Practice Makes Perfect—but Only If You Practice Beyond the Point of Perfection

By Daniel T. Willingham

**Question:** Just how much should students practice what they learn? On the one hand, it seems obvious that practice is important. After all, "practice makes perfect." On the other hand, it seems just as obvious that practicing the same material again and again would be boring for students. How much practice is the right amount?

**Answer:** It is difficult to overstate the value of practice. For a new skill to become automatic or for new knowledge to become long-lasting, **sustained practice, beyond the point of mastery, is necessary.** This column summarizes why practice is so important and reviews the different effects of intense short-term practice versus sustained, long-term practice.

That students would benefit from practice might be deemed unsurprising. After all, doesn't practice make perfect? The unexpected finding from cognitive science is that practice **does not** make perfect. Practice...
consider findings from this field that are strong and clear enough to merit classroom application.

until you are perfect and you will be perfect only briefly. What's necessary is sustained practice. By sustained practice I mean regular, ongoing review or use of the target material (e.g., regularly using new calculating skills to solve increasingly more complex math problems, reflecting on recently-learned historical material as one studies a subsequent history unit, taking regular quizzes or tests that draw on material learned earlier in the year). This kind of practice past the point of mastery is necessary to meet any of these three important goals of instruction: acquiring facts and knowledge, learning skills, or becoming an expert.

Acquiring Facts and Knowledge

Intuition tells us that more practice leads to better memory. Research tells us something more precise: Memory in either the short- or long-term requires ongoing practice.

Let's first consider memory in the short-term, meaning days or weeks. Suppose I am trying to learn the procedures necessary for a bill to become a federal law. I might study these facts (using any number of techniques) and periodically test myself. Suppose further that I study until I perform perfectly on my self test. Do I know these facts? Yes, I know them now. But what about tomorrow? In order to protect this learning from the ravages of forgetting, I need to practice beyond one perfect recitation. Studying material that one already knows is called overlearning. Because memory is prone to forgetting, one cannot learn material to a criterion and then expect the memory to stay at that level very long.

Anticipating the effect of forgetting dictates that we continue our practice beyond the mastery we desire. In an illustrative experiment (Gilbert, 1957), subjects were read a brief paragraph about a fictional country and then asked 22 questions based on the paragraph. If the subject answered a question correctly, the question was discarded. Then the subject heard the paragraph again, and was asked those questions that he or she had missed. The procedure was repeated until the subject successfully answered all of the questions. Another group of subjects participated in a second condition that required overlearning. A question was not discarded until it had been answered correctly three times rather than once. All subjects
received a surprise retest after a delay of either 15 minutes or two days. The overlearning group performed better at the short delay (22 questions correct versus 15) and also at the long delay (17 questions correct versus 13). Overlearning has been studied (although not extensively) for many years. These results are typical, but most of the experiments deal with short-term retention.

It may seem that the emphasis on short-term knowledge is peripheral to education. As teachers, we want long-lasting knowledge, not just knowledge for a few days. But, in fact, teachers may have goals that entail short-term knowledge. For example, a science teacher may want students to have a series of facts about certain species at their fingertips so that the teacher can introduce an important abstract concept concerning evolution on which those facts depend. Once the student has used the facts to gain a firm understanding of evolution, no great educational harm is done if the particular facts about particular species are forgotten. But without those facts well-lodged in memory for at least a short time, harm would be done to a student's ability to grasp the larger concept.

For other material, we most certainly do want longer-term retention. In this case again, practice past the point of mastery is essential. In the case of overlearning, the practice begins with active studying for the purpose of learning. Over time, practice will take the form of using old material in the course of studying some new material. For example, students will initially study the terms isthmus and delta to master their meanings, and will later practice these meanings as they use the terms in their continued study of geography.

Although practice takes on a different character for the longer-term, it is no less important. Studies show that if material is studied for one semester or one year, it will be retained adequately for perhaps a year after the last practice (Semb, Ellis, & Araujo, 1993), but most of it will be forgotten by the end of three or four years in the absence of further practice. If material is studied for three or four years, however, the learning may be retained for as long as 50 years after the last practice (Bahrick, 1984; Bahrick & Hall, 1991). There is some forgetting over the first five years, but after that, forgetting stops and the remainder
will not be forgotten even if it is not practiced again. Researchers have examined a large number of variables that potentially could account for why research subjects forgot or failed to forget material, and they concluded that the key variable in very long-term memory was practice.* Exactly what knowledge will be retained over the long-term has not been examined in detail, but it is reasonable to suppose that it is the material that overlaps multiple courses of study: Students who study American history for four years will retain the facts and themes that came up again and again in their history courses.

Learning Skills

Acquiring factual knowledge is only part of what we want our students to gain from their schooling. We also want them to be skilled problem solvers, effective written and oral communicators, and creative thinkers. These skills—and indeed, all skills that involve thinking—rely on working memory capacity. Working memory is, to put it colloquially, the place in the mind where thought happens. It is often called the bottleneck of the mind because there is a limited amount of space in working memory. That is why it is difficult to mentally divide 34,516 by 87. It is hard to simultaneously maintain the numbers, employ the processes for long division, and update the answer as you derive it. This space limitation is relevant not just to mental arithmetic, but to most types of problems we would like our students to solve, such as writing a clear laboratory report, reading an essay with deep understanding, or seeing the links between historical events.

Our ability to think would be limited indeed if there were not ways to overcome the space constraint of working memory. One of the more important mechanisms is the development of automaticity. When cognitive processes (e.g., reading, writing grammatically, reading a map, identifying the dependent variable in a science experiment, using simple mathematical procedures) become automatic, they demand very little space in working memory, they occur rapidly, and they often occur without conscious effort.

For example, if you are reading this article, the process of reading is very likely automatic for you. You do not need to laboriously piece
together the letters of each word to puzzle out its identity. Your mind seems to divine the meaning of prose immediately and without effort on your part. Try this classic demonstration of automaticity for advanced readers. In this task you are asked to name the ink color in which the words are printed, but ignore the word that the letters spell. Hence for the stimulus TURKEY, the proper response is "blue." First try this list:

LION
BEAR
TIGER
LION
BEAR
BEAR
TIGER

Now try this list:

RED
GREEN
BLUE
RED
BLUE
BLUE
GREEN

The second list is much harder to read than the first list because, for you, reading is automatic. Even though you try not to read the words that the letters form, you read them automatically and doing so conflicts with naming the ink color. For someone who cannot read, the second list is no harder than the first.

But most of the time automaticity is helpful, rather than disruptive. Picture a beginning reader slowly puzzling out the word "blue." Doing so consumes all of working memory, so it is difficult for the student to follow the plot of the story in which the word appears. Once reading is automatic, however, precious working memory resources can be devoted to considering the meaning of a text, the effectiveness of its argument, and so on.

Automaticity is important not only in reading, but in all mental life. Consider how difficult it would be to navigate an unfamiliar city by car if you had to focus on how hard to press the accelerator and brake, how far to turn the steering wheel, when to monitor your mirrors, and all of the other components of driving that have become automatized.
Automaticity is vital in education because it allows us to become more skillful in mental tasks. An effective writer knows the rules of grammar and usage to the point of automaticity—and knows automatically to begin a paragraph with a topic sentence, include relevant detail, etc. The effective mathematician invokes important math facts and procedures automatically. Readers who are able to visualize a map of the world will find various books and assignments easier to read (and learn more from them). In each field, certain procedures are used again and again. Those procedures must be learned to the point of automaticity so that they no longer consume working memory space. Only then will the student be able to bypass the bottleneck imposed by working memory and move on to higher levels of competence.

The development of automaticity for generalized skills depends on high levels of practice (e.g., Shiffrin & Schneider, 1984). There is no substitute. Ensuring consistent, sustained practice is the most reliable way to ensure that a student will become an effective reader, writer, or scientist. Following a complex written argument, writing a convincing essay, or engaging in scientific reasoning are all skills that are enabled by the automatization of each discipline's basics.

**Becoming an Expert**

What does it take to become an expert in a field? Consider a true expert, meaning one who is recognized not just as fully competent, but as a unique contributor to the discipline. In competitive arenas (e.g., athletics or chess), we would say that an expert competes at the national or international level. When asked how an expert gained such a high level of skill, non-experts usually attribute the success to innate talent. Experts themselves, however, tell a different story. They attribute their success to practice and to the ability to maintain concentration during long practice sessions (Ericsson, 1996). (The importance of practice doesn't mean that innate talent is meaningless, of course; practice is necessary for excellence, but it may not be sufficient to ensure it.)

Research studies indicate that experts are right, at least in that they do practice a great deal. Descriptive studies (Roe, 1953) of eminent scientists indicate that the most
important factor predicting their success is not innate talent or intelligence, but the willingness to work hard for extended periods of time. This commitment to practice was reinforced by a large-scale study (Bloom, 1985) in which experts in athletics, science, and the arts were interviewed, along with their parents and teachers. Bloom proposed that the training of an expert typically involved four stages. The future expert was usually introduced to the domain under playful conditions as a child. His or her promise was noted, and in stage two, lessons were provided, usually with a teacher or coach who worked well with children, and regular practice habits were established. In the third stage, an internationally recognized teacher or coach was engaged, usually requiring a significant commitment of resources from the parents, as well as dedicated and likely exclusive study by the child. In the fourth stage, the student had absorbed all that he or she could from teachers and began to develop his or her personal contribution to the field.

Recent research that measures practice time more carefully paints a similar picture. The figure below depicts the estimated cumulative practice time of violinists separated by their ability levels. The best and good students were enrolled at a music academy that trains professional musicians; they were put into these categories, unbeknownst to them, by their professors for the purpose of this study. Subjects were asked to estimate the time they spent practicing each week. The graph below shows the total accumulated practice time at each age. Two conclusions may be drawn from the graph: Experts engage in a great deal of practice, and that even among very able performers, the best are those who have practiced more.

The better violinists engaged in more practice
Some evidence that a great deal of practice, and not just talent, is a prerequisite for expertise is the "ten year rule," which states that individuals must practice intensively for at least 10 years before they are ready to make a substantive contribution to their field. What about prodigies like Mozart, who began composing at the age of six? Prodigies are very advanced for their age, but their contributions to their respective fields as children are widely considered to be ordinary. It is not until they are older (and have practiced more) that they achieve the works for which they are known.

How are such studies relevant to the average student? Few students will become a Mozart, Shakespeare, or Einstein, but if we want children to understand and appreciate excellence, we would do well to send the message that excellence requires sustained practice. The athletes and artists revered by many students excel not solely by virtue of their talent, but because of their hard work. Edison remarked that "genius is one percent inspiration and ninety-nine percent perspiration." The relative percentages of talent and practice are unclear, but the necessity of long periods of focused practice to exploit inborn talent is not.

What Material Merits Practice?

When we refer to "practice," it is important to be clear that it differs from play (which is done purely for one's own pleasure), performance (which is done for the pleasure of others), and work (which is done for compensation). Practice is done for the sake of improvement. Practice, therefore, requires concentration and requires feedback about whether or not progress is being made. Plainly put, practice is not easy. It requires a student's time and effort, and it is, therefore, worth considering when it is appropriate.

It was noted above that sustained practice over time is especially useful for developing automaticity in specific skills (which enables higher-level thinking) and in ensuring that a memory lasts as long as needed. Thus, the following types of material are worthy of practice:
1. The core skills and knowledge that will be used again and again. In this case, we give practice in order to ensure automaticity. The student who struggles to remember the rules of punctuation and usage (or must stop to look them up in a reference book) cannot devote sufficient working memory resources to building a compelling argument in his or her writing. The student who does not have simple math facts at his or her disposal will struggle with higher math.

2. The type of knowledge that students need to know well in the short term to enable long-term retention of key concepts. In this case, short-term overlearning is merited. For example, as noted earlier, a science teacher may want students to know a set of facts about certain species so that she can introduce an important abstract concept concerning evolution that depends on these facts. Or, a high school history teacher may want students to master the facts of several Supreme Court cases in order to build long-term understanding of a particular constitutional principle.

3. The type of knowledge we believe is important enough that students should remember it later in life. In this case, one might consider certain material so vital to an education that it is worthy of sustained practice over many years to assure that students remember it all of their life. A science teacher might spend the better part of a year emphasizing basic principles of evolution in the belief that the material is essential to consider oneself conversant in biology. Further, the curriculum might address and require practice in evolution in multiple years to assure that such knowledge will last a lifetime. Do we expect that a 40-year-old will have retained everything learned through the 12th grade? No, but do we expect that she will retain anything? Should she be able to grasp the basics of evolution or describe the different responsibilities of the three branches of the federal government or calculate the area of a circle? Exactly what sorts of knowledge merit the focus required to create long-lasting memory will be controversial, but that practice is required to create such memories is not.

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How should practice be structured—should a teacher strive for overlearning in the short term or repeated learning over the long term? The answer will depend on whether the goal is automaticity in skills, short-term knowledge, or long-term knowledge—and what the teacher knows about the future curriculum students will encounter. For example, an English teacher might deem it very important that students understand the use of metaphor in poetry, but extensive, focused practice may not be practical or necessary. This knowledge will likely be developed over a number of years, and there will be opportunities for practice in the future. In other cases there will be future opportunities for practice, but the timeliness of the learning is important. For example, one teacher might provide just a cursory introduction to first-graders on how to tell time, figuring that the students will have ample opportunities for practice in the future. But another teacher might also reason that first-graders need to know how to tell time (so that, for example, they can monitor their activities during the day and be more self-directed) and so focus practice on this skill. Similarly, a French teacher may realize that students will have plenty of practice conjugating the verb être (to be) over the long term, but may justly believe that students must know this material early in their training or their ability to read, write, and understand French will be badly hampered.

Exactly when to engage students in practice, through what method, and for what duration are educational decisions that teachers will need to make on a regular basis. But, that students will only remember what they have extensively practiced—and that they will only remember for the long term that which they have practiced in a sustained way over many years—are realities that can’t be bypassed.

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*It is likely relevant that there is not only more practice in this case, but that the practice is distributed across time rather than
References


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