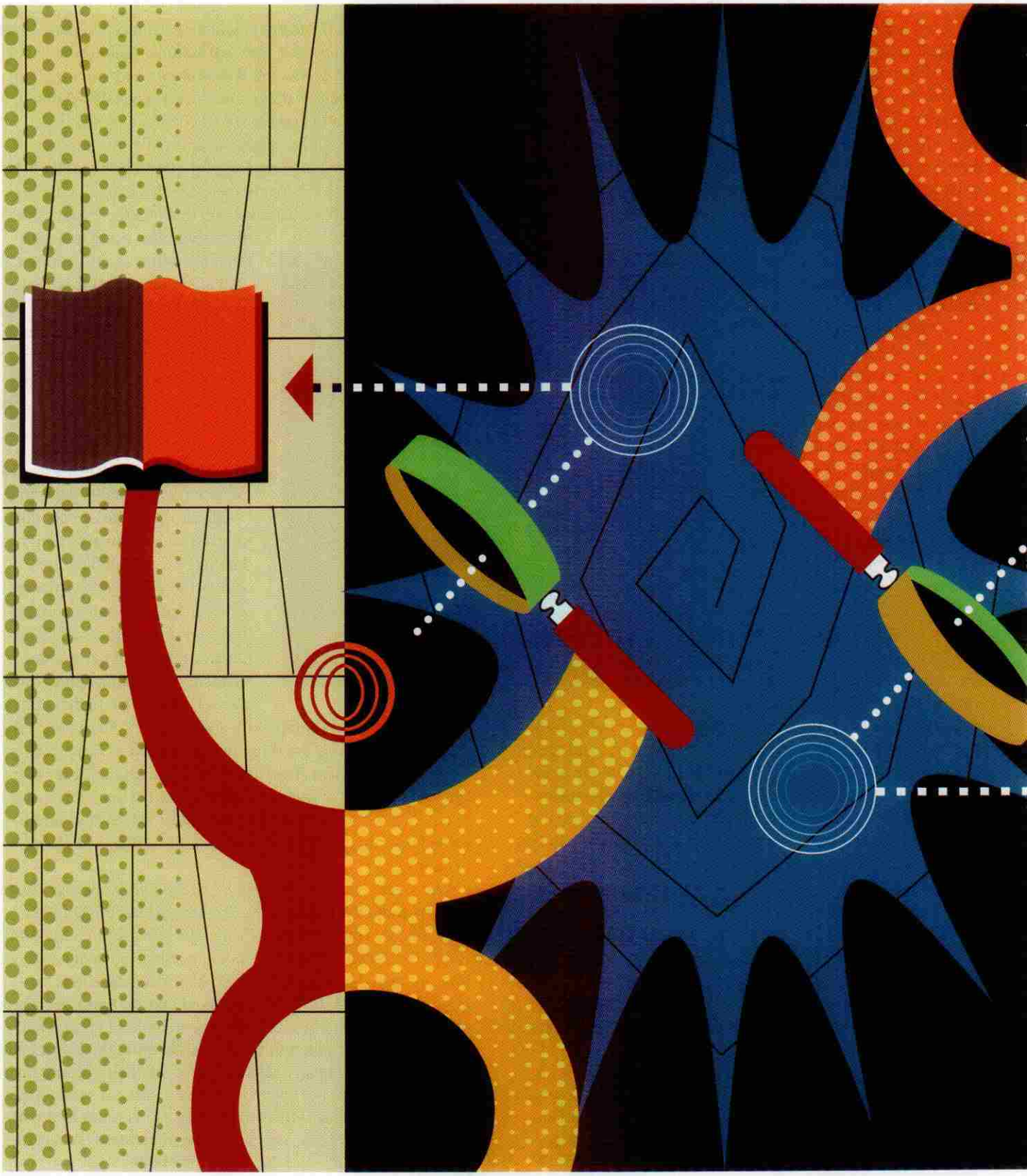
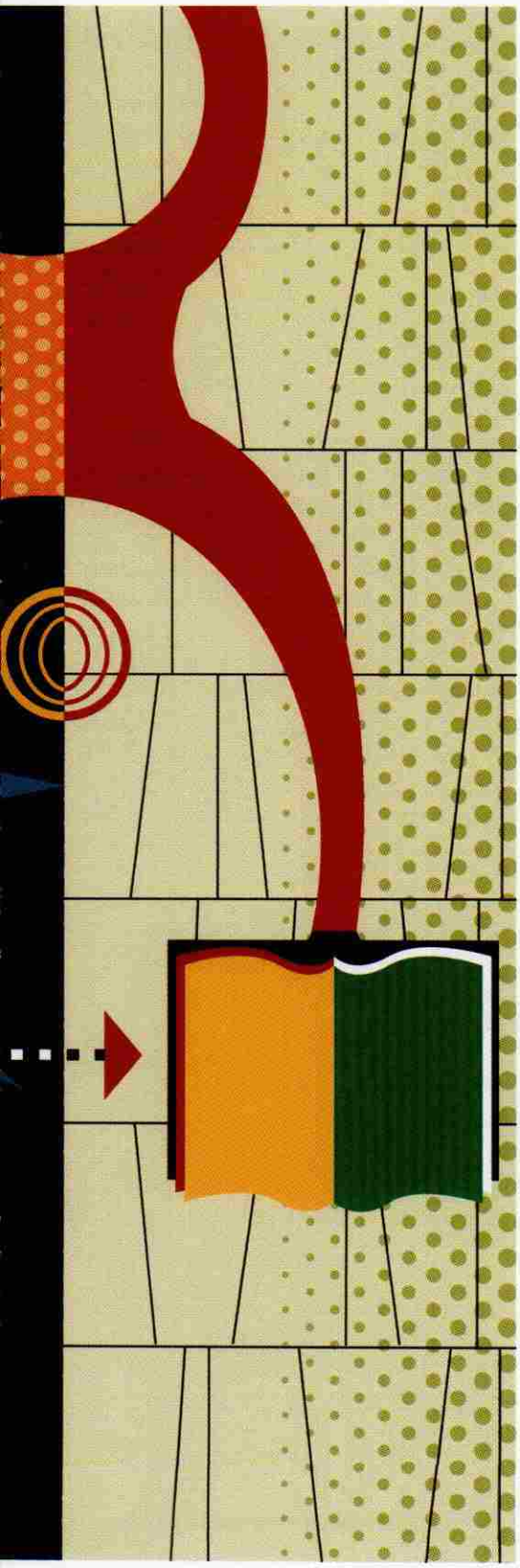
Applying the Science of Learning

By Diane F. Halpern and Milton D. Hakel



to the University and Beyond



Teaching for Long-Term Retention and Transfer

There is nothing more annoying than telling a new acquaintance that we are college professors and getting the enthusiastic reply, "It must be great to have all your summers off." Most of the general public—including the parents of the students we teach, students themselves, and many of the people who ultimately pay our salaries—believe that college faculty are primarily teachers who have little to do when classes are not in session.

Of course, most of the general public know that we also "do research" and committee work. But they believe that these other parts of the professor's job are secondary to teaching. Those outside academia further assume that because we are college faculty, we actually have a reasonable understanding of how people learn and that we apply this knowledge in our teaching.

It is easy to imagine where these fantastic notions come from. Have you actually *read* those glossy brochures (known as "View Books" to those in the trade) that our colleges and universities send out to prospective students and to others they want to impress? Invariably, beautiful images of campus life are presented, together with well-crafted language that explains how our students learn lifelong skills that prepare them for lucrative careers and to face the many challenges of adult life.

It would be reasonable for anyone reading these fine words to assume that the faculty who prepare students to meet these lofty goals must have had considerable academic preparation to equip them for this task. But this seemingly plausible assumption is, for the most part, just plain wrong.

The preparation of virtually every college teacher consists of in-depth study in an academic discipline: chemistry professors study advanced chemistry, historians study historical methods and periods, and so on. Very little, if any, of our formal training addresses topics like adult learning, memory, or transfer of learning. And these observations are just as applicable to the cognitive, organizational, and educational psychologists who teach topics like principles of learning and performing, or evidence-based decision-making.

We have found precious little evidence that content experts in the learning sciences actually apply the principles they teach in their own classrooms. Like virtually all college faculty, they teach the way they were taught. But, ironical-

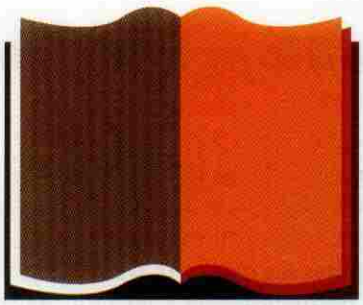
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ly (and embarrassingly), it would be difficult to design an educational model that is more at odds with the findings of current research about human cognition than the one being used today at most colleges and universities.

Most faculty do in fact spend substantial amounts of time in teaching-related activities—and this is true at even the most research-centered institutions. Most care about their students' learning and want to be effective teachers. Most also believe that they are good teachers and tell those who ask that their teaching skills are above average. But what most college faculty actually know about adult cognition is generally gained through a process of practical trial and error.



Unfortunately, because their intuitive knowledge of good teaching practices is rarely put to a systematic test, what faculty often "know" to be sound educational practice may not be so at all. Nora Newcombe, a developmental psychologist at Temple University, notes wisely that biology has become the scientific basis for medicine, while cognitive psychology and learning research have not become the scientific basis for education (see Newcombe in Suggested Readings). The study of human cognition is an empirical science with a solid theoretical foundation and research-based applications that we can and should be using in college classrooms.

Psychologists, educators, and other professionals already have available to them a substantial body of research that can be drawn upon to inform those responsible for designing and implementing learning programs. Unfortunately, the research literature is usually ignored, while educational leaders and policymakers grasp at the ephemeral "magic" of quick fixes. How can we apply what research on human learning can tell us to both higher education institutions and the many other places where adults learn?

About 30 experts from different areas of the learning sciences recently met to answer this question. They included cognitive, developmental, educational, motivational, social, cultural, and organizational psychologists, physicists and other science instructors, and representatives from such bodies as the National Science Foundation and regional accrediting agencies.

The empirically validated principles that we offer in this article are based on discussions at that meeting, embellished by our own personal biases and memories. They can be applied in any adult learning situation, including distance education with online components, learning from texts, laboratory and classroom instruction, and learning in informal settings. (An extensive list of references supporting these principles can be found in Halpern and Hakel, in Suggested Readings.)

The First and Only Goal: Teach for Long-Term Retention and Transfer

Why do we have colleges and universities? The main reason—some might argue the only reason—is transfer of learning. The underlying rationale for any kind of formal instruction is the assumption that knowledge, skills, and attitudes learned in this setting will be recalled accurately, and will be used in some other context at some time in the future. We only care about student performance in school because we believe that it predicts what students will remember and do when they are somewhere else at some other time. Yet we often teach and test as though the underlying rationale for education were to improve student performance *in school*. As a consequence, we rarely assess student learning in the context or at the time for which we are teaching.

Sometimes information learned in a school context will transfer to an out-of-school context and sometimes it won't. If we want transfer, we need to teach in ways that actually enhance the probabilities of transfer. *The purpose of formal education is transfer.* We teach students how to write, use mathematics, and think because we believe that they will use these skills when they are not in school. We need to always remember that we are teaching toward some time in the future when we will not be present—and preparing students for unpredictable real-world "tests" that we will not be giving—instead of preparing them for traditional midterm and final exams.

Teaching for retention during a single academic term to prepare students for an assessment that will be given to them in the same context in which the learning occurs is very different from teaching for long-term retention and transfer. Consider, for example, a common concept like statistical correlation that is taught in many different disciplines. After completing a standard course in statistics or analysis, most students can define the term, can compute a correlation coefficient, and can probably explain why correlation is not the same as causation.

As a result, they can usually achieve high grades on an examination at the end of the term that asks straightforward questions about this set of knowledge and skills. But what happens when they are at their own kitchen table reading a newspaper article describing a finding that children who attended preschool are better readers in first grade than those who did not attend preschool? Does it occur to them to ask whether the children who attended or did not attend preschool are distributed randomly? Or do they automatically assume that attendance at preschool *causes* children to be better readers in first grade? Most likely the latter.

Basic Principles

If we want to enhance long-term retention and transfer of learning, we need to apply a few basic laboratory-tested principles drawn from what we know about human learning.

1) *The single most important variable in promoting long-term retention and transfer is "practice at retrieval."* This principle means that learners need to generate responses, with minimal cues, repeatedly over time with varied applications so that recall becomes fluent and is more likely to occur across different contexts and content domains. Simply stated, information that is frequently retrieved becomes more retrievable. In the jargon of cognitive psychology, the strength of the "memory trace" for any information that is recalled grows stronger with each retrieval.

Actual practice at retrieval helps later recall of any learned information more than does additional practice without retrieval, or time expended in learning the information in the first place. For example, the "testing effect" is a term used to

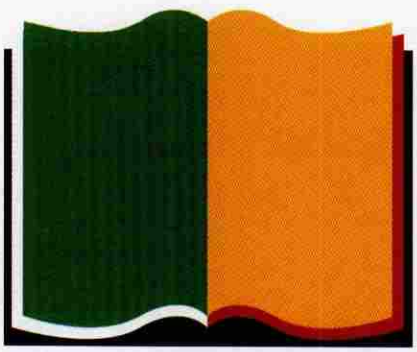
describe the frequent finding in educational measurement that the act of taking a particular test often facilitates subsequent test performance—but *only* for those items recalled from the first test.

The benefits of retrieving information learned earlier to produce answers in response to new questions are among the most robust findings in the learning literature. Practice at retrieval necessarily occurs over time and within a particular context. Transfer of learning can be aided by altering the context for retrieval. For example, students can practice retrieval by teaching learned concepts and skills to other students, or by responding to frequent questions asked in class or posed online.

The effects of practice at retrieval are necessarily tied to a second robust finding in the learning literature—*spaced* practice is preferable to massed practice. For example, Bjork and his colleagues recommend spacing the intervals between instances of retrieval so that the time between them becomes increasingly longer—but not so long that retrieval accuracy suffers (see deWinstanley and Bjork in Suggested Readings).

Applying this principle, a first examination to test a given concept or element of knowledge might be given to students one day after the initial learning, the second exam a few days after the first, the third a week after the second, and the fourth a month after the third, with the interval for each subsequent exam determined by the level of accuracy of student performance on the preceding one.

2) *Varying the conditions under which learning takes place makes learning harder for learners but results in better learning.* Like practice at retrieval, varied learning conditions pay high dividends for the effort exerted. In the jargon of cognitive psychology, when learning occurs under varied conditions, key ideas have "multiple retrieval cues" and thus are more "available" in memory. For example, educational research suggests that significant learning gains can occur when different types of problems and solutions are mixed in the same lesson, even though the initial learning can take significantly longer. Like practice at retrieval, variability in constructing learning situations requires greater student effort. As a result, engaging in such situations may be less enjoyable for students and lead to lower student ratings of their instructors.



This can be an important consideration on campuses where small differences in student responses on course evaluations are used—we believe inappropriately—to inform salary, promotion, and tenure decisions. We mention this only because changes in institutional practices and incentives, not only changes in faculty knowledge and behavior, will frequently be necessary to put these principles to work on real college campuses.

3) *Learning is generally enhanced when learners are required to take information that is presented in one format and "re-represent" it in an alternative format.* Cognitive research has established the fact that humans process information by means of two distinct channels—one for visuospatial information and one for auditory-verbal information. A given piece of information can be organized and "stored" in memory in either or both of these representational systems. According to dual-coding theory, information that is represented in both formats is more likely to be recalled than information that is stored in either format alone.

Learning and recall are thus enhanced when learners integrate information from both verbal and visuospatial representations. For example, requiring learners to draw visuospatial "concept maps" makes them a) create an organizational framework in terms of which to arrange the information they are learning, and b) communicate this framework visually through a "network" of ideas—both of which are activities that enhance learning. Complex concepts can be related to one another in numerous ways, and depicting correct relationships among concepts is central to all graphic organizing techniques.

When students engage in concept mapping, they focus on and identify different types of relationships or links among concepts. Many students report that concept mapping is a challenging experience, but that it pays off in long-term learning gains. Similarly, requiring students to write about or explain verbally what they have learned in a mathematical or schematic learning task also takes advantage of dual coding. Faculty need to use both verbal and visuospatial processing activities in *all* of the learning tasks that they construct.

4) *What and how much is learned in any situation depends heavily on prior knowledge and experience.* Psychologists use the term "construction of knowledge" because each learner creates new meaning using what he or she already knows. Thus, the best predictor of what is learned at the completion of any lesson, course, or program of study is what the learner thinks and knows at the start of the experience. Yet few college faculty try to discover anything about the prior knowledge or beliefs of their students, despite the importance of prior conditions in determining what they will learn.

We need to assess learner knowledge and understanding at the *start* of every instructional encounter, probing for often-unstated underlying assumptions and beliefs that may influence the knowledge, skills, and abilities that we want students to acquire. We also need to test continually for changes in knowledge structures as learning progresses—and look especially for post-learning drifts, because student understanding can easily revert back toward pre-instructional levels.

5) *Learning is influenced by both our students' and our own epistemologies.* Academic motivation is related to underlying epistemological beliefs about learning itself and about how learning works. Many college students complain that they "cannot do math," cannot succeed in a literature course, or will automatically have trouble with some other academic discipline. When questioned about this belief, what most are really saying is that they think learning ought to be easy but, in these disciplines, it is hard.

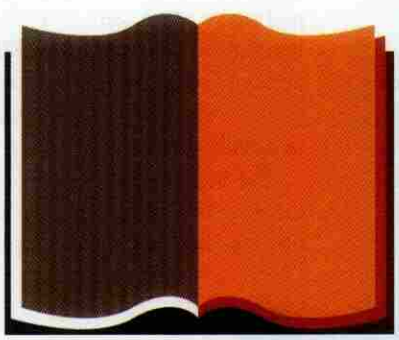
What they don't know is that learning and remembering involve multiple, interdependent processes. Some types of learning occur implicitly, without conscious awareness. Others occur consciously but are relatively easy. Still other types of learning involve considerable effort, and are perhaps even painful and aversive, like learning how to do long division or

how to multiply matrices. It is only after an initial investment in the hard work of learning that additional learning in these fields becomes more automatic, and consequently becomes easier.

Determining the best way for students to learn and recall something will thus depend on *what* you want learners to learn and be able to recall, what they *already know*, and their *own beliefs* about the nature of learning. College faculty can help students articulate their implicit beliefs about learning so that these beliefs can be explicitly examined. And based on this knowledge, instructors' construction of the learning task itself can also help students construct new models of how they learn.

6) *Experience alone is a poor teacher.* There are countless examples that illustrate that what people learn from experience can be systematically wrong. For example, physicians often believe that an intervention has worked when a patient improves after a particular treatment regime. But most patients will improve no matter what intervention occurs. If the patient does not improve, then physicians may reason that he or she was "too sick" to have benefited from effective treatment. There are countless examples of this sort of erroneous thinking in both professional practice and everyday life, where current beliefs about the world and how it works are maintained and strengthened, despite the fact that they are wrong.

People, therefore, frequently end up with great confidence in their erroneous beliefs. Confidence is not a reliable indicator of depth or quality of learning. In fact, research in metacognition has shown that most people are poor judges of how well they comprehend a complex topic.



The fact that most people don't know much about the quality of their comprehension is important, because there is a popular belief that all learning and assessment should be "authentic"—that is, nearly identical in content and context to the situation in which the information to be learned will be used. But what is missing from most authentic situations—and from most real-life situations as well—is systematic and corrective feedback about the consequences of various actions.

To return to the example of physicians, many medical schools have now adopted simulated patients as a teaching and testing tool—actors trained to present a variety of symptoms for novice practitioners to diagnose—because unplanned clinical encounters with real patients can't provide the necessary variety and feedback.

7) *Lectures work well for learning assessed with recognition tests, but work badly for understanding.* Virtually all introductory college courses involve a lecture portion, in which a lone teacher mostly talks and writes on the board, while students take notes. This is a satisfactory arrangement for learning if the desired outcome is to produce learners who can repeat or recognize the information presented. But it is one of the worst arrangements for promoting in-depth understanding.

There are two related points in this principle. The first is the fact that lecturing is not optimal to foster deep learning. The second is the consequent reliance on recognition-based tests as an index of learning. These two problems are often related because large-lecture learning settings are often associated with multiple-choice tests.

The combination of large lecture classes and multiple-choice tests constitutes a relatively low-cost approach to instruction, so it is easy to understand the widespread use of this pedagogical model for large-enrollment courses on college campuses. But understanding is an *interpretive* process in which students must be active participants.

Learners need "cues" that trigger interpretation and force them to engage the material actively, even if they are sitting silently in a large lecture hall. For example, it is possible to get students to elaborate on information that is presented in lectures by relating it to information that they already know through the use of imagery or probing questions that test for understanding.

A major problem with recognition-based tests like multiple-choice exams where questions tap only lower-level cognitive processes, or with tests that require students only to repeat back course material, is that both faculty and students believe that achieving a high score is evidence of "good learning."

Unfortunately, it is quite possible for students to achieve high scores on tests like these and not be able to recognize a given concept's application in a slightly altered context, or not be able to apply the concept at some time in the future.

The ability to simply recognize a correct answer on an examination is not a good indicator of whether the learner can recognize other instances in which a concept applies when he or she is outside the classroom. Thus the type of assessment used needs to match the learning objectives. High scores on traditionally constructed tests do not necessarily indicate enduring or transferable learning.

8) *The act of remembering itself influences what learners will and will not remember in the future.* Asking learners to recall particular pieces of the information they've been taught often leads to "selective forgetting" of related information that they were *not* asked to recall. And even if they do well on a test taken soon after initial learning, students often perform less well on a later test after a longer retention interval.

Principles of learning are difficult to discuss in isolation because learning activities that occur at different times—at the point of initial learning, during the retention interval, and at the point of recall—are all interdependent. They work together to determine what is remembered at some point in the future, well after the first recall test is administered. According to standard "memory trace" theories of how we remember, the act of remembering strengthens some memory traces and weakens—or at least fails to strengthen—others.

Few instructors are aware of this effect and inadvertently create learning activities that actually *cause* students to forget information that they want them to retain. This may especially be the case when faculty test for relatively unimportant points, in the belief that "testing for the footnotes" will enhance learning. In fact, it will probably lead to better student retention of the footnotes at the cost of the main points.

Another variable that is often ignored in pedagogical design is the length of the retention interval between the point of initial learning and the first test. When students are tested fre-

quently, they receive higher scores than students who are tested infrequently, thus creating the impression that frequent testing is a sound educational practice.

But frequent testing also leads to overconfidence for learners who erroneously believe that their long-term retention of the information will be better than it actually is. This belief may lead them to invest less time and effort in studying the material for future recall. The detrimental effect of testing soon after information is learned is another example where the short-term benefits of an educational practice can mask important long-term detriments.

9) Less is more, especially when we think about long-term retention and transfer. Some introductory texts in psychology, biology, or economics seem to weigh almost as much as the students who carry them around. Faculty need to consider carefully the balance between how much and how well something is learned. This is especially the case when external bodies like boards and accreditors favor domain coverage, no matter how thin, of more and more content at the cost of deeper understanding.

Instructional designers need to make careful choices about how much content to include. An emphasis on in-depth understanding of basic principles often constitutes a better instructional design than more encyclopedic coverage of a broad range of topics. Again, it is important to stress that classroom instruction is intended to provide learners with information and skills that they will need sometime in the future when the instructor is not present.

The amount of detail that learners will need at this future, unknown time and place is what should be guiding decisions about how deeply a particular element of content should be learned and what level of detail is important. If cursory knowledge of a broad area is indeed desirable, as it sometimes is, then learners and instructors should be collectively conscious of this goal so that they can learn and teach in ways that will achieve broad coverage.

But if deep understanding of basic principles is what is wanted, then the teaching and learning process needs to be structured accordingly. This means that instructors and learners ought to have clearly articulated goal statements at the start of instruction that guide instructional design and learning activities. And they need to carefully match the learning activities they engage in to these goals.

10) What learners do determines what and how much is learned, how well it will be remembered, and the conditions under which it will be recalled. There is an old saying in psychology, "The head remembers what it does." Our most important role as teachers is to direct learning activities in ways that maximize long-term retention and transfer. What professors do in their classes matters far less than what they ask *students* to do.

Regardless of class size or format—in lecture halls, in laboratories, in seminar rooms, or online—faculty can use these empirically validated principles to enhance learning. Most of us devote considerable time and energy to the hard work of teaching, and we want to do it well. By applying the science of learning in our classrooms, we practice what we preach in helping students learn.

We need to look constantly for concrete evidence when we evaluate claims about what works in education. Consequently, we urge you to develop a healthy skepticism about all educational claims. If a colleague or a teaching newsletter advises, for example, that you should match student learning styles with your own teaching style, or that giving students an outline of the text will promote retention, employ some basic concepts of critical thinking and ask about the *evidence* that supports these claims.

There is a large amount of well-intentioned, feel-good psychobabble about teaching out there that falls apart upon investigation of the validity of its supporting evidence. As college faculty, we can have a lifelong effect on what our students remember, and consequently on what they will think and do. Or we can have a minimal effect. Most of the difference depends on how we design and direct learning activities. It's time we applied what we know about learning generated in our own cognitive laboratories and applied research settings to systematically enhance teaching and learning practice in college. ©

Suggested Readings

- Applying the Science of Learning to the University and Beyond: Cognitive, Motivational, and Social Factors. Online at berger.claremontmckenna.edu/asl.
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