independent variables: a case library as a learning resource without guided questions, a case library as a learning resource with guided questions, and articles as learning resources. A case will be defined as a description of a specific design incident or observation. Traditionally, cases have been conveyed orally and in writing, but multimedia technologies now provide for case presentation through film, graphics, and animation. In this study, the cases will be presented in writing in a course web site. The cases will be created by the professors of the course or purchased from groups such as idea group publishing. One issue about the cases is that sometimes the complex cases are too huge. Domesheck and Kolodner (1993) set an example about how to chunk the architecture design cases into pieces. Two main approaches are suggested: breaking the case up to reflect a goal/subgoal decomposition; breaking the case to reflect its physical parts. Also, the case library should consider the following principles: a sufficiently wide
range of cases to cover the opportunities for learning that may rise in the task environment; the indexing should be based on different design variables, such as design issues, system, stakeholders, and life cycle.

Instrument

The dependent variables are students’ indexing ability and analogical reasoning ability. The indexing ability skills will be assessed in two ways. For one, students will be given five multiple choice items; in each item, students will be asked to select the most appropriate indexing description for a case. Next, students will be asked to scale four different cases by the relevance of each case to a given problem. Five test items in this assessment will be given; the answers will be scored against the scale rated by an expert. The rationale behind these two assessments is from the viewpoint of knowledge organization. The more able the learners, the more likely their memory structure will be similar to an expert’s. The method of assessing analogical reasoning skills will be to give students a case to read and then ask them to solve two types of problems with supporting reasoning: surface-similar and structure-similar. The quality of the reasoning will be assessed by a rubric created by an expert in the field. The rubric will consist of criteria such as the appropriate association between cases and the validity of content support. The data collection involves the administration of a pretest and a posttest that measure the dependent variable after a four-week session on a system design issue. Although the pretest might produce threats to internal and external validity, it is used here to detect the initial differences between three groups.
Procedure

The sequence of the treatment procedure is modified based on Hernandez-Serrao’s research (1999). The procedure is expected to last a four-week session on a major topic on information technology design. The procedure is divided into the following steps:

1. In the first class period, all students will be given a problem case dealing with an information system design issue, such as client/server technology. All participants spend 50 minutes in reading, analyzing and discussing the case individually and in groups.

2. A pretest will be administered.

3. Students will be randomly assigned to one control group and two experimental groups. Different access codes will be given to students in each group to give them different access to the learning resources.

4. For the next three weeks, all three groups will continue to work on their own as well as other regular class activities. Students are asked to use the resource to help them to work on the problem case.

5. A posttest will be administered.

In summary, a pretest-posttest experiment with cluster sampling assignment of subjects to experimental and control groups will be employed to examine any possible treatment effect due to exposure to a case library and guided questions. The main analysis of data in this study concerns the group differences in problem solving skills related to case-based reasoning. Analysis of Variance (ANOVA) will be employed, in which the effects of different treatments on the dependent variable will be examined by the group
differences in the gains of the posttest against the pretest. The statistical significance of the contribution to indexing ability and analogical skills of learning treatments will be tested.

References


http://www.utmb.edu/meo/f0000003.htm


