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Retrieval-Based Learning: Active Retrieval Promotes Meaningful Learning

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Abstract

Retrieval is the key process for understanding learning and for promoting learning, yet retrieval is not often granted the central role it deserves. Learning is typically identified with the encoding or construction of knowledge, and retrieval is considered merely the assessment of learning that occurred in a prior experience. The retrieval-based learning perspective outlined here is grounded in the fact that all expressions of knowledge involve retrieval and depend on the retrieval cues available in a given context. Further, every time a person retrieves knowledge, that knowledge is changed, because retrieving knowledge improves one's ability to retrieve it again in the future. Practicing retrieval does not merely produce rote, transient learning; it produces meaningful, long-term learning. Yet retrieval practice is a tool many students lack metacognitive awareness of and do not use as often as they should. Active retrieval is an effective but undervalued strategy for promoting meaningful learning.

Keywords

retrieval processes, learning, education, metacognition, meaningful learning

> If you know something, or if you have stored information about an event from the distant past, and never use that information, never think of it, your brain is functionally equivalent to that of an otherwise identical brain that does not "contain" that information.
>
> —Endel Tulving (1991)

To understand learning, it is essential to understand the processes involved in retrieving and reconstructing knowledge. We may think we know something, that our minds contain or possess some knowledge, but the only way to assess knowledge is by engaging in an act of retrieval. Differences in the ability to recover knowledge may not stem from what is "stored" in our minds but rather from differences in the retrieval cues available in particular contexts. Given the fundamental importance of retrieval for understanding the process of learning, it is surprising that retrieval processes have not received more attention in educational research. Consider that over the past decade, many influential National Research Council books on how people learn have contained no mention of retrieval (National Research Council, 2000, 2005a, 2005b).

It is essential to consider retrieval processes not only because they are central to understanding learning but also because the act of retrieval itself is a powerful tool for enhancing learning. Moreover, active retrieval does not merely produce rote, transient learning; it produces meaningful, long-term learning. The idea that retrieval is the centerpiece for understanding learning, coupled with the importance of active retrieval for producing learning, is referred to as *retrieval-based learning*.

Learning Based on the Design of the Mind

We often think of our minds as places in our heads, mental spaces or containers where we store knowledge. Roediger (1980) noted that for centuries, most metaphors used to describe mental processes have characterized the mind as a physical space and knowledge as physical things in that space—for example, by likening our minds to libraries filled with books or cabinets loaded with files (see too Moscovitch, 2007). In education, the metaphor of a physical building is often used to describe the mind and knowledge. Knowledge is *constructed* by learners who actively build knowledge *structures*; researchers seek to understand the *architecture* of the mind; and instructors aid students by providing *scaffolding* for learning.

When minds are viewed as places for storing knowledge, it is natural to focus attention on processes involved in constructing new knowledge in storage. Educational research

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and instructional practices have placed a premium on identifying the best ways to *encode* knowledge and experiences. Retrieval processes, the processes involved in using available cues to actively reconstruct knowledge, have received less attention. There seems to be a tacit assumption that successful encoding or construction of knowledge, in itself, is sufficient to ensure learning.

Basic research on learning and memory, however, has emphasized that retrieval must be considered in any analysis of learning. In part, this is because people do not store static, exact copies of experiences that are reproduced verbatim at retrieval. Instead, knowledge is actively reconstructed on the basis of the present context and available retrieval cues (Bartlett, 1932; Neisser, 1967; see too Moscovitch, 2007; Roediger, 2000). The reconstructive nature of mind is revealed in the systematic errors people make in retrieving knowledge, errors that verbatim recording devices would not make. The past never occurs again in its exact form, so a mental storehouse of copies of past experiences would be of little use. People instead have the ability to use the past to meet the demands of the present by reconstructing knowledge rather than reproducing it exactly.

What people express when they reconstruct knowledge depends on the retrieval cues available in a given context. Ultimately, knowledge reconstruction depends on the diagnostic value of cues, the degree to which cues help people recover particular target information to the exclusion of competing candidates (Nairne, 2002; Raaijmakers & Shiffrin, 1981). We may wish to examine what a person has constructed or stored in mind, but it is impossible to directly assess the contents of storage, per se. We can only ever examine what a person reconstructs given the available cues and context (Roediger, 2000; Roediger & Guynn, 1996; Tulving & Pearlstone, 1966). Thus, it is essential to consider retrieval processes in any analysis of learning.

The second crucial reason retrieval is important for learning is that learning is altered by the act of retrieval itself. Every time a person retrieves knowledge, that knowledge is changed, because retrieving knowledge improves one's ability to retrieve it again in the future (Karpicke & Roediger, 2007, 2008; Karpicke & Zaromb, 2010). This is a feature of a functional learning and memory system. Our minds are sensitive to the likelihood that we will need knowledge at a future time, and if we retrieve something in the present, there is a good chance we will need to recover it again. The process of retrieval itself alters knowledge in anticipation of demands we may encounter in the future. Retrieval is therefore not only a tool for assessing learning but also a tool for enhancing learning (Roediger & Karpicke, 2006a).

Repeated Retrieval Enhances Long-Term Learning

Imagine you are studying for an upcoming exam. After you have read through your notes or your textbook one time, what would you want to do next? You have three options: You can (a) go back and restudy either all of the material or parts of it, (b) try to recall the material without restudying afterward, or (c) do something else. Which would you choose?

We (Karpicke, Butler, & Roediger, 2009) gave this question to a large group of college students. Most students (57%) said they would reread their notes or textbook, and 21% said they would do something else. Only 18% said they would attempt to recall material after reading it.[1] The decision to repeatedly read makes sense if we identify learning with processes of encoding and constructing knowledge and consider retrieval to be only a way to assess prior learning. It stands to reason that more studying (i.e., more encoding and knowledge construction) should produce more learning, whereas retrieval should measure learning but not produce it.

Would students be better off repeatedly reading than engaging in retrieval? We conducted an experiment with a design that mirrored the question asked in the survey (Roediger & Karpicke, 2006b). Students read educational texts and recalled them under one of three conditions. One group of students spent time repeatedly studying a text in four study periods. A second group read a text in three study periods and then recalled it in one retrieval period (labeled SSSR), in which the students wrote down as many ideas from the text as they could recall. A third group read the text during one study period and then practiced recalling it during three consecutive repeated retrieval periods. Students did not reread the text or receive any feedback after any of the recall periods; they only practiced actively retrieving material.

At the end of the learning phase, the students made a *judgment of learning*: a prediction of how well they would remember the material in the future. Then, one week later, students recalled the material again to see how much they actually retained in the long term.

Figure 1b shows students' judgments of learning. The more times students repeatedly read the material, the better they believed they had learned it. However, Figure 1a shows that students' actual learning exhibited the opposite pattern. The more times students practiced actively retrieving the material, the better they retained it in the long term. Students spent the same amount of time experiencing the material in all three conditions, and students in the repeated-retrieval condition only recalled and did not restudy the text, yet active retrieval produced the best long-term retention (for further discussion of metacognitive awareness of the effects of retrieval practice, see Karpicke & Grimaldi, 2012).

Returning to the survey of student learning strategies (Karpicke et al., 2009), one might think the results would change if we reworded the survey question. Namely, students might choose to engage in active retrieval if they could reread after attempting retrieval. In a second version of the survey, we asked students the exact question described above, but changed option (b) to say, "try to recall the material, and then go back and restudy the text." Students' choices did change, but not as dramatically as one might expect: Forty-two percent

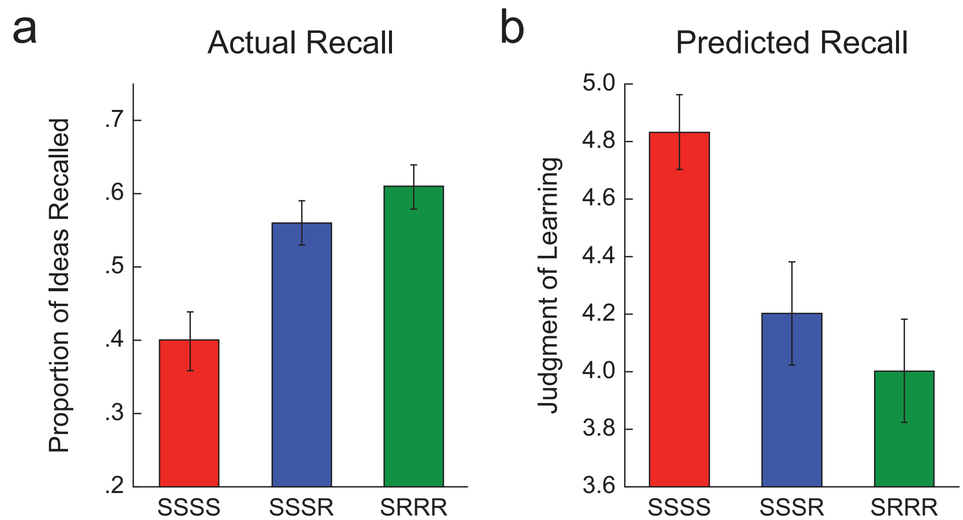

Fig. 1. Final recall (a) after repeatedly studying a text in four study periods (SSSS condition), reading a text in three study periods and then recalling it in one retrieval period (SSSR condition), or reading a text in one study period and then repeatedly recalling it in three retrieval periods (SRRR condition). Judgments of learning (b) were made on a 7-point scale, where 7 indicated that students believed they would remember material very well. The data presented in these graphs are adapted from Experiment 2 of Roediger and Karpicke (2006b). The pattern of students' metacognitive judgments of learning (predicted recall) was exactly the opposite of the pattern of students' actual long-term retention.

of students said they would practice retrieval and then reread. However, 41% of students still said they would only reread, and 17% said they would do something else. In other words, 58% of students indicated that they would not practice active retrieval even when they would have the opportunity to reread afterward.

The benefits of active retrieval are large when students retrieve and then reread. In part, this is because attempting retrieval improves students' encoding when they restudy material, a phenomenon known as the "potentiating" effect of retrieval (see Grimaldi & Karpicke, in press; Karpicke, 2009; Kornell, Hays, & Bjork, 2009; Wissman, Rawson, & Pyc, 2011). In an experiment that demonstrated the power of retrieving plus rereading, we (Karpicke & Roediger, 2010) had students practice retrieval of educational texts about scientific topics. There were several conditions in this experiment, but three particular conditions are relevant to this discussion. In one condition, students read a text once in a single study period, whereas students in a second condition read the text, recalled as much as they could in a recall period, and then reread the text briefly. In a third condition, students repeatedly recalled the text across a series of eight alternating study/recall periods (four study periods and four recall periods in total). One week later, the students recalled the material again to assess long-term retention.

Figure 2 shows the proportion of ideas recalled one week after the original learning session. Practicing retrieval one time doubled long-term retention relative to reading the text once (34% vs. 15%), and engaging in repeated retrieval increased retention to 80%. Thus, practicing active retrieval with brief rereading between recall attempts, in what amounted to about a 30-minute learning session, produced large benefits for long-term learning (see too McDaniel, Howard, & Einstein, 2009).

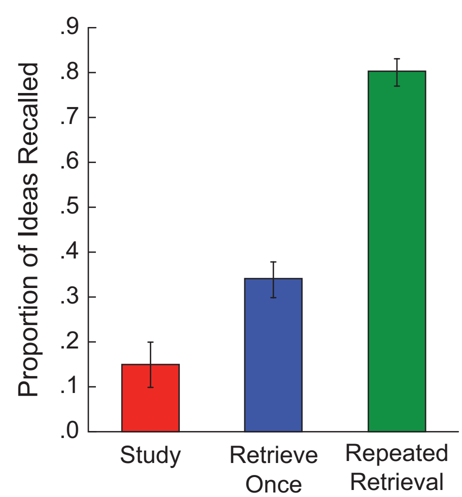

Fig. 2. Long-term retention after studying once, practicing retrieval once (followed by rereading), or practicing repeated retrieval. The data presented in this graph are adapted from Experiment 2 of Karpicke and Roediger (2010). Practicing retrieval one time doubled long-term retention, and repeated retrieval produced a 400% improvement in retention relative to studying once.

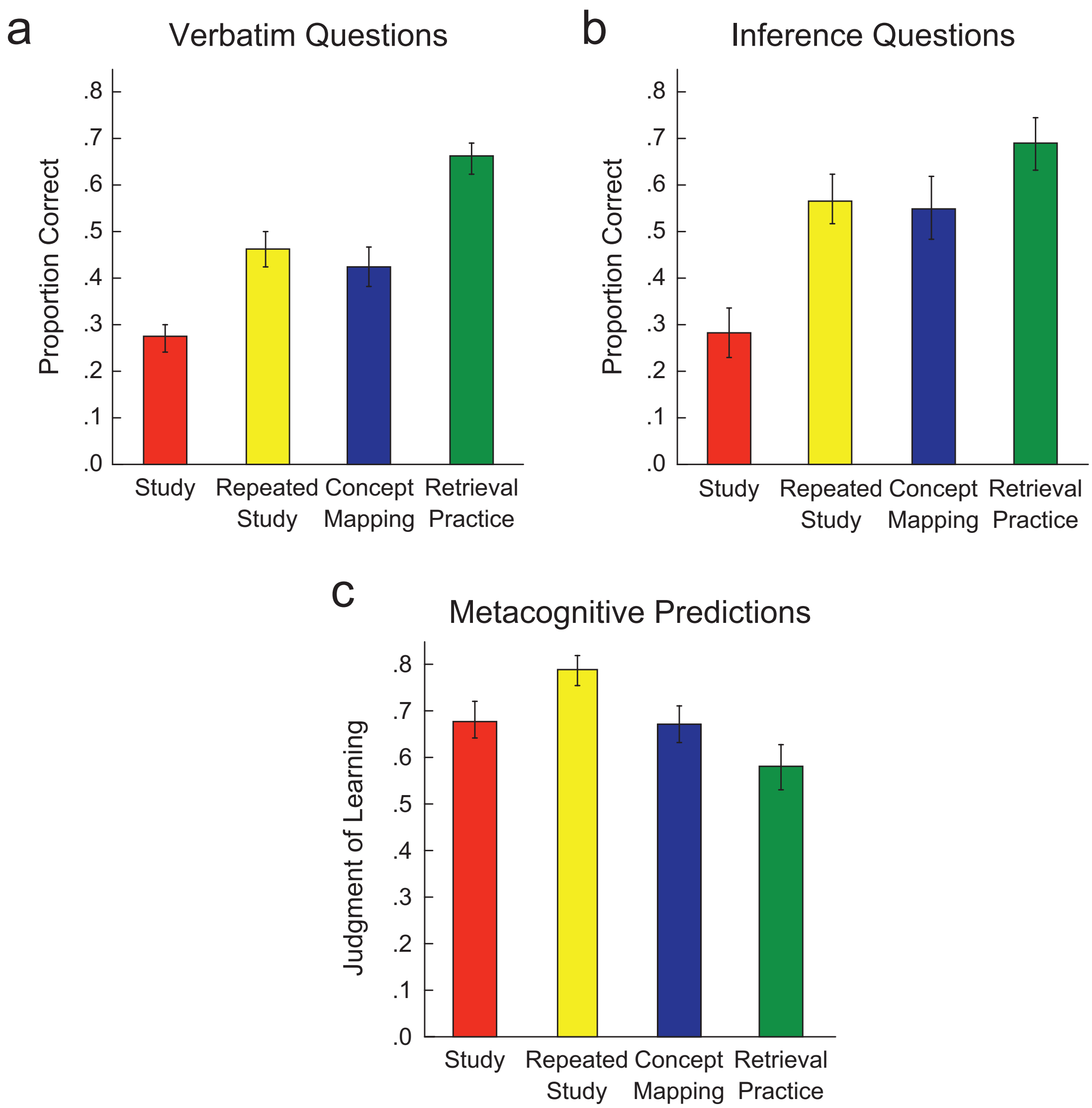

Fig. 3. Proportion correct on final short-answer verbatim questions (a) and inference questions (b) 1 week after learning, and metacognitive judgments of learning (predicted proportion of items correct) made during the initial learning phase (c). Practicing retrieval enhanced long-term learning relative to elaborative studying with concept mapping, yet this benefit was largely unanticipated by students. Reprinted from "Retrieval Practice Produces More Learning Than Elaborative Studying With Concept Mapping," by J. D. Karpicke and J. R. Blunt, 2011, *Science, 331*, pp. 772–775. Copyright 2011 by the American Association for the Advancement of Science. Reprinted with permission.

Active Retrieval Promotes Meaningful Learning

A current challenge is to establish the effectiveness of retrieval-based learning activities with educational materials and assessments that reflect complex, meaningful learning. "Meaningful learning" is often defined in contrast to "rote learning" (Mayer, 2008). Whereas rote learning is brittle and transient, meaningful learning is robust and enduring. Rote learning is thought to produce poorly organized knowledge that lacks coherence and integration, which is reflected in failures to make inferences and transfer knowledge to new problems. Meaningful learning, in contrast, is thought to produce organized, coherent, and integrated mental models that allow people to make inferences and apply knowledge.

It is important to remember that, in all circumstances, people transfer past experiences to meet the demands of a unique present. This always involves reconstructing knowledge by using the cues available in a given retrieval context. Outcomes identified as "rote" or "meaningful" learning may not reflect differences in what learners have encoded, stored, or constructed. Instead, the distinction between rote and meaningful learning hinges upon the similarity between retrieval scenarios in the present and learning experiences from the past. The ability to use knowledge in the present depends on the diagnostic value of retrieval cues regardless of whether the goal of

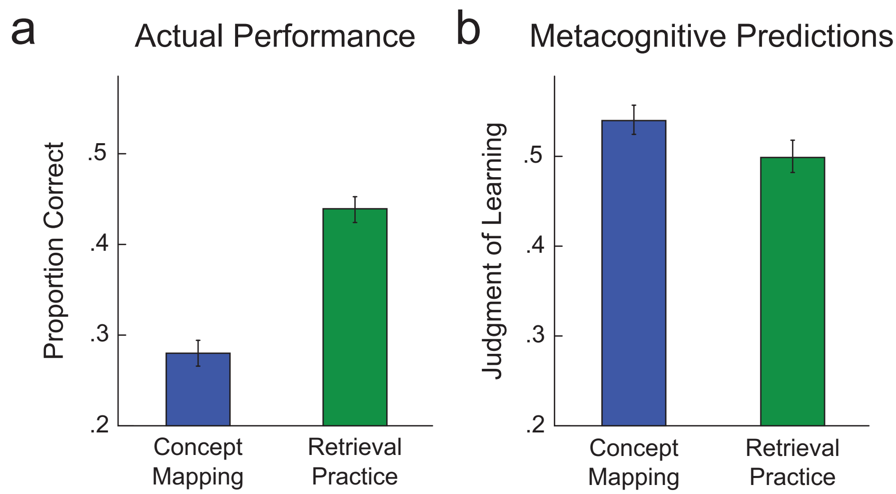

Fig. 4. Proportion correct on a final concept-map test (a) and metacognitive judgments of learning (predicted proportion of items correct) during the initial learning phase (b). The data presented in these graphs are adapted from Experiment 2 of Karpicke and Blunt (2011b). Even though the criterial test involved creating a concept map, practicing retrieval during original learning enhanced performance relative to elaborative studying with concept mapping, despite the fact that students believed elaborative concept mapping would produce better learning.

retrieval is to recall a fact, make an inference, or solve a new problem.

Investigators have taken two general approaches to examine the effects of active retrieval on meaningful assessments. One approach has been to use final-assessment questions that differ from questions experienced during original learning (e.g., Butler, 2010; Chan, 2009; Chan, McDermott, & Roediger, 2006; Hinze & Wiley, 2011; Johnson & Mayer, 2009; Rohrer, Taylor, & Sholar, 2010).[2] A second approach has been to design assessments that measure students' abilities to make inferences, apply knowledge, and solve new problems, or that otherwise measure the coherence and integration of students' mental models. We have already seen that active retrieval enhances learning of meaningful educational materials and that these effects are long-lasting, not short-lived. Recent research has shown that practicing active retrieval enhances performance as measured on meaningful assessments of learning and that these effects can be greater than those produced by other active-learning strategies.

In a recent study, we (Karpicke & Blunt, 2011b) examined the effects of active retrieval using measures of meaningful learning; importantly, we compared these effects to those produced by a popular learning strategy known as *concept mapping* (Novak & Gowin, 1984). Concept mapping involves having students create diagrams in which concepts are represented as nodes and relations among concepts are represented as links connecting the nodes. This activity involves elaborative studying because it is thought to help students organize and encode meaningful relationships among concepts. Concept mapping can also be used as a tool to assess students' knowledge, as discussed in the following paragraphs. Concept mapping is a popular strategy and enjoys strong advocacy among many educators. Indeed, the activity would seem to be an effective tool for promoting elaborative processing, although there has not been a wealth of randomized, controlled experiments examining the most effective ways to use concept mapping as a learning activity (see Karpicke & Blunt, 2011a).

We had students read science texts and create a concept map or practice actively retrieving the ideas from the texts. In two control conditions, students read the material once or repeatedly. One week after the learning phase, the students answered two types of questions designed to assess meaningful conceptual learning: *verbatim questions*, which assessed conceptual knowledge directly included in the text, and *inference questions*, which required students to make connections across concepts. As shown in Figures 3a and 3b, practicing retrieval produced the best performance on both types of conceptual questions, even better than elaborative studying with concept mapping did. However, when students made predictions of their long-term learning during the initial learning phase (Fig. 3c), they believed that rereading and concept mapping would produce more learning than active retrieval would, even though the opposite was true.

In a second experiment, we again had students either create concept maps or practice active retrieval while they studied. This time, however, as our criterial assessment of long-term learning, we had students create a concept map, which itself is a method of assessing the coherence and integration of students' conceptual knowledge. Even on this final concept-map assessment (Fig. 4a), students performed best when they had engaged in active retrieval during learning, a result indicating that active retrieval enhanced students' deep, conceptual learning of the material. Yet once again, the students generally believed they would do better after elaborative studying than after practicing retrieval, as shown in Figure 4b. Most students did not expect active retrieval to produce more learning than elaborative studying with concept mapping, but in fact it did.

Retrieval-Based Learning: Reprise

Retrieval is the key process for understanding learning and for promoting learning. It is essential for understanding learning because all expressions of knowledge involve retrieval and therefore depend on the retrieval cues that are available in a given context. The diagnostic value of retrieval cues—the degree to which cues help people recover particular target knowledge to the exclusion of competing candidates—is the critical factor for all learning. Retrieval is the key to promoting learning, and active retrieval has powerful effects on long-term learning. Each act of retrieval alters the diagnostic value of retrieval cues and improves one's ability to retrieve knowledge again in the future. Retrieval may enhance learning because it improves the match between a cue and particular desired knowledge, or it may enhance learning by constraining the size of the search set—the set of potentially recoverable candidates that comes to mind in the context of a cue (Karpicke & Blunt, 2011b; Karpicke & Zaromb, 2010). Practicing retrieval has also been shown to enhance organizational processing (Congleton & Rajaram, in press; Zaromb & Roediger, 2010), and such processing is likely necessary to support performance on assessments of meaningful learning. Thus, there are a number of potential mechanisms by which active retrieval may enhance long-term learning.

Retrieval-based learning is a broad, general perspective on how to improve student performance. There are many learning activities that active retrieval could potentially be incorporated into, and there are many different ways in which retrieval could be integrated into such activities. For instance, group discussions, reciprocal teaching, and questioning techniques (both formal ones, such as providing classroom quizzes, and informal ones, such as integrating questions within lectures) are all likely to engage retrieval processes to a certain extent. Spending time actively attempting to retrieve and reconstruct one's knowledge is a simple yet powerful way to enhance long-term, meaningful learning. The central challenge for future research will be to continue identifying the most effective ways to use retrieval as a tool to enhance meaningful learning.

Recommended Reading

Karpicke, J. D., & Grimaldi, P. J. (2012). (See References). A recent overview of retrieval-based learning that covers additional topics, including metacognitive aspects of retrieval practice and the potentiating effects of retrieval on subsequent encoding.

Moscovitch, M. (2007). (See References). An accessible critique of the storehouse metaphor of memory that also emphasizes the essential role of retrieval in understanding learning.

Roediger, H. L. (2000). (See References). An in-depth discussion of why retrieval is the key process for understanding learning.

Roediger, H. L., & Karpicke, J. D. (2006a). (See References). A comprehensive and historical overview of research on the effects of active retrieval on learning.

Tulving, E. (1991). (See References). Essential reading for any student of learning and memory: an interview in which Tulving explains why retrieval processes must be considered in any analysis of learning.

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Note

1. We were unable to score ambiguous responses given by 4% of students.
2. There is some evidence that retrieving a portion of some material can impair recovery of nonpracticed parts of the material (Storm, 2011), but with meaningful and integrated educational materials, practicing retrieval of part of the materials typically enhances learning of nonpracticed parts of the materials (Chan, 2009; Chan, McDermott, & Roediger, 2006).

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