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7. ADAPTING NARRATIVE THEORY TO IMPROVE THE IMPLEMENTATION OF STORY IN PROBLEM-BASED LEARNING

INTRODUCTION

Modern work is frequently characterized by complex, ill-structured problems. This is increasingly the case in domains across all sectors of society, both public and private, where safety and effectiveness depend on individuals and teams rapidly adapting to ambiguous and dynamic environments. However, the training and education programs designed to prepare personnel for these types of work environments tend to rely heavily on the acquisition of discrete knowledge. When practice opportunities are available, they often involve well-structured problems that are not representative of the real world complexity trainees will be expected to deal with on the job. These educational and training practices, in general, can leave individuals under-prepared for work in complex domains. Undoubtedly, expert performance depends on a large and well-organized knowledge base (de Groot, 1946/1978; Chase & Simon, 1973; Chi, Glaser, & Rees, 1982). However, the possession of discrete knowledge and experience applying it in highly structured problems has proven to be inadequate for ensuring high levels of performance in tasks demanding complex collaborative problem solving. In short, individuals are unable to adapt their knowledge acquired in well-structured classroom instruction to the ill-structured real world. To address this issue, Problem-based Learning (PBL) has been developed as an approach to curriculum design that seeks to bridge the traditionally present gulf between education or training and performance in the real world.

Formally beginning in the medical domain, PBL has a long history of implementation and is developed and applied in increasingly numerous contexts and domains. This expansion of application has created many variants of PBL methodology, none of which enjoy universal acceptance. Many people are implementing PBL into curricula, but just as many are doing it quite differently. In fact, the theoretical basis of PBL has been criticized as being insufficient to guide all aspects of its application (e.g., Colliver, 2000). In this chapter, we seek to strengthen the theoretical base supporting PBL through a critical examination of the role of narrative in complex team problem solving. Narrative plays an important role in the problem solving process in real world tasks, and through careful analysis of the theory of narrative and problem solving processes, the

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theoretical basis of PBL can be bolstered and more comprehensive guidance to the development of PBL curricula can be given. To this end, the goals of this chapter are to: 1) provide an understanding the type of performance that PBL must support in modern organizations by reviewing recent theorizing on macrocognition in teams, 2) outline the fundamentals of PBL and draw connections between complex collaborative problem solving, narrative, and PBL, and 3) provide an analysis of complex team problem solving from the perspective of narrative theory to further the understanding of how to develop PBL environments that may more effectively train problem solving in complex environments.

In short, by making these connections between PBL, macrocognition, and narrative theory, we hope to provide an initial starting point for further development of PBL strategies based in narrative theory. This approach holds promise generating guidance for the design of PBL that is more capable of developing the knowledge and skills necessary for proficient performance in naturalistic and complex environments. We begin with an introduction to macrocognition in teams.

DEVELOPMENT OF MACROCOGNITION CONCEPT

The past ten years have produced a substantial body of interdisciplinary research – much emerging from the fields of cognitive and organizational science – devoted to the study of teams. In some of this earlier research, constructs from cognitive psychology were used to foster the development of the team cognition movement in naturalistic decision making (NDM) research (e.g., Cannon-Bowers & Salas, & Converse, 1990; Hutchins, 1991; Orasanu, 1990; Rouse, Cannon-Bowers, & Salas, 1992). Since then, researchers have also focused on determining how cognition contributes to effective collaboration. A key idea shared across disciplinary boundaries is the notion that shared information processing among team members has both inter- and intra-individual outcomes (e.g., Engestrom & Middleton, 1996; Rouse et al., 1992). In this view, cognitive processes such as encoding, storage, and retrieval of information are thought to be equally applicable to both individuals and groups (e.g., Hinsz, Tindale, & Vollrath, 1997; Klein & Zsambok, 1997; Larson & Christensen, 1993; Thompson, Levine, & Messick, 1999; Tindale & Kameda, 2000). Such research has helped to develop a richer understanding of cognition in teams in naturalistic settings (e.g., Salas & Fiore, 2004).

To add to this body of research, we suggest bolstering these ideas from the cognitive and organizational sciences with principles of narrative theory in order to produce a more holistic understanding of problem solving in naturalistic environments. This understanding can then provide a more robust theoretical base to guide the PBL curricula needed to support the development of proficient performers in these types of tasks. Just as recent theorizing more closely links NDM with organizational decision making (see Lipshitz, Klein, & Carroll, 2006), we suggest that NDM and PBL designed to support decision makers in naturalistic environments would similarly benefit from consideration of theories emerging from other disciplines such as narratology (e.g., Bal, 1997; Onega & Landa, 1996). To support this assertion, we use this chapter to discuss how such an integration can proceed and emphasize its benefit to understanding macrocognition in teams and PBL.

The term 'macrocognition,' in contrast to the term 'microcognition,' is used to describe a variety of cognitive phenomena. In connectionism and cognitive science, researchers state that macrocognition refers to "those processes, such as reasoning and communication, where analysis does not take place at the level of the single processing unit. At these high level cognitive domains, analysis and simulation do not concern the *individual behavior of each neuron, but the functioning of the mind as a whole*" (Bara, 1995, p. 77, emphasis added). Within cognitive engineering, theorists suggest using the term 'macrocognition' to describe how cognition emerges in natural environments. This line of thinking is essentially based upon the work of Cacciabue and Hollnagel (1995) who introduced the term 'macrocognition' to describe naturalistic cognition and "the study of the role of cognition in realistic tasks, that is, in interacting with the environment" (Cacciabue & Hollnagel, 1995, p. 57). Klein and colleagues (2003) similarly argued that contextually bound cognitive processes (e.g., sense making, uncertainty management) must be studied in natural settings (Klein et al., 2003). These are environments in which complex and emergent cognitive processes arise (i.e., macrocognitive processes), as opposed to 'micro-cognitive' processes described as cognition used in laboratory studies. More recently, macrocognition was described in a discussion of the varied methods of cognitive task analysis to provide an illustration of the varied cognitive skills and strategies used in complex real world decision making (Crandall, Klein, & Hoffman, 2006).

Macrocognition has also been developed in the context of cognition in collaborative problem solving. In studies of collaboration, "macrocognition in teams", is used to describe internalized and externalized cognitive processes occurring during the solving of complex problems (see Warner, Letsky, & Cowen 2005). More specifically, macrocognition in teams is defined as the internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving (Letsky, Warner, Fiore, Rosen, & Salas, 2007). Here, 'high-level' is described as cognitive processing involved in the combining, visualizing, and aggregating of information to resolve ambiguity in support of the discovery of new knowledge and relationships.

Internalized processes can occur at either the individual or team level, but they can only be assessed using indirect techniques, such as qualitative metrics like cognitive mapping or think aloud protocols, or by using surrogate quantitative metrics such as galvanic skin response. Externalized processes are described as those higher-level cognitive processes which occur at the individual or the team level and which are associated only with actions that are observable and measurable in a consistent, reliable, repeatable manner. These are used by groups in complex settings where collaborative problem solving focuses on one-of-a-kind situations (e.g., hostage rescue scenarios). In this chapter we emphasize these types of problem solving environments to show how macrocognitive theory can be augmented with concepts from narrative theory and support instruction in preparation for problem solving contexts. Before providing an analysis and synthesis of complex team problem

solving and narrative theory, we first discuss some of the essential features of PBL. This discussion is necessary to illustrate the importance of connecting instructional strategies with a theoretical understanding of the type of performance being trained, that is, macrocognition in teams with PBL, as well as to illustrate the role that a view of macrocognition informed by narrative theory can play in PBL.

FUNDAMENTALS OF PBL

PBL has its formal origins within the School of Medicine at McMaster University in Candada in 1969 (Johnson & Finucane, 2000). The medical curriculum at McMaster was radical for its time, taking PBL as a cornerstone of its educational process. This fundamental change was spurred by a growing feeling among medical educators that traditional methods of medical education (i.e., extensive lecture-based coursework followed by the see one, do one, teach one method of practice-based learning) were insufficient. For example, medical students would undergo several years of lecture based instruction on the fundamental knowledge involved in practicing medicine (e.g., anatomy, physiology, disease processes). However, when students reached the hands-on clerkship portion of education, they were required to recall and apply this knowledge to the ambiguous and dynamic problems involved in patient care. Essentially, students were being asked to recall discrete knowledge, that was learned a year or two (or more) beforehand in a well-structured environment, and apply it in a dynamic and fluid manner to complex and ill-structured problems. The fundamental mismatch between the environment and methods of instruction as well as the temporal lag between acquisition and application of knowledge created large obstacles in the transfer of knowledge from the context of acquisition to the context of performance. It was not uncommon for students that performed at the top of their class in coursework to appear as if they had never learned anything about the basic science involved in medicine once they were finally given the opportunity to apply their knowledge to solving problems (Walton & Mathews, 1989).

As an alternative to this traditional method of medical education that separated the acquisition of discrete knowledge from the process of solving complex problems (which ultimately is one of the primary tasks of interest), PBL was designed to integrate the activities of knowledge acquisition with experience solving complex problems representative of real world performance. Generally defined as "the learning that results from the process of working toward the understanding or resolution of a problem" (Barrows & Tamblyn, 1980, p. 8), PBL is considered an educational strategy, or approach, but not a specific codified teaching methodology (Walton & Matthews, 1989). Although there are many methods of developing or implementing PBL, none are universally accepted. However, the core model developed from the original approach taken at McMaster includes the following features: 1) learning is student-centered, 2) learning occurs in small student groups, 3) a tutor is present as a facilitator or guide, 4) authentic problems are presented at the beginning of the learning sequence, before any preparation or study has occurred, 5) the problems encountered are used as tools to

achieve the required knowledge and the problem-solving skills necessary to eventually solve the problems, and 6) new information is acquired through self-directed learning (Barrows, 1996). These features of PBL have important implications for the present purposes. Fundamentally, learners engage in problem solving activities collaboratively as they work on 'authentic' problems. Thus, as with macrocognition in teams, the focus is on contextually sound problem solving scenarios – that is, problems developed with an understanding of their nature in complex real world environments. Therefore, an understanding of the nature of how teams solve problems in the real world is necessary to drive effective PBL.

While there is great variety in the specifics of how PBL is implemented, there is a general consensus on the goals of PBL. That is, PBL seeks to: 1) construct an extensive and flexible knowledge base, 2) develop effective problem-solving skills, 3) develop self-directed, lifelong learning skills, 4) create effective collaborators, and 5) produce students who are intrinsically motivated to learn (Barrows & Kelson, 1995). As will be illustrated in the following sections, we argue that an understanding of macrocognition viewed from the perspective of narrative theory can inform PBL design and implementation. Specifically, this approach can bolster the ability of PBL to develop large and flexible knowledge bases, effective problem-solving skills, as well as the learner's ability to solve problems in a collaborative setting.

There have been many efforts at testing the comparative effectiveness of PBL and traditional educational approaches at meeting these four goals in medical education (for recent reviews, see Gijbels, Dochy, Van den Bossche, & Segers, 2005; Colliver, 2000; Hmelo-Silver, 2004). The results of these efforts have been equivocal, but in general, it has been shown that students in PBL curricula do as least as well or better than students in traditional curricula (e.g., Distlehorst & Robbs, 1998). However, the large scale gains in performance outcomes hoped for by PBL advocates have not been born out in empirical studies. The general consensus attributes this shortfall to methodological problems with the studies evaluating the effectiveness of PBL (Gijbels et al., 2005; Albanese, 2000; Norman & Schmidt, 2000). Additionally, it has been argued that PBL lacks a solid theoretical basis, one that can sufficiently guide the development of a methodology of implementation (Colliver, 2000) and that different theories need to be explored (Albanese, 2000). There is substantial research on the first three goals of PBL, but there is far less theory or empirical research to guide the development of curricula to meet the goals of being effective collaborators (Hmelo-Silver, 2004). As such, in addition to providing general insight into the process of complex problem solving, narrative theory can also provide insight into the *collaborative* process of *team* problem solving. Before turning to an analysis of team problem solving based in narrative theory, we first discuss the role of stories to PBL.

The Importance of Stories in PBL.

The overall aim of PBL is to create experts in a domain—individuals with large and well structured knowledge bases who can quickly and effectively adapt their knowledge to new situation. Stories play a critical role in this endeavor for two main reasons. First, expertise is a product of years of experience within a domain

(e.g., Ericsson, Krampe, & Tesch-Romer, 1993) and stories can serve as a surrogate for some of this experience by augmenting the repertoire of first-hand experience with the essence of the experience of others (Klein, 1998; Jonassen & Hernandez-Serrano, 2002). Second, and most relevant to the design and delivery of PBL, stories are a part of the problem solving process. They are a means to building individual knowledge as well as a means to collaboratively generate a shared understanding of a problem. For example, problems in PBL for medical education have been most commonly framed as a data querying task (Barrows, 1986); that is, students are provided with a patient's chief complaint and are subsequently free to request any one of hundreds of pieces of information about the patient (e.g., history, physical exam, lab results). However, although this is representative of modern medical practice in general, this method has been criticized as deemphasizing the role of listening to the patient's narrative (Yamada & Maskarinec, 2003). Instead, the clinical problem solving process has been conceptualized as a process of social construction whereby the clinician student must understand the patient narrative and combine it with clinical information to build a shared narrative of what is happening to the patient (Yamada & Maskarinec, 2003). Even remaining within a positivist framework, narrative is considered a critical means by which individuals and teams build a shared representation or understanding of the situation. Building a quality representation of a problem is a critical step in solving the problem (Newel & Simon, 1972), particularly in team problem solving (Fiore & Schooler, 2004), as the representation of the problem serves as the basis for the pattern matching processes that allow experts to leverage their extensive experience and knowledge (Klein, 1998; Zeitz, 1997; Randel, Pugh, & Reed, 1996). While the importance of stories to solving problems in the real world in general and to PBL specifically has been noted in the literature at various points, a systematic evaluation of problem solving and PBL from the perspective of narrative is absent from the literature. In the following sections we provide the initial steps at integrating narrative theory, real world complex team problem solving, and PBL.

NARRATIVE THEORY AND COLLABORATIVE PROBLEM SOLVING

In the preceding sections, we have attempted to make the case that there is much to be gained from a synthesis of theoretical views. Specifically, we suggest that a richer understanding of the processes involved in complex team problem solving, driven by narrative theory, can inform the design and delivery of PBL curricula. In the following sections, we hope to lay the groundwork for such a synthesis by providing an analysis of complex team problem solving from the perspective of narrative theory.

REPRESENTING REALITY

Perhaps humankind's greatest accomplishment has been the multi-faceted ways it has developed to represent reality (Donald, 1991; Norman, 1993). As Fiore et al. (2007) noted, humans have developed four primary representational systems

through the ages to encapsulate and communicate our numerous conceptual and emotional understandings of our world. First is the visual or pictorial system of representation where images are used to capture some phenomenon. From the first cave paintings to the literal interpretations of the renaissance artist to the abstract forms of modern art, images varying in complexity and meaning have been developed to help us understand, appreciate, and interpret the world around us.

In addition to visual forms of representation, we invented mathematical systems as the symbolic tools to help us account for and predict the abstractions of the physical world and music to capture the emotional and affect laden aspects of our existence. But it is narrative that is perhaps best suited to effectively convey a complex reality. When done well, narrative is able to capture and convey not only the evocative but the cognitive complexities we experience as we interact with our world. Interestingly, in the context of problem solving and decision making, we have seen narrative, imagery, and even mathematics used in different capacities. The Naturalistic Decision Making (NDM) community favored both the narrative and the visual form over the mathematical and algorithmic means of decision making (see Klein, Orasanu, Calderwood, & Zsambok, 1993; Salas & Klein, 2001; Zsambok & Klein, 1997). But, just as visualization tools for decision making are increasing in sophistication, we suggest that the use of narrative in NDM must similarly mature.

Storytelling and narrative have long been used in organizations to convey notions of culture and organizational experience and to tackle the complex questions that emerge in business contexts on a daily basis (e.g., Feldman, 1990; Fiore & McDaniel, 2006; Smith & Keyton, 2001). We suggest that information related to team problem solving (such as after action reviews, pre-training information, or even in-scenario updates) can be more effective and more memorable when transported through narrative (Fiore, Johnson, & McDaniel, 2005; 2007). In particular, narrative allows for an elaboration of three interrelated dimensions – social, cognitive and affective – that have the potential to create a powerful problem solving context.

From the social perspective, Bruner (1991) suggested that narrative is inherent to human existence. He argues that we create internal representations of social interactions and human experience using forms of narrative and story for representing and organizing these activities. Others have argued that the narrative form is one of the earliest means for retaining knowledge and for passing that knowledge on to our peers and offspring (e.g., Bal, 1997; Dautenhahn, 2003; Denning, 2001; Snowden, 1999).

In terms of cognition, research from cognitive science has explored how humans find it natural to interpret and comprehend script-like or schematic structures (e.g., Bower & Morrow, 1990; Schank, 1998). The formulaic elements of narrative (plot, character, and environment) can then be stored as generic templates. When a new situation is encountered, we simply encode new variations of existing canonical narratives, thereby contributing to both an efficient and memorable system for the encoding of experience.

Norman (1993) writes of the affective power of storytelling. Whereas techniques in logic allow a listener/reader to formulate a "detached, global judgment" (p. 130), techniques in storytelling allow an author to include their personal point of view and to understand – and take advantage of – the emotional influence that their story will have on others (e.g., Linde, 2001).

We suggest that narrative may be powerful tool for supporting certain problem solving elements of macrocognition. Researchers in NDM have long discussed how stories are used in processes such as decision making, planning, and sense-making (see Lipshitz, Klein, & Carroll, 2006). For example, Klein's model of recognition-primed decision (RPD) contains a narrative component in that he describes how experts often engage in systematic story building strategies. In these instances, when it is not readily apparent what solution path should be followed, experts use story in an attempt to overcome ambiguity in the environment.

Related to this is the cognitive exercise in which potential actions are imagined to help the problem solver to better interpret a given situation. Often this form of story building enables a clearer understanding of existing situations and the nature of any constraints to the successful resolution of obstacles or barriers (Klein, 1998). Within NDM, others have used story and the narrative form to evaluate the quality of organizational learning contexts. Here narrative enables a more precise diagnosis of report quality – that is, the degree to which well written team reports describe causes and provide lessons generalizable across problem solving context (see Carroll, Hatakenaka, & Rudolph, 2006).

Similarly, in explanation based models, one works to generate a coherent story that enables one to deal with an incomplete set of facts. Under this model, the problem solver actively works to fill in gaps and form expectancies such that they can identify potential choices and outcomes (Pennington & Hastie, 1993). Story is more explicitly integrated in NDM models such as Recognition/Metacognition (Cohen, Freeman, & Wolf, 1996) where the problem solvers work in time-stressed environments to develop procedures that help them overcome failures in order to recognize how to proceed with a given problem. In this theory, teams work to construct and test stories generated from limited data available in the environment.

In short, a number of researchers have utilized story for understanding naturalistic decision making process. We support this line of thinking and our goal here is to build upon this body of research by more precisely linking concepts from narratology to problem solving environments. In the final section of this chapter, we describe a set of fundamental narrative features to illustrate how they can help us better understand certain problem solving processes as they unfold in naturalistic environments. This better understanding can subsequently be used to support the design of PBL instructional strategies as they pertain to these environments.

Narrative Systems for Problem Solving

We emphasize the process of *developing a shared problem conceptualization*, a foundational element of macrocognition in teams. From the cognitive sciences, this has been said to involve the encoding, representing, and sharing of salient aspects

of the problem. With respect to this latter aspect, it involves developing overlap between team members' understanding of the essential problem characteristics (e.g., Fiore & Schooler, 2004; Hinsz et al., 1997; Orasanu, 1994). In the present context, we suggest this involves the identification of initial problem states, goals, and operators. These are actions that change one problem state into another, along with any restrictions on the operators (Newell & Simon, 1972; Hayes, 1989). What is important to recognize is that, following knowledge building activities by the team, individuals within the team use collaborative activities to build a perceptual and conceptual understanding of their problem. This process enables the team to create a common ground concerning the problem they are facing, thus, supporting the development of the team's problem model (see Fiore, Rosen, Salas, Burke, & Jentsch, 2008). The narrative concept is applicable in a number of ways and we next discuss how the features of narrative as outlined by Bruner (1991) can be adopted to help understand some of the facets of collaborative problem solving.

Table 1 lists the features of narrative (from Bruner, 1991) most relevant to our discussion. These features can be studied to analyze narrative in a hermeneutic sense, moving below the surface layer of actions and environment to uncover deeper meanings that may exist in the problem solving context. Bruner uses the phrase *intentional state entailment* to describe how agents within a narrative have desires or goals which motivate them to move through the various parts of a story. This is well-suited for problem solving in that problem solving teams must be cognizant of both overall team objectives and idiosyncratic factors that shape activities embedded in particular social contexts. Within complex problem solving environments, the narrative actors (perhaps representing team members) all have goals within the parameters of their particular situation. But these intentions are often thwarted in some way such that problem solving does not always proceed as expected (e.g., through faulty data or the actions of others). As such, this component of narrative helps us to interpret why, for example, a distributed team

Table 1. Features of Narrative (from Bruner, 1991).

Intentional State Entailment	Describes how an actor within a given story has within him/her certain goals or desires that must be attained
Context Sensitivity	Notion of how a reader's background knowledge interacts with the interpretation of the narrative
Negotiability	The separating out of truth from the story, thus allowing for differing explanations of what occurred based upon the idiosyncratic interpretations one may have of what transpired
Referentiality	Term describing how narrative does not refer to reality, rather it creates its own reality
Narrative Diachronicity	Used to describe how events within a narrative occur over time or the particular patterns of events that unfold over time
Canonicity and Breach	Features within a narrative that make a story interesting enough to tell - that is, a break from a predetermined sequence of events'(e.g., a script)
Precipitating Event	The factor leading to the breach of the canonical script

member or even an adversary, behaved as he/she did (see Fiore, Johnston, & McDaniel, 2007). Considering *intentional state entailment* in the context of PBL, we can see how this will facilitate the learner's understanding of the more social and/or affective elements sometimes present in complex problem solving. Motivational processes, whether in organizational settings (e.g., relating to productivity) or in medical ailments and treatment (e.g., relating to personal care), are very pertinent to understanding why something happened as it did. Specifically, desires for some outcome, or avoidance of some consequence, are very often the reasons for some sequence of actions that may or may not be logical. As such, problem solvers assuming rational behavior will often fail to consider the contextual issues leading to particular problems. Reifying this through narrative and presenting it as a foundational element of PBL instruction, will support the learner's appreciation of such factors.

Bruner's notions of *context sensitivity and negotiability* also have interesting connections to collaborative problem solving. Context sensitivity applies individual experiential knowledge to the interpretation of narratives, essentially allowing the narrative and the reader to form an organic relationship within the mind of the individual. Similarly, in problem solving, both the individual knowledge of team members, and the team knowledge collectively, are significantly brought to bear on the problem solving process. This organic knowledge that arises from the embedded activity of the team, along with the team's individual and collective knowledge, interact to shape the beginnings of the team problem model. Indeed, this is analogous to the creation of the "situation model" as espoused by researchers such as Kintsch (1988). Bruner's notion of negotiability, however, pertains to the disparity between narrative truth and individual interpretations or recollections. Both of these features support what literary critics have often called the *reader-response* method of criticism, in which a narrative is thought to be experienced in a subjective and personal fashion which cannot be objectively studied by those outside the reading "experience". Such processes may occur in problem solving contexts via generation of alternative problem interpretations. *Context sensitivity and negotiability* are features particularly crucial to understanding and training collaborative problem solving. Because individual knowledge coalesces with team knowledge, social-cognitive processes can very often alter the particular path of that knowledge integration. For example, dynamics arising due to hierarchies, or even due to personalities, can negatively influence the accurate construction of a team's problem model. Here PBL can take advantage of these factors by developing scenarios that attend to not only problem content, but to team roles and the personalities and/or attitudes arising in such roles. By presenting the multi-faceted ways that problem knowledge can get represented (e.g., the differing perspectives of stake-holders), scenarios may more effectively convey the complexity inherent in problem solving.

Other features of narrative, such as referentiality, can be used to similarly study narrative-based problem solving systems. *Referentiality* refers to the emergent meaning-making capacity of narrative: rather than being bound to reality, narratives can – and sometime do – create their own realities. This is best understood by

recognizing that ambiguity always exists in problem solving contexts and that problem representations may not always represent "ground truth". Within the context of integrating narrative into an understanding of problem solving, this is an important issue. The danger is that narrative can have a truth all its own, requiring that problem solvers recognize narrative truth from verisimilitude, that is, an *appearance of truth*, rather than truth through verifiability (Bruner, 1991). Specifically, in order to effectively document the complexity inherent in problem solving contexts, that is, develop an accurate story, we must have an accurate understanding of the reality of the situation. This is based upon the identification of critical events and their consequences. Any resultant story needs to be constructed from these events and based upon the interpretations of the varied team members – this becomes the reality through which solutions are generated (Fiore et al., 2005). As with context sensitivity and negotiability, *referentiality* similarly is a feature of narrative to which we must carefully attend. Using appropriately crafted PBL scenarios can make the learner aware of the distinction between a compelling narrative (the one fitting the most facts) and one that may actually represent truth. For example, medical researchers studying diagnosis have found that a critical cue may often be overlooked, even by more experienced diagnosticians (e.g., Feltovich, Spiro, & Coulson, 1997). Here they may have constructed a narrative because the majority of symptoms fit a preconceived schema for some illness and this prevents them from realization that a particular cue can be diagnostic simply as an anomaly to the story that has been constructed. This form of problem solving error can occur, not just in medical domains, but across many environments. As such, increasing the learner's awareness of this possibility will enhance their vigilance against such faulty problem solving.

Time-based elements of narrative are also relevant to supporting macrocognitive problem solving. Bruner describes the temporal sequencing feature of narrative as *narrative diachronicity*. Viewing this within the context of complex problem solving, a problem can be represented as a series of temporally and causally connected events that can be used to help represent the complexity inherent in certain real world situations. This temporal sequence supports the narrative system and may highlight or prominently position certain occurrences for interpretation by the team. Furthermore, one can differentiate between narrative time and real world time. With this, teams can consider a story chronology via the internal temporal sequence and its causal structure and/or alternative patterns based upon variations in narrative time. Certain benefits may be found in manipulating this temporal sequence in alternate, unplanned directions, such as reversing the plot sequence or accessing plot elements in random order. Depending on the context storytelling can be a powerful device simply in terms of temporal sequencing and attending to features such as *narrative diachronicity* can help problem solving teams better understand the temporal nature of problems as they occur in complex environments. In many instances, the problem emerges not just with the occurrence of a particular cue, but with a pattern of cues that often times do not co-occur (see Fiore et al., 2008). As such, PBL scenarios can embed these types of cues to help the learner come to recognize and appreciate the integration of data as it comes in over time.

The last feature of Bruner's we will discuss, *canonicity and breach*, is what he uses to describe the tendencies of narratives to follow fundamental structures, or canons, and deviate from those patterns to powerful effect. Bruner (1991) explains why narrative differs from a predetermined sequence of events (e.g., a script), "for [a story] to be worth telling, a tale must be about how an implicit canonical script has been breached" (p. 11). This breach of the canonical script is referred to as a *precipitating event* (Bruner, 1991; Herrnstein-Smith, 1978). Viewing these constructs within problem solving environments, we can use the narrative structure to help us interpret the actions of actors in the story. The *breach* helps us understand why the script did not go as planned, in turn, leading to the problem(s) at hand. As with diachronicity, this underlying concept is used to fold together the critical events that are used to help the team members understand the problem. This then forms the basis for structuring the story used to present to the team for solution generation. Thus, when considering problem solving as an unfolding narrative, and the contents of the situation as a particular *story*, the value of our metaphor can be strengthened. In particular, the breach in the canonical script, that is, the precipitating event, becomes a potential target for solution generation (see also Fiore et al., 2005; 2008). Finally, features such as canonicity and breach and precipitating event, like narrative diachronicity, can help the learner better understand a problem's overall structure. When developing content for PBL environments, these features, much like the plot of a well-written novel, must be attended to if the learner is to understand the complex causal nature of the factors that led to a particular problem.

CONCLUDING REMARKS

The ubiquity of narrative in our lives, and the rich theorizing from narratology and related fields, makes this concept one that is well positioned to aid our understanding of cognition in complex environments. Our goal was to provide an illustration of how the features of narrative can be integrated with PBL as a potential means of bolstering the development of systems for learning and training in problem solving. The features of narrative elaborated upon here present a potentially fertile area of inquiry for conceptualizing elements of collaborative problem solving and how they might be structured to aid training in such environments.

Findings from such research could inform a more theoretically grounded and effective PBL approach. Essentially, it is the unfolding of events in complex collaborative problem solving, and the interaction of actors within the situation, that creates the story that needs to be understood. Narrative can enable this process because it "operates as an instrument of mind in the construction of reality" (p. 6, Bruner, 1991) and in the present case, the reality of what is occurring when teams collaborate to solve problems as they occur in naturalistic environments.

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