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Research in discourse processing can help improve the comprehension of material in textbooks, classrooms, human tutoring, and computer-based training.

Improving Comprehension Through Discourse Processing

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The painful fact that students rarely acquire a deep understanding of the material they are supposed to learn in their courses is widely acknowledged in the field of education. Students normally settle for shallow knowledge, such as a list of concepts, a handful of facts about each concept, and simple definitions of key terms. What is missing are the deep, coherent explanations that organize the shallow knowledge and fortify learners for generating inferences, solving problems, reasoning, and applying their knowledge to practical situations. The acquisition of shallow knowledge is unfortunately reinforced by the normal classroom activities and testing formats. Classroom lectures typically are information delivery systems for shallow knowledge. The teachers' questions in the classroom typically are shallow short-answer questions that require only single words or short phrases in the student response. Most examinations consist of multiple-choice, true-false, or fill-in-the-blank questions that tap primarily the shallow knowledge. Given this unfortunate state of affairs, many researchers and teachers in education have been exploring learning environments and pedagogical strategies that promote deep comprehension.

The field of discourse processing offers some solutions to the challenge of promoting deep comprehension during learning. This chapter sketches the salient components of discourse processing mechanisms and subsequently points out how such mechanisms can be recruited to improve deep comprehension.

Researchers in the field of discourse processing investigate the structures, patterns, mental representations, and psychological processes that underlie written and spoken discourse. It is an interdisciplinary field that includes psychology, rhetoric, sociolinguistics, computational linguistics, conversation analysis, education, sociology, anthropology, and computer science; its practical mission is to improve the comprehension of material in textbooks, classrooms, human tutoring, and computer-based training.

Components of Discourse Processing

Discourse psychologists have identified five levels of discourse representation that are constructed during comprehension (Graesser, Millis, and Zwaan, 1997; Kintsch, 1998): the surface code, textbase, situation model, pragmatic communication, and discourse genre. In order to illustrate these five levels, consider the following excerpt about a cylinder lock from the book *The Way Things Work* (Macaulay, 1988): "When the door is closed, the spring presses the bolt into the door frame. Inserting the key raises the pins and frees the cylinder. When the key is turned, the cylinder rotates, making the cam draw back the bolt against the spring" (p. 17).

The *surface code* preserves the exact wording and syntax of the sentences. The *textbase* contains explicit propositions in the text in a stripped-down form that preserves the meaning, but not the surface code. For example, the following propositions would be in the textbase of the second sentence: PROP1(someone inserts key), PROP2(PROP1 raises pins), and PROP3(PROP1 frees cylinder). The *situation model* (sometimes called the mental model) is the referential microworld of what the text is about; it contains the people, setting, states, actions, and events that are either explicitly mentioned or inferentially suggested by the text. In this cylinder lock excerpt, the situation model would contain causal chains of events that unfold as the key unlocks the door, the spatial composition of the parts of the lock, and the goals of the person who uses the lock. The *pragmatic communication* level refers to the exchange between the speech participants, between the reader and writer, or between the narrator and audience. In the example, the expert is communicating with a learner who presumably wants to understand how a cylinder lock works. *Discourse genre* is the category of discourse, such as narration, exposition, and persuasion. Discourse analysts have proposed several discourse classification schemes that are organized in a multilevel hierarchical taxonomy or a multidimensional space (Biber, 1988). The example cylinder lock excerpt would be classified in the expository text genre.

Deep comprehenders construct rich representations at the levels of the situation model, pragmatic communication, and discourse genre. These three levels are preserved in memory for a long time if they are successfully constructed during comprehension. In contrast, the surface code and textbase have a secondary status. In fact, memory for the surface code is normally thirty seconds or less, whereas memory for the textbase normally decays after a few hours. Paradoxically, the examinations that students normally receive tap the surface code and textbase rather than the deeper levels. Teachers ask students to recall explicit content or complete a multiple-choice test that is skewed toward word recognition, definitions, or attributes of concepts. One way of promoting deep comprehension is to compose exams with questions that emphasize the situation model, inferences, reasoning, and other aspects of the deeper levels. There needs to be a shift in standards of assessment.

When comprehension is successful, there is coherence both within and between the levels of representation. Stated differently, there are no serious coherence gaps within a particular level, and there is harmony between the levels of representation. Examples of coherence gaps within the surface code are misspelled words and ungrammatical sentences. An example of a coherence gap within the situation model is an incoming clause in the text that cannot be linked to the previous content on any conceptual dimension, such as causality, temporality, spatiality, or the goals of characters (Gernsbacher, 1997; Zwaan and Radvansky, 1998). In essence, the incoming event seems to be mentioned out of the blue. Similarly, there may be comparable coherence gaps at the levels of the textbase, the pragmatic communication, and the discourse genre. Regarding coherence between levels, there needs to be a mapping between the elements of the representation at one level and the elements at another level. For example, the surface code has words and syntactic patterns that signal content features at the level of the situation model. Comprehension suffers when there is a clash between the surface code and situation model. If the text stated, "The key is turned after the cylinder rotates," there would be a discrepancy between the order of events in the situation model (the key is turned *before* the cylinder rotates) and the surface code (clause X *after* clause Y).

The comprehender obviously needs an adequate repertoire of world knowledge and cognitive skills in order to construct coherent representations. Comprehension breaks down when there are deficits in world knowledge or processing skills at particular levels of representation. When all of the background knowledge and skills are intact, the comprehender constructs a meaningful representation that is coherent at the local and global levels. However, when there is a deficit at a particular level of representation, the problems propagate to other levels or, in some cases, other levels can compensate. For example, nonnative speakers of English may have trouble processing the words and syntax of English. That would make it difficult for them to process the deeper levels of representation; they might try to compensate by using their knowledge of the situation model, pragmatics, and the discourse genre to reconstruct what was being said. As another example, readers have trouble comprehending technical texts on arcane topics because they lack world knowledge about the topic. This deficit at the situation model ends up confining their processing to the surface code and textbase levels, so they might parrot back explicit information in a textbook but have no understanding at a deeper level. This routinely occurs in schools. The challenge is to design the discourse or the testing format to encourage deeper levels of processing.

McNamara, Kintsch, Songer, and Kintsch (1996) documented an intriguing interaction among the readers' knowledge about a topic, the coherence of the textbase, and the level of representation that was being tapped in a test. The readers varied in the amount of prior knowledge they had about the topic covered in the text (which was the functioning of the heart). Half of the readers read a text with a coherent textbase; clauses were linked by appropriate connectives (*therefore, so, and*), and the topic sentences, headings, and subheadings were inserted at appropriate locations. The other half of the texts had low coherence because there were violations in the insertion of connectives, topic sentences, headings, and subheadings. The tests tapped either the textbase level of representation (which included recall tests) or the situation level (which included tests of inferences and answers to deep-reasoning questions). The results of the study were not particularly surprising for the low-knowledge readers. For these readers, texts with high coherence consistently produced higher performance scores than did texts with low coherence. The results were more complex for the readers with a high amount of prior knowledge about the heart. A coherent textbase slightly enhanced recall but actually lowered performance on tasks that tapped the situation model. The gaps in text coherence forced high-knowledge readers to draw inferences, construct rich elaborations, and compensate by allocating more processing effort to the situation model. In essence, deep comprehension was a positive compensatory result of coherence gaps at the shallow levels of representation.

One of the counterintuitive results of comprehension research is that most adult readers have a poor ability to calibrate the success of their comprehension (Glenberg, Wilkinson, and Epstein, 1982; Hacker, Dunlosky, and Graessser, 1998). Comprehension calibration can be measured by asking readers to rate how well they comprehend a text and correlating such ratings with their comprehension scores on an objective test. These ratings are either low or modest (r = .2 to .4), which suggests that college students have disappointing comprehension calibration. Another method of calibrating comprehension is to plant contradictions in text and observe whether readers detect them. In fact, a surprising number of adult readers do not detect the contradictions. There is a strong tendency for readers to have an illusion of comprehension by pitching their expectations at handling the surface code and textbase. They need to be trained to adjust their metacognitive expectations and strategies to focus on the deeper levels.

Classroom discourse also is seriously skewed to the shallow rather than the deep end of the comprehension continuum. Teachers typically follow a curriculum script that covers definitions, facts, concepts, attributes of concepts, and examples. This content is at the lower levels of Bloom's taxonomy of cognitive objectives (1956). Less frequently do they attempt Bloom's higher levels of inference, synthesis, integration, and the application of knowledge to practical problems. The primary form of interaction with students in a classroom is the sequence of teacher initiation, student response, and teacher evaluation (IRE sequence) or the teacher question, student answer, and teacher feedback (QAF sequence; Mehan, 1979; Graesser and Person, 1994)—for example:

TEACHER: What is it that rotates when the door is unlocked?
STUDENT: The cam.
TEACHER: Right. It's the cam.

Ethnographic studies of the classroom have revealed that over 90 percent of the teacher questions are shallow ones that grill students on explicit information in the textbook (Dillon, 1988). There are very few open-class questions that require deep reasoning (such as why, how, what if, and what if not). Teachers need to model deep question asking and answering skills if there is any hope of promoting deep comprehension in the students.

Discourse Mechanisms Promoting Deep Comprehension and Learning

Methods of improving deep comprehension during learning are based on research in discourse processing, although aspects of these methods are also grounded in cognitive psychology more generally. Here, we focus on methods that are believed to have a substantial impact on learning and that have a solid empirical research base.

Constructing Explanations. Good comprehenders generate explanations as they read text or listen to lectures (Bransford, Goldman, and Vye, 1991; Chi, de Leeuw, Chiu, and LaVancher, 1994; Graesser, Singer, and Trabasso, 1994; Pressley and others, 1992; Trabasso and Magliano, 1996). The explanations trace the causes and consequences of events, the plans and goals of agents (humans, animals, or organizations), and the logical derivations of assertions. The questions that drive explanations are Why? How? What if? and What if not? For example, a deep comprehender might implicitly ask the following questions while reading the cylinder lock text: Why does the person turn the key? How does the bolt move back? What causes the cam to rotate? and What if the pins do not rise? Students learn much more when they construct these explanations on their own (which are called *self-explanations*) than when they merely read or listen to explanations.

Computer software can be designed to encourage learners to construct explanations. One simple way to do this is to ask the learner to think aloud while studying the material and to probe with explanation-based prompts (such as Why? Please explain, and How does that occur?). More sophisticated software can present animations of the causal mechanisms and allow students to manipulate inputs and steps in the causal stream (Hegarty, Narayanan, and Freitas, forthcoming; Mayer, 1997). Simulation software is said to provide an excellent learning environment for acquiring deep explanations of complex systems.

Asking Deep-Reasoning Questions. Students should be encouraged to ask and answer deep-reasoning questions during comprehension because the process helps them to construct explanations. Unfortunately, students are not in the habit of asking many questions, and most of their questions are shallow. A typical student asks only .17 question per hour in a classroom (Graesser and Person, 1994), and less than 10 percent of student questions involve deep reasoning. When students are taught how to ask good questions while reading or listening to lectures, their comprehension scores increase on objective tests (King, 1992, 1994; Rosenshine, Meister, and Chapman, 1996); the median effect size is .36 when standardized texts are used and .86 when experimenter-developed comprehension tests are used. Teachers rarely ask deep-reasoning questions in classroom settings, so it would be prudent to train them to model good questioning skills.

Computer software has been developed to train students how to ask good questions while learning. For example, Graesser, Langston, and Baggett (1993) developed a point-and-query hypermedia system in which students learn about woodwind instruments by asking questions and comprehending answers to the questions. Whenever they point to a hot spot on the display, a menu of good questions pops up, and they select one of the questions. The computer immediately answers the selected question, and then the student points to another hot spot. Students ask seven hundred times as many questions with this point-and-query software as they do when they sit in a classroom. Moreover, the questions on the question menu can be skewed toward deep-reasoning questions, so students can be exposed to better questions than in a classroom. This software has the potential to reinstate curiosity and skilled inquiry if students automatize good question asking.

Challenging the Learner's Beliefs and Knowledge. One of the easiest ways to get students to ask questions is to challenge one of their entrenched beliefs and thereby put them in cognitive disequilibrium. Imagine walking into a classroom and claiming that today's students are prone to follow fads, that rap music is dead, or that global warming is not a significant problem to worry about. A long stream of questions will accompany the long stream of arguments. Research on question asking has revealed that genuine information-seeking questions are triggered by salient discrepancies between two or more stimulus elements, or between input and world knowledge (Graesser and McMahen, 1993; Otero and Graesser, forthcoming). Questions are asked when there are contradictions, anomalies, incompatibilities, obstacles to goals, salient contrasts, uncertainty, and obvious gaps in knowledge. The secret to eliciting student questions is to create cognitive disequilibrium and then to provide useful information when students ask questions.

Graesser, Olde, and Lu (2000) have used breakdown scenarios to elicit questions while college students read illustrated texts about everyday devices (cylinder locks, toasters, dishwashers). For example, the following breakdown scenario accompanied Macaulay's illustrated text on the cylinder lock: "A person puts the key into the lock and turns the lock, but the bolt does not move." The students were instructed to think aloud or to ask questions while they troubleshoot possible faults that explain the breakdown. Later, the students completed an objective test that assessed their understanding of the device mechanism. The results of the study revealed that the students who had a deep understanding of the device mechanism asked a higher proportion of good questions but not a higher frequency of questions. A good question was defined as one that focused on a likely fault that explained the device malfunction. Therefore, deep comprehension is manifested in question quality, not question quantity (see also Fishbein and others, 1990).

Tutoring. One-to-one human tutoring is superior to normal learning experiences in traditional classroom environments. Meta-analyses on learning gains have revealed that the effect size of the advantage of tutoring over the classroom has ranged from .4 to 2.0 standard deviation units (Bloom, 1984; Cohen, Kulik, and Kulik, 1982). This advantage cannot be attributed to the possibility that tutors are more accomplished pedagogical experts than teachers. An ideal tutor would have substantial knowledge about the topic being tutored, extensive training on effective tutoring techniques, and several years of tutoring experience. However, ideal tutors are the rare exception rather than the rule. The vast majority of tutors in a school system are peers of the learner, slightly older students, adult volunteers, and paraprofessionals who have had no tutoring training. Cohen's meta-analysis also revealed that the learning gains were not significantly related to the amount of tutoring training and the age differences between tutor and learner. Peers often do an excellent job serving as tutors (Rogoff, 1990).

The robust advantage of tutoring motivated Graesser, Person, and Magliano (1995) to investigate what it is about tutoring that is better than the classroom. They videotaped, transcribed, and analyzed approximately one hundred hours of naturalistic tutoring on mathematics in a middle school and research methods in a university course. The research methods tutoring corpus was compared to classroom instruction on the same content. They identified a number of factors that do not explain the advantages of tutoring: tutors do not implement sophisticated pedagogical strategies, such as the Socratic method, building on prerequisites, error diagnosis and repair, or modeling-scaffolding-fading. Such strategies require extensive training to implement, so they are virtually absent in the protocols of the typical (unskilled) tutors. Students are not active learners who set the agenda, introduce topics, point out problems, and ask questions; it is the tutor who guides the session by following a curriculum script. There is not a high degree of shared knowledge and the meeting of minds in tutoring. Instead, the tutor and student have only an approximate sense of what each other knows. They usually give incorrect feedback to each other on what they believe each other knows. When the tutor asks the student, “Do you understand?” the student typically says yes even when he or she has serious gaps in comprehension. In fact, it is the more knowledgeable students who answer that they do not quite understand. When the student says something that is extremely vague or riddled with misconceptions, the tutor normally gives positive feedback rather than negative feedback.

So what is it that tutors do that explains the advantages of tutoring over the classroom? According to the analysis of Graesser, Person, and Magliano (1995), the discourse patterns in tutoring involve collaborative problem solving, question answering, and explanation building in the context of specific examples. There is a turn-by-turn collaborative exchange in tutoring that would be impractical to implement in the classroom. Compared to teachers in the classroom, tutors ask more deep-reasoning questions, introduce more problems to solve, and work on more specific cases. Some dialogue patterns were particularly frequent in tutoring, including the following three:

- *Five-step dialogue frame.* This dialogue frame is initiated by the tutor who asks a question or introduces a problem.

Step 1: The tutor asks a question.
Step 2: The student answers the question.
Step 3: The tutor gives short feedback on the quality of the answer, such as “yeah,” “uh-huh,” or “not quite.”
Step 4: The tutor and student collaboratively improve the quality of the answer by a multiturn exchange.
Step 5: The tutor assesses the student’s understanding of the answer by a comprehension-gauging question (“Do you understand?”) or occasionally a substantive question.

This five-step dialogue frame is an extension of the three-step IRE and QAF patterns that routinely occur in classrooms. In essence, steps 4 and 5 build on the IRE-QAF classroom sequence by improving the answer collaboratively. Classroom questions are normally shallow, whereas there is a high frequency of deep-reasoning questions in tutoring.

- *Tutor turn composition.* The turns of the tutor are much shorter than the lengthy monologues of the teacher in the classroom. In steps 3 and 4, the tutor’s turns typically are composed of two or three parts: short feedback (positive, negative, or neutral), a substantive speech act that advances the dialogue (such as an assertion or a hint), and a prompting signal or speech act that cues the learner what to do next (Person, Graesser, Kreuz, and Pomeroy, forthcoming).

- *Hinting.* Tutors frequently try to get the student to articulate some piece of information or correct any of their own errors. Hints are indirect ways of getting the student to be more active. Tutors sometimes hint with progressive specificity. They start out with a vague directive ("What about the cam?"), then give a more specific leading hint ("What happens when the cam rotates?"), and end with an assertion ("The cam's rotating pulls the bolt back"). Hinting is much more elaborate in tutoring than the classroom.

Psychologists and computer scientists have recently built intelligent tutoring systems that help learners reason and solve difficult problems. Some of these tutoring systems incorporate sophisticated pedagogical strategies, such as the PACT algebra tutor (Koedinger, Anderson, Hadley, and Mark, 1997), the SHERLOCK tutor for troubleshooting and repairing electronic equipment (Lesgold, Lajoie, Bunzo, and Eggan, 1992), and the ANDES physics tutor (Van Lehn, 1996). Recent intelligent tutoring systems are attempting to incorporate tutorial dialogue patterns that humans use during tutoring. For example, AutoTutor teaches students about computer literacy by holding a multiturn conversation with the student and implementing the tutoring tactics of normal human tutors (Graesser and others, 1999, forthcoming; Person and others, forthcoming). AutoTutor has a talking head that speaks to the student and attempts to comprehend what the student types on the keyboard in natural language. AutoTutor has been tested on approximately two hundred students in a computer literacy course and produces learning gains of .5 to .6 standard deviation unit, compared to a control condition in which students reread a chapter.

Reciprocal Teaching Method. In this method, the skills of comprehension, reasoning, or problem solving are first modeled by a teacher for the learner. Then the learner performs the skills and receives feedback on his or her performance. There can be turn taking between two or more individuals, each performing the skills and receiving feedback. Over time, the modeling and feedback fade, and the learner works alone. The student eventually becomes a self-regulated learner who asks and answers questions, identifies comprehension deficits, forecasts predictions, and summarizes the material to be learned. The reciprocal teaching method is similar to cognitive apprenticeship models and modeling-scaffolding-fading strategies except that the latter techniques emphasize learning from an accomplished expert (Collins, Brown, and Newman, 1990; Palincsar and Brown, 1984; Rogoff, 1990). All of these methods use discourse strategies and patterns of social interaction that expose cognitive strategies and help the learner use them. It is well documented that the reciprocal teaching methods are capable of producing impressive learning gains when used appropriately (Palincsar and Brown, 1984; Rosenshine, Meister, and Chapman, 1996).

Questioning the Author. Beck, McKeown, Hamilton, and Kucan (1997) have developed and tested a "questioning the author" method of improving reading instruction for children by making the pragmatic communication level more salient to readers. The students are trained to imagine the author in flesh and blood and that they are having a conversation with him or her. The method opens the door to the possibility that the author is not perfect. The students learn how to question claims in the text

("What evidence does the author have for claim C?"), the success of the author's communication clarity ("Did the author explain that clearly?" "What is the author trying to say?"), and the motivations behind the author's claims ("Why did the author say X?"). This method produces impressive gains in comprehension, perhaps because it adds another layer of elaboration to the meaning representation, a layer that normally is not constructed. Most students become absorbed in the content of the text and assume that whatever is expressed is true. If the author is viewed as fallible, however, the learner must scrutinize the content more carefully and integrate it with the learner's world knowledge.

Conclusion

Research in discourse processing can help solve some of the pressing challenges in our educational enterprise. Discourse plays an important role in helping the learner shift from the shallow waters to the deep, from being a fact collector to becoming an inquisitive explainer, from being a repository of inert knowledge to becoming a vital agent who puts the knowledge into action. The field of discourse processing has some excellent theories that are grounded in solid scientific research that has shown its currency in the practical arena of education.

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