Are Our Students Studying Effectively?

To best advise our students on how to study, particularly students who ask how they can better prepare for the next exam, we should be aware of studies on how students learn and how they should study. Most chemical engineering students who attended *How to Study/How to Learn* workshops in our department indicated that they use some ineffective study methods, including:

- Rereading the textbook
- Underlining and highlighting the textbook
- Reviewing notes before an exam
- Rereading solutions to an assignment before an exam

Instead, studies show that the most-effective way to learn is practice testing, also known as active retrieval.[1] Activities that require students to retrieve or generate information make learning more durable. That is, students who read something and then try to retrieve that information retain more than students who spend the same amount of time rereading. This means, for example, that to prepare for an exam, students should try to solve assignment problems again, rather than look at their solutions. That is, the best preparation for an exam is to do the same thing that they will do on the exam. Practice testing improves learning for facts, concepts, and problem-solving techniques. In contrast, rereading the textbook, reviewing notes, and rereading solutions to assignments can result in fluency illusion; the material looks familiar when reviewing or rereading, but recall is different from recognizing. Rereading does not result in durable memory.

In addition to practice testing, recently-published books on how students learn [1-3] recommend that students use:

- *Spaced practice or distributed learning*: studying 30 minutes a day for three days is better than 90 minutes on one day. Retention was slightly worse for distributed learning compared to massed learning (all in one day) when students were tested after one day, but some studies show retention was a factor of two (or more) better for distributed learning when students were tested after one week.
- *Interleaving*: performance on a test one week later was higher for student who switched between types of problems instead of repeatedly solving the same type problem.
- *Self-explanation*: when students explain to themselves how new information is related to known information, explain steps during problem solving, or ask "why?" or "what if?", their performance can be as much as three times higher on abstract transfer problems.
- *Percolation*: starting work on a project early and then stopping when stuck helps students solve the problem after a delay.

Studies also show that studying in different locations can significantly improve retention, and that students should take breaks instead of studying several hours non-stop; e.g., study for 25 minutes, take a 5-minute break, repeat. Moreover, both exercise and getting sufficient sleep significantly improve retention. Studies show that exercise improves memory, enhances growth of hippocampus cells, reduces stress, and improves the ability to focus. Sleep is a memory aid, both before and after learning. Moreover, in one study students were given a series of math problems, along with a method to solve them. After a 12-hour delay in which the students were awake, 20% discovered a shortcut method to solve the problems, but 60% of students who slept for 8 hours during the delay discovered the shortcut.

REFERENCES

1. Brown PC, Roediger HL and McDaniel M A (2014) *Make it Stick: The Science of Successful Learning*. Harvard University Press/Belknap, Cambridge MA.
2. Carey B (2015) *How We Learn: The Surprising Truth About When and Where and Why it Happens*. Random House, New York, NY
3. Screencasts, useful links, and a list of additional references, are available on http://www.learncheme.com/student-resources/how-to-study-resources. ❐

—JOHN L. FALCONER, UNIVERSITY OF COLORADO BOULDER, BOULDER, CO 80309