Case-Based Reasoning and Instructional Design: Using Stories to Support Problem Solving

David H. Jonassen
Julian Hernandez-Serrano

With an increased emphasis on problem solving and problem-based learning in the instructional design field, new methods for task analysis and models for designing instruction are needed. An important methodology for both entails the elicitation, analysis, and inclusion of stories as a primary form of instructional support while learning to solve problems. Stories are the most natural and powerful formalism for storing and describing experiential knowledge that is essential to problem solving. The rationale and means for analyzing, organizing, and presenting stories to support problem solving are defined by case-based reasoning. Problems are solved by retrieving similar past experiences in the form of stories and applying the lessons learned from those stories to the new problems. In this paper, after justifying the use of stories as instructional supports, we describe methods for eliciting, indexing, and making stories available as instructional support for learning to solve problems.

Most contemporary models of instruction, including anchored instruction (Cognition and Technology Group at Vanderbilt, 1994), problem-based learning (Savery & Duffy, 1995), open-ended learning environments (Land & Hannafin, 1996), constructivist learning environments (Jonassen, 1998), goal-based scenarios (Schank, Fano, Bell, & Jona, 1993), and others share an essential characteristic. The learning outcome for each is problem solving. That is, each of these models supports learning how to solve some kind of a problem. The emphasis on problem solving in the field of instructional design has increased. For example, the first principle of Merrill's (2000) first principles is that instruction should occur in the context of solving a problem.

Problem solving is a complex, multifaceted, and poorly understood kind of learning. Jonassen (1997, 2000) has attempted to articulate different kinds of problem solving and different learning and instructional requirements for each. However, insufficient advice is available to instructional designers to help them to design and develop learning and instructional supports for every kind of problem solving. In this paper, we describe perhaps the most generic and applicable form of learning support for problem solving, stories. We believe that stories elicited from skilled problem solvers, indexed for the lessons they have to teach, and made available to learners in the form of case libraries can support a broader range of problem solving than any other strategy or tactic. After describing the role of stories in individual, social and cultural meaning making, we describe methods for elicit-

ing, indexing, and making stories available as instructional support for learning to solve problems

STORIES, NARRATIVE DESCRIPTION AND LOGICAL EXPLICATION

Stories are the oldest and most natural form of sense making. Stories are the "means [by] which human beings give meaning to their experience of temporality and personal actions" (Polkinghorne, 1988, p. 11). Cultures have maintained their existence through different types of stories, including myths, fairy tales, and histories. Humans appear to have an innate ability and predisposition to organize and represent their experiences in the form of stories. One reason for that proclivity is that stories require less cognitive effort than exposition because of the narrative form of framing experience (Bruner, 1990). To be part of a culture, it is necessary to be connected to the stories that abound in that culture (Bruner, 1990). We are surrounded by stories in our everyday and professional lives. Telling stories has many functions. It:

- Is a method of negotiating and renegotiating meanings (Bruner, 1990; Lodge, 1990; Witherell, 1995) that allows us to enter into others' realms of meaning through the messages they utter in their stories (Polkinghorne, 1988);
- Helps us find our place in a culture (Bruner, 1990; White, 1981);
- Assists us in the sharing of our human diversity (Bruner, 1990);
- Helps us to learn, to conserve memory, or to alter the past (Bruner, 1990);
- Allows us to explicate (Bruner, 1990) and to interpret (Gudmundsdottir, 1995);
- Assists us in understanding human action, intentionality and temporality (Bruner, 1990; Huberman, 1995) by facilitating the understanding of the past events of one's life and the planning of future actions (Polkinghorne, 1988);
- Permits us to remember the unusual (as when we recount a traumatic incident) (Bruner, 1990; Schank, 1999);
- Aids us in the building of persuasive arguments (Bruner, 1990);
- Facilitates the attainment of vicarious experience (Bruner, 1990; Sutton-Smith, 1995) by helping us to distinguish the positive models to emulate from the negative models to avoid (Polkinghorne, 1988);
- Mediates in the process of articulating our identity so that we can explain to others who we are with a series of interconnected stories (Polkinghorne, 1988; Schafer, 1981); and
- Allows us to embark on the authentic exploration of experience from a particular perspective (McEwan & Egan, 1995).

Historical Perspective

Given that stories are so ubiquitous, why are stories not a commonly accepted form of teaching and learning along with logical exposition? Despite their centrality for recounting human affairs, narrative has only recently been examined in cognitive science (Polkinghome, 1988). Stories traditionally represented a scientifically unacceptable form of logic. Logical exposition, the preferred medium for scientific discourse, applies formal and empirical proofs, while narrative convinces through verisimilitude (Bruner, 1986). Logical exposition has traditionally been used to teach problem solving, because education was impelled to appear scientific in its discourse. Despite the dominance of logical forms of exposition in academic disciplines, it is the narrative form of explanation that "just plain folks" (Lave, 1988) use in their everyday negotiations of meaning and problem solving. Narrative seems to convey its message in an inherently human dimension, a dimension that is inexorably lost in a logical exposition (Coles, 1989; McEwan & Egan, 1995; Polkinghorne, 1988).

Narrative has been ascribed the quality of "entertainment value" (McEwan & Egan, 1995, p. xii) and was thus not seriously considered as an alternative—certainly not an equal—form of explanation in most scientific disciplines. The exceptions to the dominance of logical exposition in scientific discourse are history, anthropology, and qualitative sociology ex-

planations (Bruner, 1990; Polkinghorne, 1988). In the natural sciences, narrative was not considered a form of explanation at all. Narrative was considered to be "simply too elementary a form of discourse even to pretend to satisfy the requirements for scientific deductive-nomological explanation" (Polkinghorne, 1988, p. 45). In addition, since narrative expression is highly dependent on context and voice, traditionally it has been suppressed in scholarly writing in an attempt to meet "the scientific ideal that identifies objectivity with the scientist's detachment from the object of study" (McEwan, 1995, p. 167).

Recently, narrative has begun to play a more important role, at least within the social sciences. This results from a paradigm shift within the social disciplines. Starting with debates on history in the 1960s, literary criticism in the 1970s, and psychology in the 1980s (Polkinghorne, 1988), this move has brought most social disciplines—such as cognitive psychology, linguistics, philosophy, literary theory, education, humanities, anthropology, history, and other—to revisit or accept interpretative approaches of research as legitimate means of understanding (Bruner, 1990). Rather than generating scientific and rigorously rational explanations of phenomena, the new concern of these disciplines now seems to be with "meaning-making" (Bruner, 1990). With renewed interest in finding ways to explain how people—particularly just plain folks—construct and negotiate meaning in a community, these disciplines are concentrating on the role that language plays in the process of creation and negotiation of meaning, and the role that narrative plays in this process. According to Polkinghorne (1988), only narrative can play this important role because it "functions to organize elements of awareness into meaningful episodes" (p. 1).

Stories in the Workplace

In professional contexts, people are usually expected to solve problems. In order to solve problems in those contexts, stories are almost always used in the process. Polkinghorne (1988) found that practitioners primarily prefer to work with narrative knowledge when asked to provide explanations. They seem to be most concerned with people's stories: "They work with case histories and use narrative explanations to understand why the people they work with behave the way they do" (p. x). Schön's (1993) research revealed that the subjects he studied—architects, engineers and psychotherapists—most often encoded their experiences in narrative form by using case histories and narrative explanations. This was particularly true of psychotherapists whose work primarily involved people. These practitioners offered stories to explain and justify their thinking and actions drawing from "a *repertoire* of examples, images, understandings, and actions" (p. 138, emphasis his). The world of these practitioners revolved around a "virtual world of talk" in which "storytelling represents and substitutes for firsthand experience" (p. 160). Furthermore, Schön found that intuitive understanding with these practitioners was supported not so much by technical and logical expositions as it was by "their repertoire of familiar examples and themes" (p. 166) as articulated in "stories of past experience which served as exemplars for future action" (p. 242).

In an ethnographic study of problem solving among refrigeration service technicians, Henning (1996) found that stories served as a mechanism for promoting an ongoing discourse between technicians, machines, products and people. Stories afforded technicians a means to form and express their identity as technicians and to assist others in their initiation. By being able to tell stories to their co-workers, technicians, particularly the newer ones, were able to form and strengthen the bonds that give cohesiveness to their community of practice. Technicians shared stories about initiation, identity formation, their sense of pride, and in general about the drama of facing responsibility, and unusual and difficult situations. These stories reinforced the technicians' identity, which contributed to their further participation in the community they were continuously building.

Orr (1996) found that among photocopy technicians "narrative forms a primary element of this practice" (p. 2). He found that diagnosis happened through a narrative process, it formed

the basis of the technician's discourse, and it provided "the means for the social distribution of experiential knowledge through community interaction" (p. 2). Orr found that these practitioners employed storytelling for framing and dealing with problems. Narrative was used for explaining catastrophes; for understanding, explaining, and arriving at diagnoses; for teaching and learning new methods; for dealing with uncertainty; for changing perspectives on problems; for warning about failures; for providing solutions; for expanding the problem space; for finding causes to problems; for illustrating a point; for challenging a fellow technician; for building confidence as problem solvers; and for anticipating future problems (Orr). For these photocopy technicians, stories were an important source of information that served as the "community memory of the technicians, in which they preserve and circulate their hard-won knowledge of machine arcane, usually in the form of war stories" (p. 117). When called out on a difficult problem, a technician was invariably expected to bring good recollections to bear to the problem situation by producing a good diagnostic story. A good memory of stories of this sort would make a technician "a popular resource" (p. 117).

Lave and Wenger (1991) found stories to be critical also for initiating new members into a practice. While studying apprentices in their work setting, they found that "apprenticeship learning is supported by conversations and stories about problematic and especially difficult cases" (p. 108). In these settings, stories were used as "communal forms of memory and reflection" (p. 109).

To summarize, these studies in everyday and professional contexts have shown that narrative is a primary medium for problem solving. The narrative dialogue of reflection and interpretation sustained by these practitioners is how "experience is transformed into pedagogical content knowledge" (Lave & Wenger, p. 30). Having reviewed how stories play such an important role in the nonformal learning settings like the workplace (as opposed to formal learning settings such as the classroom), we now turn to how stories can play a more important role in formal learning settings.

THE ROLE OF STORIES IN LEARNING TO SOLVE PROBLEMS

In this section, we propose that in order to educate professionals equipped to deal with the complexity of workplace situations (i.e., to solve ill-structured problems) we should expose them to stories generated at the workplace. One way to do this is by exposing them to narratives or stories or cases that have been compiled into a case library (database of stories made available to learners as a form of instructional support). Why should we do this?

The skills and techniques of traditional expertise, particularly as they are being taught in schools, do not match the complexity found in the fields of medicine, management, engineering and many other professions. Novices in school are trained only to work on problems that are, by nature, decontextualized and well structured, while problems in everyday and professional contexts are complex and ill structured (Jonassen, 1997, 2000; Lave, 1988). Unlike well-structured problems encountered in formal education, ill-structured problems do not have single solutions, are open ended, are composed of many subproblems, frequently have many possible solution paths, and possess no clear beginning or end (Jonassen, 1997; Kolodner, Hmelo & Narayanan, 1996; Sinnott, 1989).

Given this mismatch between the kinds of problem solving being learned in formal settings and the methods used to solve problems in nonformal settings, we propose the use of stories as a primary instructional method.

Why use cases and stories in instruction? Klein and Calderwood (1988) found that experts (fire commanders, tank commanders, and system designers) relied more heavily on cases based on past experience than on abstract principles when making decisions with a high degree of uncertainty. The stories they recalled focused on situational awareness and generating expectancies and options. Ross (1986, 1989) found that people learning a new skill naturally use what they have learned in a previous problem and apply it to a new problem. Lancaster and Kolodner (1988) found that car mechanics frequently use their experiences and those of others when wrestling with new problems,

while Kopeikina, Brandau, and Lemmon (1988) found similar evidence with GTE™ engineers trouble-shooting phone switching networks. The reuse of cases is essential to learning how to perform complex tasks.

How can we uses cases and stories in instruction? In business education, Schön (1993) recommended conducting a "carefully guided analysis of innumerable stories drawn from real-world business contexts in order to help students develop the generic problem-solving skills essential to effective management" (p. 30). Learners should reflect on the similarities and differences between the problem situation and the given case or story. By being exposed to numerous cases or stories while wrestling with a problem situation, the learner will be expected to "reflect in action," that is, "on-the-spot surfacing, criticizing, restructuring, and testing of intuitive understandings of experienced [sic]" (p. 241). Lave and Wegner (1991) also supported the use of stories because "apprenticeship learning is supported by conversations and stories about problematic and especially difficult cases" (p. 108). For these reasons, Schön (1993) urged educators and trainers to accumulate and describe cases or stories in ways that engage reflection in action for all professions.

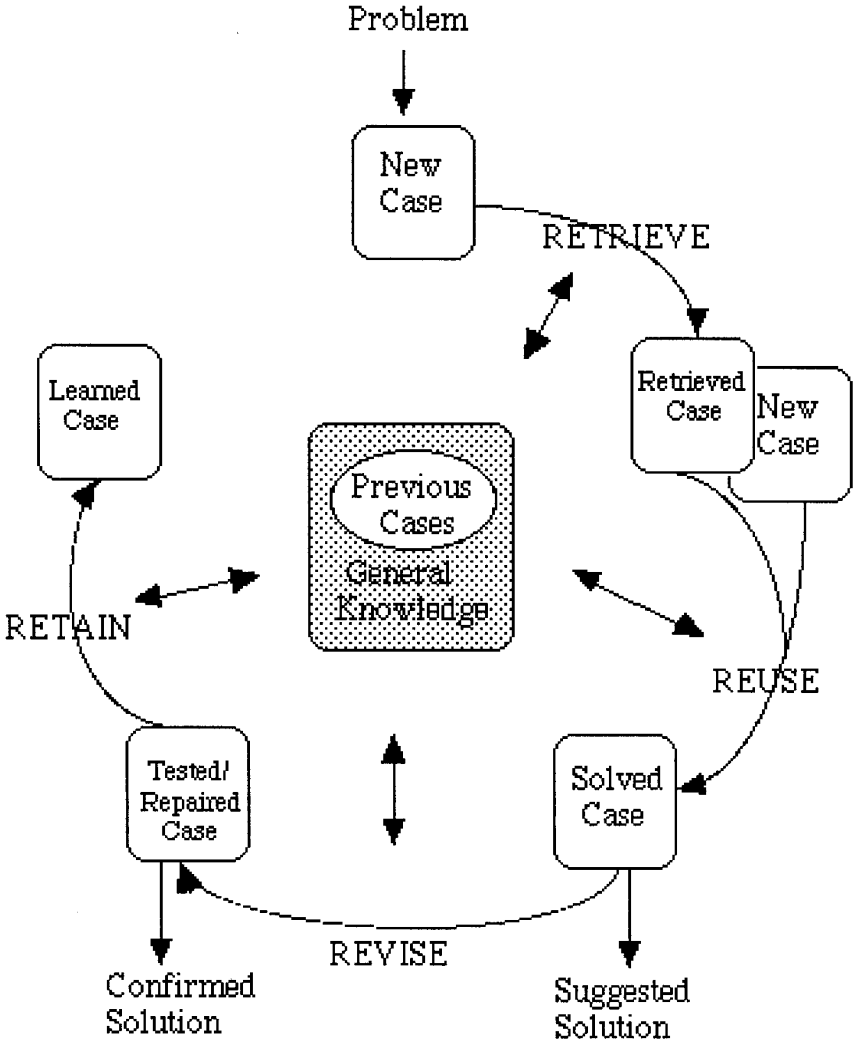
Schank (1990, 1999), an early proponent of using stories for promoting problem-solving skills, believed that relating and listening to stories was the most important element in learning. Why is that? Bruner (1990), Randall (1999), and Polkinghorne (1988) also argued that because the sharing of stories through our lives is so important, we must possess some kind of "narrative intelligence" that allows us to formulate or follow a story. Like Schank, they all recognized stories as being part of our cognitive repertoire for thinking, explaining, understanding, and remembering.

An assumption shared by all of these researchers is that stories can function as a substitute for direct experience, which novice problem solvers do not possess. Supporting learning with stories can help students to gain experience vicariously. If you recall the stories that you most like to tell, it is likely that many of them were told to you by someone else. They do not represent your direct experience. Some people believe that hearing stories is tantamount to experiencing the phenomenon oneself (Ferguson, Bareiss, Birnbaum, & Osgood, 1991). In other words, the memory structures used for understanding the story are the same as those used to carry out the task. Given the lack of previous experiences by novices, experiences available through a case library are expected to augment their repertoire of experiences by connecting with those they have experienced. Their prior experiences serve as a basis for interpreting current and future stories, forewarning us of potential problems, realizing what to avoid, and foreseeing the consequences of our decisions or actions. It is suggested that this kind of reasoning—that is, reasoning from stories or cases—provides support to "inferences necessary for addressing the kinds of ill-defined or complex problems that come our way in the workplace, at school, and at home" (Kolodner, 1997, p. 58).

Collins (1991) proposed that learning environments (specifically those that follow cognitive apprenticeship prescriptions) ought to have ways to incorporate demonstrations on how experts solve problems. He lamented that in textbooks students see only worked-out solutions that do not show the false starts or dead ends that characterize real-world problem solving. Furthermore, he stated that by having an expert reflect on how she or he solves problems, learners can benefit greatly by "seeing" this otherwise covert problem-solving process at work.

The process of understanding and solving new problems using case libraries has three parts: (a) recalling old experiences, (b) interpreting the new situation in terms of the old experience based on the lessons that we learned from the old experience, or (c) adapting the old solution to meet the needs of the new situation (Kolodner, 1992). Recalling old experiences depends on how well those stories are indexed; that is, how well the characteristics or attributes of the old experience were filed in memory. More clearly indexed stories are more accessible and therefore more usable. Interpreting a problem is a process of mapping (comparing and contrasting) the old experience onto the new one. If the old case offers useful advice or solutions for the new one, then it is used. If not, then

Figure 1 □ Case-based reasoning (CBR) Cycle, Aamodt & Plaza, 1996



the old case is adapted by inserting something new into an old solution, deleting something, or making a substitution (Kolodner, 1992).

This process is described by Aamodt and Plaza (1996) as the case-based reasoning (CBR) cycle (Figure 1). An encountered problem (the new case) prompts the reasoner to retrieve cases from memory, to reuse the old case (i.e., interpret the new in terms of the old), which suggests a solution. If the suggested solution will not work, then the old and or new cases are revised. When the effectiveness is confirmed, then the learned case is retained for later use.

Although CBR appears intuitively sensible, very little empirical research on the role of stories in problem solving has been conducted. Most of the research in case-based reasoning has been conceptual and developmental, focusing on the building of case libraries without testing their efficacy.

INSTRUCTIONAL DESIGN WITH STORIES

Collecting and analyzing stories can be used in two primary ways by instructional designers: (a) to perform task analysis and (b) as a learning support during instruction.

Case-Based Reasoning as a Form of Cognitive Task Analysis

Collecting and indexing stories from practitioners can provide one of the richest forms of cognitive task analysis (Jonassen, Tessmer, & Hannum, 1999). Collecting stories from experienced practitioners will provide relevant information that can be used for interpreting and understanding problem-solving tasks in order to design instruction. In addition to providing potential case problems for solving, that information will also yield an abundance of conceptual and strategic knowledge that can be included in the instruction. Why? Because when eliciting stories, practitioners naturally embellish their stories with contextual information, heuristics, practical wisdom, and personal identities (Henning, 1996; Schön, 1993).

In order to analyze stories using CBR, it is necessary first to elicit and capture relevant stories about previously solved problems from the practitioners. The goal of capturing stories is to collect a set of stories that is relevant to domain problems and the kind of information that was relevant to their solution. Relevance to problem solving means that the story can provide lessons to the problem solver in order to help solve a problem. In order to collect stories from practitioners, we recommend the following four activities:

1. Identify skilled practitioners in the domain. Skilled practitioners are those who have some years of experience in solving problems similar to the ones that you are analyzing. These practitioners probably should not be deemed experts. Expertise often results in a knowledge compilation that makes articulation of knowledge about the domain difficult for the expert. Experts are often unable to unpack and articulate the reasoning behind their problem-solving activities.
2. Show the practitioners the problem for which you are seeking support. That is, present one problem at a time. Present the problem to the practitioners. It is not known how realistic the problem representation needs to be with these practitioners. It is very likely that a verbal description, that is, a story about the problem, is all that is needed to remind practitioners of their experience solving similar problems. The problem representation should include all of the important components of the problem situation, including contextual information.
3. Ask the practitioners if they can remember any similar problems that they have solved. If they can (and they usually can), allow them to tell a story about the problem without interruption. Audiotape or (better yet) videotape their recounting of the story. Following the telling of the story, analyze it with the practitioner. Work with the practitioner to:
   - Identify the problem goals and expectations
   - Describe the context in which the problem occurred
   - Describe the solution that was chosen
   - Describe the outcome of the solution. Was it successful? Was it a failure? Why?
   - Identify the points that each story makes (i.e., the lessons that it can teach).

   Prompting practitioners to ensure that all of the necessary information is included is very important.

   A rich model for structuring those prompts is PARI (Hall, Gott, & Pokorny, 1995). PARI seeks to find the *P*recursors (relevant factors that test for requisite prior knowledge) to the *A*ctions (decisions) with an *I*nterpretation of the *R*esults from tests of the system they are troubleshooting. PARI uses a structured interview to see how experts solve problems posed by other experts under realistic task conditions and to discover what kinds of knowledge they need in order to solve those problems. The experts are interviewed during and after solution of a problem. The postsolution interview is an *abstracted replay* of their solutions focusing on the reasoning they used in making each of the decisions. The interviews produce detailed protocols that provide recommendations for both system-specific and general kinds of strategic knowledge.
4. Decide what the stories teach. The final step in the analysis process is to index the stories. Indexing stories is the primary analytic activity in the CBR process. It is described here

because it is an important task-analysis method. Indexing a number of stories will also provide useful prompts to use when eliciting stories from other practitioners.

Schank (1990) argued that the "bulk of what passes for intelligence is no more than a massive indexing and retrieval scheme that allows an intelligent entity to determine what information it has in memory that is relevant to the situation at hand, to search for and find that information" (pp. 84–85). We tell stories with some point in mind, so the indexing process tries to elucidate what that point is, given a situation. Schank (1990) believed that indexes should include the experience and the themes, goals, plans, results, and lessons from the story. Themes are the subjects that people talk about. Goals motivated the experience. Plans are personal approaches to accomplishing those goals. Results describe the outcome of the experience. The lesson is the moral of the story—the principle that we should take away from the case. Indexing is the process of assigning labels to cases at the time that they are entered into the case library (Kolodner, 1993). These indexes are used to retrieve stories when needed by comparing new problems to those stored in the case library.

Stories can be indexed in two ways. (a) The more common method is through direct input by the human user, who must appropriately index the stories in order to make them accessible in a case library. (b) Stories can also be indexed for case libraries by adapting and reindexing already existing cases to new situations (Kolodner, 1992; Kolodner & Guzdial, 2000). For each case, identify the relevant indexes that would allow cases to be recalled in the situation. Choose from among the following indexes, most of which were suggested by Kolodner (1993):

Problem-situation-topic indexes

—What were the goals-subgoals-intentions to be achieved in solving the problem or explaining the situation?

—What constraints affected those goals?

—Which features of the problem situation were most important and what was the relationship between its parts?

—What plans were developed for accomplishing the goal?

Appropriate solution indexes

—What solution was used?

—What activities were involved in accomplishing the solution?

—What were the reasoning steps used to derive the solution?

—How did you justify the solution?

—What expectations did you have about results?

—What acceptable, alternative solutions were suggested but not chosen?

—What unacceptable, alternative solutions were not chosen?

Appropriate outcomes indexes

—Was the outcome fulfilled?

—Were expectations violated?

—Was the solution a success or failure?

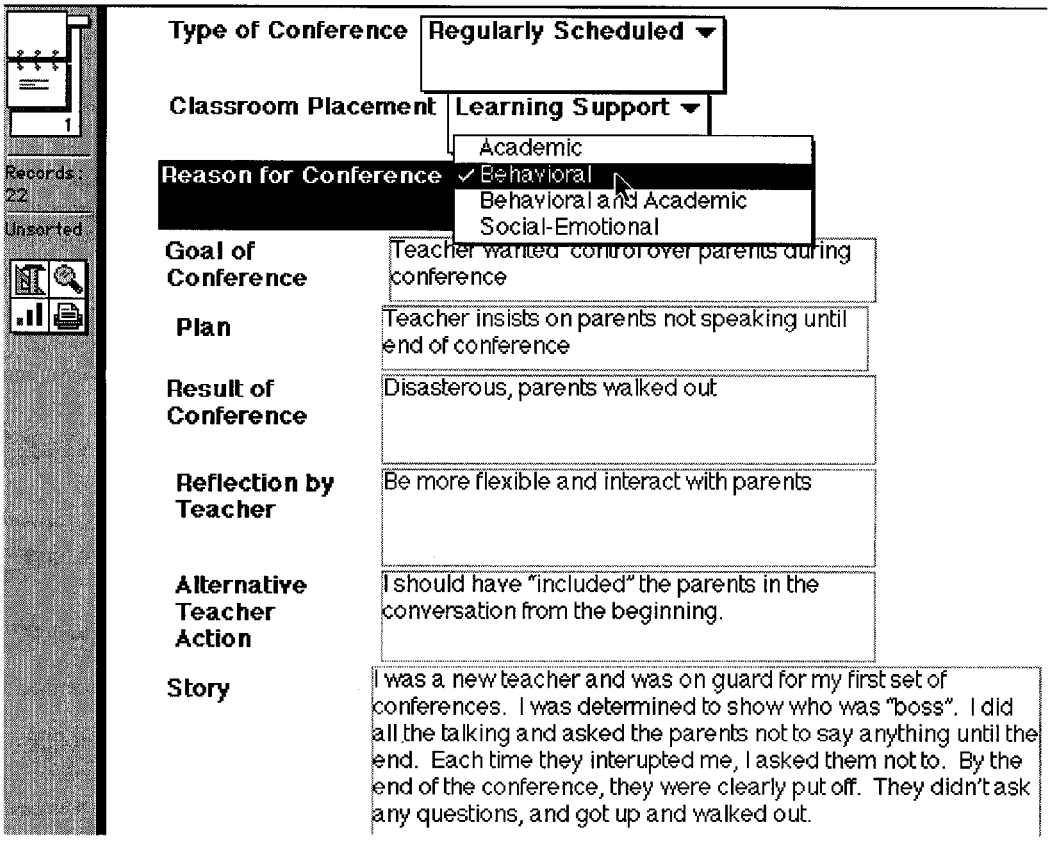
—Can you explain why any failures occurred?

—What repair strategies could have been used?

—What could have been done to avoid the problem?

The result of the elicitation and indexing of stories from practitioners will provide more than enough information to design almost any form of problem-based learning environment. Although this information is activity oriented, links to theory will be obvious in the data. Figure 2 shows a database record from a collection of stories about how to conduct parent-teacher conferences. This analysis was being conducted in order to build a constructivist learning environment for preservice teachers on different components of classroom management that had been identified from a needs assessment. Indexes that were produced to analyze each teacher story included the type of conference, classroom placement, reason for the conference, plan, result of the conference, and so on. Building an environment around these stories was greatly facilitated by this database. Although stories provide activity-based descriptions rather than content descriptions, linking to con-

Figure 2 □ Parent-Teacher conference case



tent is easy. Selecting any index and asking why that action was taken provides immediate links to principles, models, and theories related to the action. Nearly all forms of problem-based learning begin with a problem and teach the content in the context of the problem. With case-based reasoning, the task analysis also begins with the problem.

How Can Stories Be Used in Instruction?

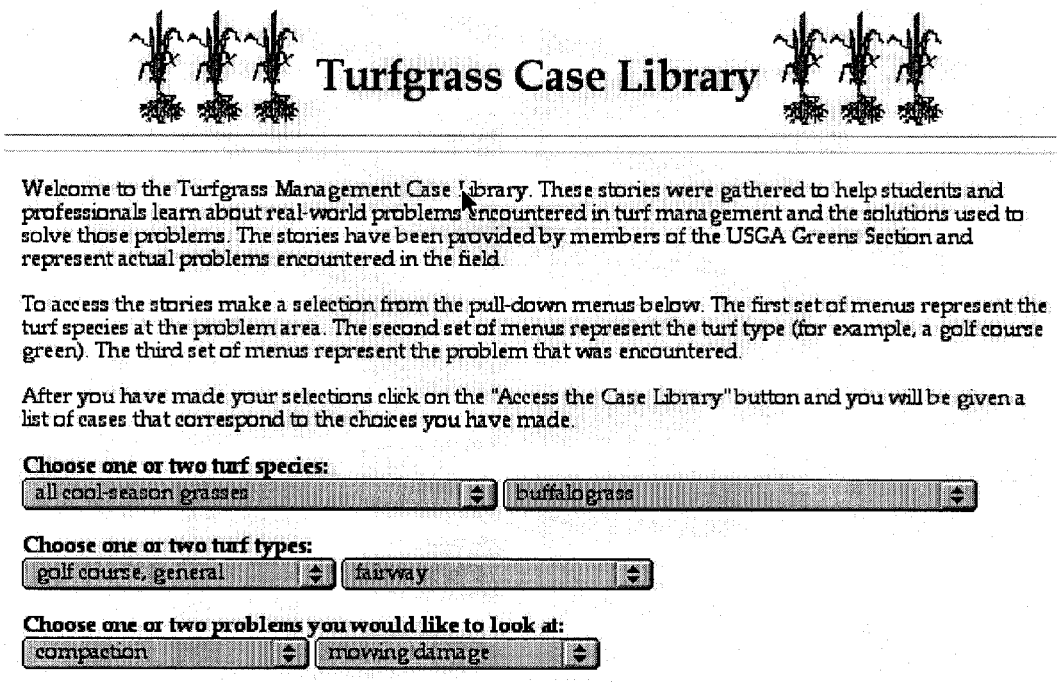
Stories that are collected during analysis can be used in at least three different ways to support learning. First, they can be used as exemplars of concepts, principles, or theories being taught by direct instruction. The role of example in instruction is perhaps the most inviolable principle of instructional design. Stories provide even richer examples, with powerful narrative memory links.

Second, they can be used as problem cases to be solved by students. Stories as problems is the basis for learning in anchored instruction, problem-based learning, constructivist learning environments, goal-based scenarios and most other contemporary models of instruction. Selecting stories that have particular lessons to be learned and representing them to learners as problem cases is a well-established teaching strategy.

Third, stories or cases can be used as advice for students, for helping them learn to solve problems. Students must examine the problem to be solved and construct meaning from similar cases in an effort to solve the current case. Because the first two uses of stories are well established in the instructional design literature, we will focus the remainder of the paper on this third application, case-based teaching.

Case-based teaching assumes that when confronted with a problem, people first try to

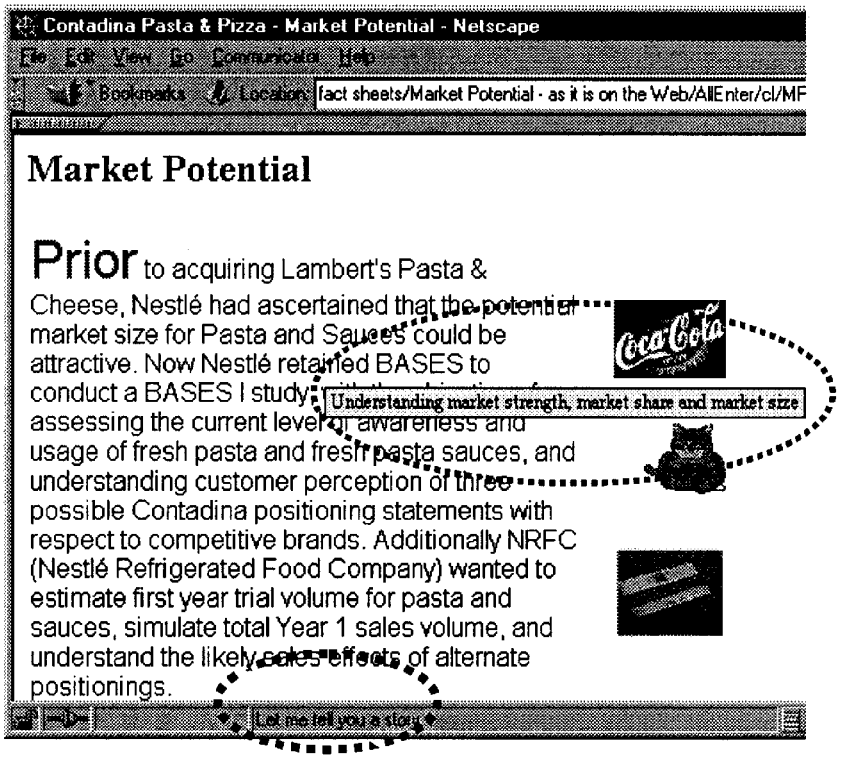
Figure 3 ☐ Turfgrass Case Library



remember a case in which they faced a similar situation (Schank, 1990, 1999). If a similar case is found, they reuse the solution to solve the current problem. If the current problem is similar, they will attempt to adapt the solution to the prior experience to use with the new situation. If the solution works, they will reindex the adapted case and commit it to memory (reindex it) as a new story applicable to this particular situation. However, if they are told that the solution is inadequate, people face what is called an expectation failure and are naturally challenged to find an explanation (Edelson, 1993; Read & Cesa, 1990; Schank, 1999). At moments such as these, people will be most receptive to learning through listening to or reading stories that show how experienced problem solvers have dealt with similar situations (Edelson, 1993; Schank, 1990, 1999). The memory structures employed while understanding and applying these stories are similar to those employed if the learner had originated the solution (Ferguson et al., 1991). In other words, understanding is functionally equivalent to experiencing. Whether understanding indirect experiences through stories by generating indexes based on the stories and situational features is indeed as powerful as direct, personal experiences is questionable. However, because direct personal experiences are difficult to execute and control, stories are the best available sources of insight while learning to solve problems. People's thinking is influenced indirectly, that is without experiencing failure, by simply being in contact with a story that embodies a potential problem-solving lesson. The story will become even more memorable if it includes a powerful index—that which makes the story truly memorable—that relates a current situation, prior experience or story with the new story.

Stories can be selected by students based on their perceived relevance, or they may be automatically selected by the learning environment using a CBR algorithm. Allowing students to select their own stories usually entails providing the indexes to the learners and allowing them to use them to retrieve what they believe are the most useful stories. An example of this use is the case library in turfgrass management (see Figure 3) that we developed. Learners logged onto the Website may choose to select cases based on specific grass species, the purpose of the turf, or

Figure 4 ☐ Learning Environment for the Food Product Development Case Library



the nature of potential problems, in order to compare these teaching cases with the problem cases they are working on. The stories themselves depict all of the contextual and functional information related to other real-world problems, the solutions that were attempted, the results of those efforts, and lessons to be learned from the case.

Stories or cases may also be automatically selected by a case-based algorithm and presented to the learners when they experience problems. That is usually accomplished by evaluating the similarity of the new problem to every index of every story contained in the case library. Typically using a nearest neighbor algorithm, the program calculates the degree of similarity between the problem as presented with those on the case library. The case example in Figure 4 is from "Market Potential" section of the Nestlé case (Bell, 1996), which presented food product development problems to college learners. The learning environment was set up around eight Web pages containing this segment of the case. Specific learning issues were raised on the case at key points in the text, and supportive stories could be accessed by learners in order to help them understand these key issues. For example, the first sentence as shown in Figure 4 raised the issue of ascertaining potential market size. At the right of this learning issue, the user would find an icon alluding to a story and its main theme. Upon sliding the mouse over it, a popup flashed the story's title, which corresponded to an "index" (Schank, 1999, p. 85) as articulated by the experts who recounted that story. This index was expected to help make the story memorable and assist in the future story retrieval process. Also, the phrase, "Let me tell you a story . . ." appeared on the browser's status line at the same time.

The best known model for this type of case-based teaching is the goal-based scenario (GBS). In GBSs, students become active participants in complex systems. They employ a "learning by doing" architecture (Schank et al., 1993), in which learners are immersed in a focused, goal-

oriented situation and required to perform authentic, real-world activities. They are supported with advice in the form of stories that are indexed and accessed using case-based reasoning. This automatic CBR analysis identifies instructive cases, those that denote the kind of problem situations for which one seeks to design instruction. Which cases are useful for analysis? If the case "is instructive such that it teaches a lesson for the future that could not have been inferred easily from the cases already recorded, then record it as a case" (Kolodner, 1993, p.12). Candidate cases have the following characteristics: They:

- Represent specific knowledge tied to a context.
- May cover small or large chunks of time.
- Record experiences that are different from what was expected.
- Possess useful lessons that helped the problem solver achieve some goal or that warn of potential failure.

SUMMARY

Stories are natural formalisms for storing and describing memories and experiential knowledge. Learning throughout the ages has relied on narrative for the communication of ideas and culture. Because stories are essential to solving complex, everyday and professional problems, we believe that stories should form a basis for learning how to solve those problems. In this paper, we have described how stories can be used as a task analysis tool and as an instructional aid in the form of case-based teaching. Problems are solved by applying the lessons learned from previous problem-solving experiences to the solution of new problems. Stories provide invaluable support to learners solving problems in problem-based learning environments. We have also described methods for eliciting, indexing, and making stories available as instructional support for learning to solve complex problems. □

David H. Jonassen is at the University of Missouri.
Julian Hernandez-Serrano is at the University of Puerto Rico.

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