A FEW THINGS COGNITIVE SCIENCE TEACHES US ABOUT EFFECTIVE TEACHING

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For most of the last nine centuries, the standard model for university teaching has been simple: professors lecture and students listen, and then the students try to replicate on assignments and examinations the facts and methods presented in the lectures. Throughout those centuries, some philosophers and psychologists and educators disagreed with this formula, but they were generally ignored by most university faculty members and administrators.

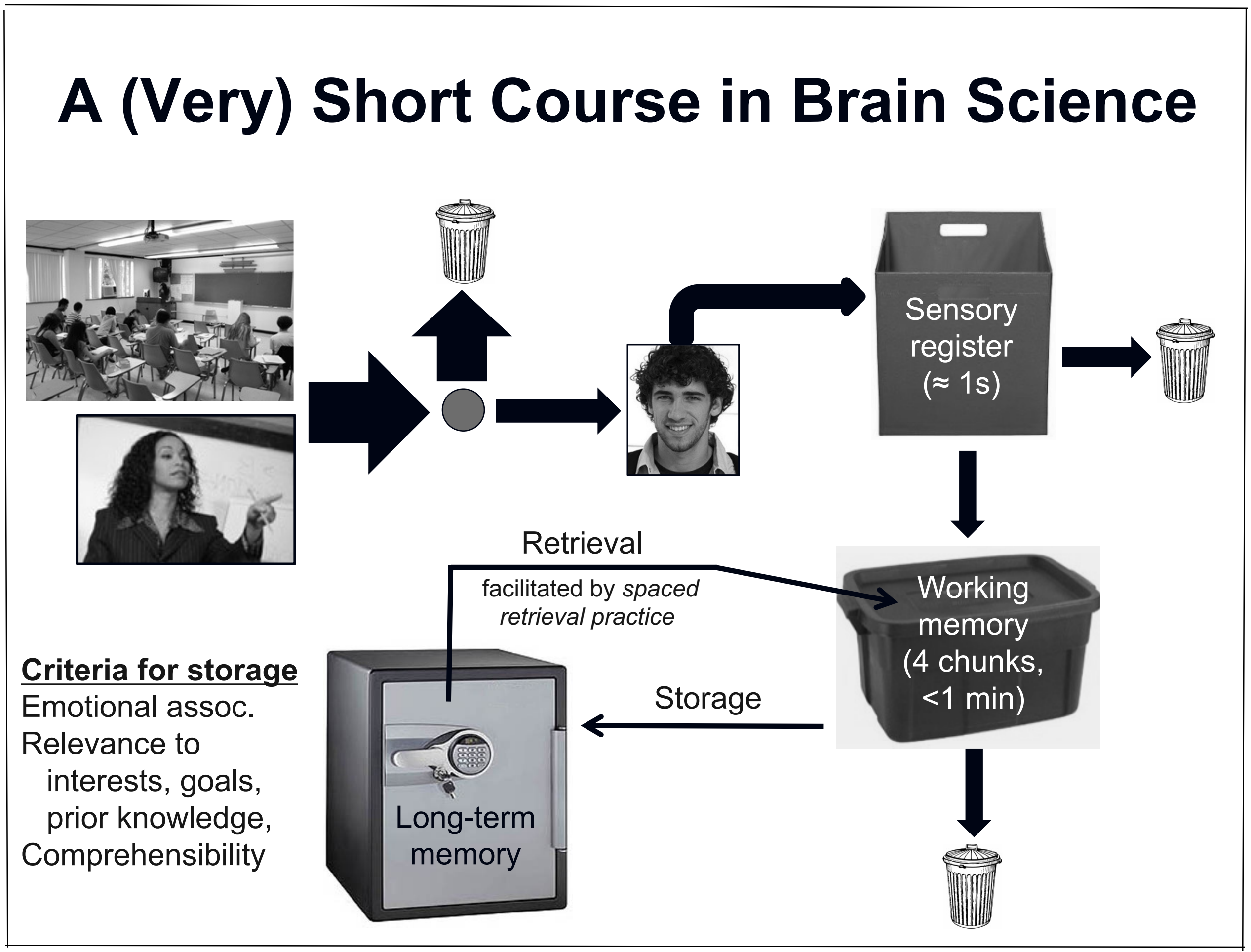
In the past three to four decades, cognitive scientists have discovered a great deal about the learning process—what happens in the brain when we learn something and what methods and conditions of instruction promote learning. It turns out that the practices of the standard teaching model are not on the list of promotive factors. This presentation reviews some of the principal findings of the scientists, suggests teaching practices consistent with those findings, and points to research-based evidence that those practices are indeed more effective than the traditional ones.

How does learning happen?[1–3]

"Learning" is shorthand for storing information in a person's long-term memory, from which it can later be retrieved and used when a need for it arises.

According to a widely accepted model of the learning process, new information comes in through the senses, is held for a fraction of a second in a *sensory register,* and is then either passed on to *working memory* or judged unimportant and discarded. Working memory, which is where all conscious mental processing takes place, has slots for about four chunks of information. Chunks that get into it generally stay there for less than a minute during which they are evaluated by an executive controller in the brain, which determines whether to store them in long-term memory or discard them. Only if they are stored can they be considered to have been learned. If they are discarded, they are irretrievably lost.

When a new chunk enters working memory, the controller judges its importance relative to the other chunks currently there and discards the least important chunk. The criteria for importance in descending priority are that the information has (1) *emotional associations* for the learner, (2) *relevance* to the learner's interests, goals, and prior knowledge, and (3) *comprehensibility* to the learner. When new information is first stored, the neural network that contains it is weak, and retrieving it after some time has passed may be difficult. Each time it is retrieved, the network becomes stronger and more extensive and subsequent retrievals become easier. The following figure shows a highly simplified graphical version of this model.[4]



Implications for instructors (and one for students)

- **Working memory has a low information processing capacity (3–5 chunks of information, less than 1 min. to process it).**

In a traditional nonstop lecture, students are flooded with information at a rate much greater than working memory can handle, so that most of the lecture content is inevitably lost to them. Instead of doing that, intersperse lecture segments with short periods in which students can reflect on and work with the information, individually or in small groups. That is, *use active learning.* [5, Ch. 6; 6]

- **The executive controller in working memory stores information based on its (1) emotional associations for students; (2) relevance to their goals, interests, and prior knowledge; (3) comprehensibility to them.**

If instructors present information irrelevant to anything students know and care about or information that makes little sense to them, the information is unlikely to be stored in long-term memory (i.e., learned). *Introduce new material in the context of things students are likely to care about and make connections between it and things they are likely to already know* (and do your best to make the new information as comprehensible as you can.)

One way to establish connections between material you are about to teach and students' prior knowledge is to use an inductive teaching method, such as inquiry-based, project-based, or problem-based learning. The traditional deductive teaching method begins presentation of a new topic with basic information (facts, theories, formulas, problem-solving methods) followed by illustrative examples and then assignments. Instead of doing that, *begin presentation of a new topic by giving the students a real-world challenge that involves both material they are likely to be familiar with and the information you are about to teach.* The challenge might be a question to be answered, an observed phenomenon or experimental result to be explained, the behavior of an individual, group, or physical or social system in a specified situation to be predicted, or a technical problem to be solved. Let the students work—ideally in small groups—for a short time to speculate on the answer to the question or the explanation of the observation or data or the prediction of the behavior, or to decide on how they would approach the problem. Then teach the new information in the context of addressing the challenge.[7,8]

- **The neural networks that contain newly stored information are weakly connected and the information may not be easily retrieved. *Spaced retrieval practice* (having to retrieve information from memory after some time has elapsed since the last time it was stored or retrieved) makes retrieval easier when the information is next needed.**

That observation has an important implication for students related to how they study. The traditional study method consists mainly of rereading. Shortly before an exam—often the night before—students look over their course text, lecture notes, and in courses that involve analytical problem solving, old problem solutions. When they're done, they believe that they remember the facts, predict the system behavior, or understand the solution methods, and could solve similar problems themselves on the exam. These beliefs are often *illusions of competence*. Since the students are not retrieving the facts and methods they need, they are not strengthening and broadening the neural networks that contain the information, and they may be unable to retrieve it when they need it on the exam. Moreover, if they confine their studying to the night before the exam, their lack of sleep and exhaustion in the morning is also likely to hurt their performance.

Instead, *students should study by giving themselves spaced retrieval practice,* starting well before the exam. Working individually or (better) with study partners, they should test themselves on factual information and discussion or procedural questions that may show up on the exam. They should also individually set up as many analytical problem solutions as possible without looking at existing solutions, proceeding until all that remains is time-consuming but routine computation. If they get stuck on a problem, they may look up the solution, put the problem aside until some time passes (at least several hours), and then attempt to solve it again without looking at the solution. The more they do these things, the better their exam grades are likely to be.[2; 5, pp. 116–117]

The role of retrieval practice in learning also has two implications for instructors. First, *give your students that information about how to study, and remind them of it before your first exam.* Second, *don't just teach a problem-solving or critical analysis method once, give several illustrations of it, and then move on, so the students don't see it again until it shows up on an exam. Instead, use* interleaving*, bringing important methods back in as many different contexts as possible.* The spaced retrieval practice interleaving provides will help equip the students to apply the methods to similar but non-identical tasks on assignments and exams.[2; 5, pp. 196–197]

References

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