Study Daily – Reinforce Your Knowledge

D.J. Dal Bello, Engineering Professor Revision I: 08/20/16. Original: 8/29/14.

"I understood the material when you talked about it in class."

I have heard this statement many times during my career at AHC, especially towards the end of the semester from students whose grades are not as high as they want them to be (and not as high as they are capable of). Sure it is "easy to understand" in class – instructors usually have studied the topic for years, have taught the course many times, and have already worked out the problem being presented. Students let themselves be ***passive observers*** instead of ***active participants***. They confuse ***being familiar*** with a topic with ***understanding*** it.

A related concern is the student who does little, if any, homework. He or she tends not to do well on exams, and thus not well in the class. Then there is the student who does the homework, but does so only to get it turned in. This student either over-relies on others to help them get through the homework, or works just to get the problems done, instead of working the problems to understand the material. These students **do not spend enough *quality time*** to learn the underlying principles of the course, nor the general approaches to problem-solving necessary to succeed not only in the current course, but in the next one.

All these problems can be summarized as not reinforcing (actively reviewing) the material sufficiently to perform at the desired level. Obtaining better results typically requires consistent quality effort – studying smart by effectively engaging the material – throughout the entire academic term.

The Forgetting Curve

In the late 1800s, German psychologist Hermann Ebbinghaus performed experiments on memory. He found that when something new was learned (in his experiment, a series of nonsense syllables), within 20 minutes, only 60% had been retained. After 9 hours, only 37% was retained (***Fig. 1***).

Memory, or retention, can be mathematically modeled as an exponential decay with time t. Roughly:

$$R = e^{-t/S} \qquad (1)$$

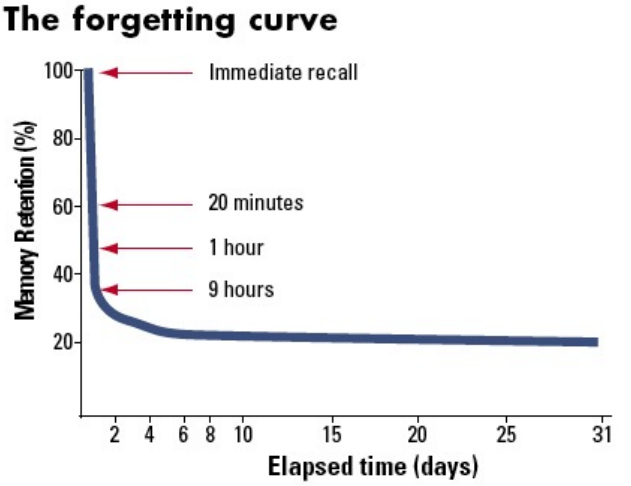
where R is the fraction retained, and S is memory strength. Memory strength can be different for different events; people often remember emotionally charged incidents (if not the exact details) fairly well. As a nation, Americans living in the early 1960s generally remember exactly where they were when they learned President Kennedy was shot. During my teenage years, the highly emotional national incident was the Space Shuttle Challenger explosion.

Think about how you study (learn). Do you:

- go to lecture but do not start the homework until several days later?
- not read the textbook?
- read without really thinking about the concepts (i.e., do you read just to say you have read)?
- study with excessive distractions?
- always study alone, and never meet with a group to discuss the course material?

If you answered "yes" to any of these questions, you should consider changing your approach.

What can you do – or what can you do better – that will help reinforce your knowledge?



The "forgetting curve" was developed by Hermann Ebbinghaus in 1885. Ebbinghaus memorized a series of nonsense syllables and then tested his memory of them at various periods ranging from 20 minutes to 31 days. This simple but landmark research project was the first to demonstrate that there is an exponential loss of memory unless information is reinforced.

Figure 1. The "Forgetting Curve" (Stahl, et al, 2010).

Leaking Buckets

A pattern students often fall into is **focusing only on one course when the test for that course nears**. They neglect their other courses, intending to catch up later. This is a very bad habit – falling behind in other courses makes life difficult since a lot of material is forgotten.

I have tried to develop a simple analogy to describe this problem. Think about a set of ***leaking buckets***. The knowledge and skills you need to learn in a course are like the water with which you are trying to keep the buckets filled. A filled bucket represents mastery of the course material up to that point in the course. You must continuously attend to the buckets to keep them full – you must study regularly to remain up-to-date with the course. If you do not study continuously and sufficiently, the water (your knowledge and skills) will start to empty out. Neglect a bucket for too long, and you will not be able to refill it in time for the next exam. Consider ***Fig. 2*** (explanation in the caption).

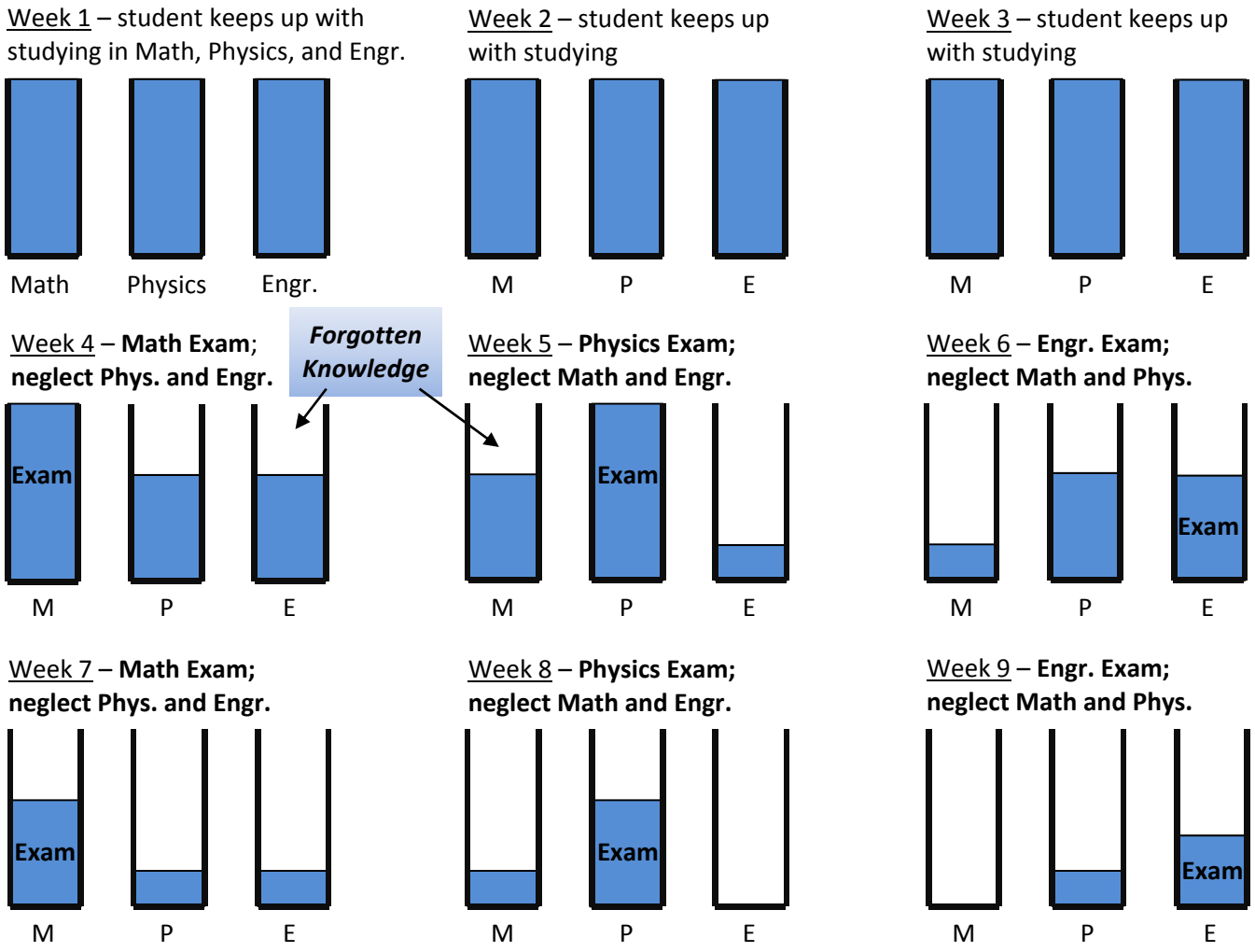


Figure 2. **Leaking Bucket Analogy** (D. Dal Bello, 2014). Pouring water into leaking buckets is analogous to pouring the knowledge of several courses into your brain. The three buckets above represent three courses: Math (M), Physics (P) and Engineering (E). For simplicity, the model assumes the buckets lose 40% if unattended for a week; i.e., you lose 40% of everything you need to know if you do not study for a week. The model also assumes the student can effectively fill at most 40% of <u>each</u> bucket with quality water (quality knowledge) each week (even if he/she concentrates on only one bucket). All three buckets can be kept filled each week.

During the first three weeks – the buckets are kept full by consistent studying; the student retains 100% of the required knowledge at that point in time.

In Week 4 – a Math exam – the student focusses <u>only</u> on Math and keeps M filled. By neglecting Physics and Engineering, 40% of both P and E leak out. In Week 5, Physics is the focus, and E is down another 40% to 20%. In Week 6 – the Engr. exam – the student is so far behind that only 60% of the knowledge/skill (water) is available for E. The pattern continues. By focusing exclusively on one course, and neglecting others, the end results can be disastrous.

Reinforcement Counters the Forgetting Curve

Repetition or reinforcement increases your ability to remember things. Scientists who study the brain tell us that new brain connections are made when a memory is formed. The more often you reinforce/repeat/review information, the more connections you make, the stronger the memory is, and the longer you will retain it.

The effect of repetition is illustrated in ***Fig. 3***. The Forgetting Curve is interrupted by each repetition (with the information remembered assumed to return to 100%). Note that each subsequent Forgetting Curve has a less-steep slope – the memory is stronger with each repetition (*S* is larger in ***Eqn. 1***) – so it takes longer to forget after each repetition. With multiple repetitions, the Forgetting Curve (an exponential decay), is turned into a Remembering Curve (an exponential step function).

So why not just cram? Many students think, "I only have to review once to get back to 100% just before an exam."

At least two things make cramming a poor choice for studying.

First, you basically need to study from "zero" to get to 100% (or sufficiently high enough to pass the test). The quality of this rushed study is suspect. You may have missed something, and complex interactions are not completely understood. You might remember equations for the exam, but not how and when to (or when not to) use them.

Second, cramming is often only the second or third time the material has been reviewed. The crammed knowledge is easily forgotten, but such knowledge, skills, and problem solving methods – especially in science and engineering – will be needed in the future.

If you study consistently (daily) from the day the material is introduced in class, you can use the day before an exam for a leisurely review instead of a stressed-out study session. Get a good night's rest.

Consider the following. You would not train your body for an important race by just running the day before. Likewise, you should not train your brain for a test by cramming the night before.

Note that the more repetitions, the more spaced out they need to be as you approach mastery.

Additionally, reviewing the same concept differently (i.e., reading and doing homework problems) – instead of repeating the same study method (just reading) – increases the quality of the memory since different brain connections are made. Also, you will likely understand a concept at a deeper level by not only reading about it, but by applying it. ***Applying*** concepts requires a higher brain function than just ***identifying*** them; thus, more knowledge will be retained.

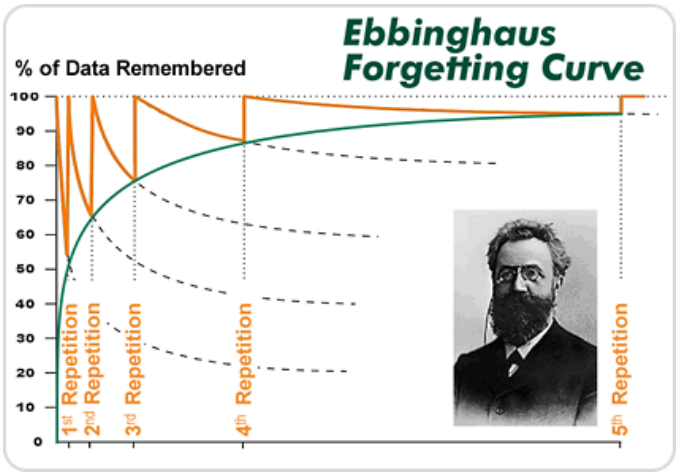


Figure 3. Effect of repetition on the Forgetting Curve: a Remembering Curve.

Reinforcing What You Learn

Hopefully, you are convinced that you should be reinforcing what you learn. You may be thinking, "I already do. I go to class. I read the book. I do the homework". Perhaps you can study more, as well as study more effectively.

***Studying* is reinforcing your understanding of the material you are trying to learn**. Note that reinforcement (or repetition) does not necessarily mean doing the same thing again and again (e.g., only reading). Reviewing the same material in different ways is a more effective method of studying.

Studying includes, but is not limited to:

1. Reading the textbook before the topic is discussed in class; preparing for class
2. Attending class, actively listening, taking good notes, asking questions
3. Reading the textbook after class
4. Reviewing your lecture notes

5. Doing practice problems/example problems from the textbook
6. Doing homework problems (and understanding what you are doing)
7. Doing extra problems not assigned in order to encounter new situations and solidify understanding
8. Discussing problems/concepts in a study group; talking through the solution
9. Re-solving homework/extra problems with new values (with a group)
10. Creating problem sets in the group to be taken as if in an exam situation
11. Explaining concepts to others; i.e., "teaching" other students
12. Asking the instructor or tutors about concepts that you are confused about
13. Reviewing homework, especially where there are mistakes
14. Creating a note sheet (whether used in an exam or not), that organizes and summarizes the concepts
15. Reviewing exam problems, especially mistakes
16. Studying related topics outside of class that extend what you learn
17. Watching videos on relevant topics
18. Reading books on the subject
19. Building demonstration models to physically see what is going on
20. …<your ideas here>

Unfortunately, many students only do *Item 2* and *Item 6*, and sometimes only partially. If you are going through the motions of just coming to class and doing the homework just to get it done, are you really using your time productively? Are you doing enough to master the material? Or are you confusing ***familiarity*** with ***mastery***?

Do you prepare for lectures (*Item 1*)? Lack of time is often used as a reason for not doing so. But if you read the book beforehand (and even attempted some problems or watched a video), would it not be easier to understand the lecture and participate? You would know what is coming, and can ask good questions during class. Even skimming the textbook beforehand would increase the quality of your in-class experience.

Do you attend your professor's office hours to seek help (*Item 12*)? A 20-minute visit to clear confusion early in the semester is much better than the 40-minute visit towards the end when it is often too late to make significant changes to the semester grade. But remember to first attempt problems. This shows you are trying, and it helps the professor assess where you are at, and what you need help with (do not make the professor have to reteach the entire topic from scratch).

It is painful to instructors when students do not even bother to pick up their homework or exams, let alone review them (*Items 13, 15*). How do these students know what they got wrong? How do they know what they need to work on? Do they even care? It might be scary to see the exam score, but it does not help to avoid what needs to be fixed. A little effort in reviewing what they did not understand, and changing study habits, can usually improve results in that course and the next.

I often wonder why many students often classify "doing homework" and "studying" as *different* activities. Perhaps this explains why some students "do homework" without gaining much understanding of the underlying principles. Homework is seen as an obstacle, rather than another chance to learn. ***Doing homework*** **is** ***studying***. Homework is another way of reinforcing the concepts that you are learning.

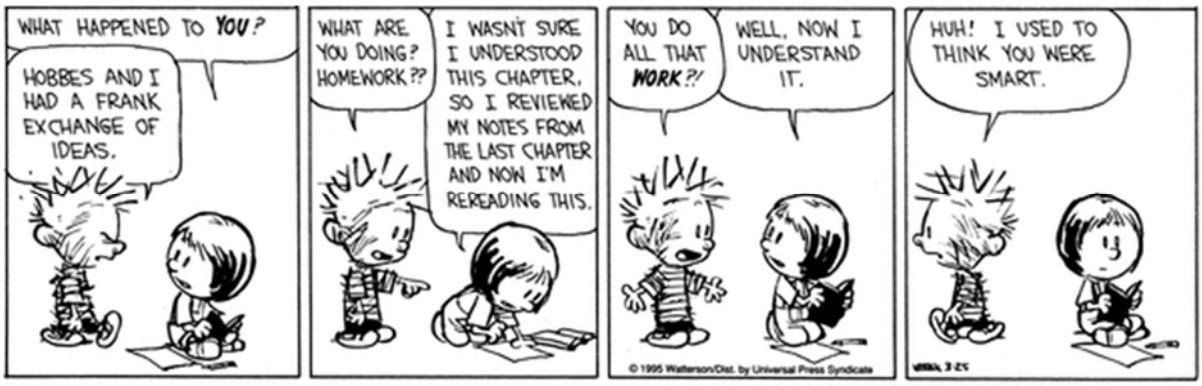


Figure 4. "Calvin and Hobbes", by Bill Watterson, March 25, 1995.

Learning – the Person Most Responsible is You

Fig. 5 is the ***Learning Pyramid***. Researchers have found that people who only listen to a verbal lecture generally retain only about 5% of what is said. Students who only read retain 10%. This does not mean you should not come to class nor read the textbook. Rather, attending class and reading are but two of the many learning techniques that complement each other.

Note that "lecture" in the pyramid means someone at a podium talking to a room of listeners. I use the term "lecture" more broadly to indicate a course held in a regular classroom (as opposed to a lab course). Besides the instructor's presentation, a good lecture course often includes many of the other items in the pyramid: videos, demonstrations, group discussions, practice and teaching others. So go to class.

Working in groups (50%) provides excellent opportunities to bounce ideas off each other and to try to figure out problems together. Also, you learn skills needed in future courses and your career (teamwork, responsibility to the group, etc.). Engineers and other professionals rarely work on projects alone.

Practice (75%) – doing homework and extra problems – is much more effective than just going to lecture. **You must *engage* the material**, not just watch someone else work it on the board.

The most effective way of learning is ***teaching others*** (90%). Teaching helps someone master the material. In preparing class activities – and during class – teachers not only come up with new ways to explain the material, but they often gain new insights to topics they have been teaching for years.

Notice that **the more *active* the learning – *the more the student is involved* in the transfer of information – the more information is retained.** Going down the pyramid requires more of the learner, but the outcome is greater. It is true that "You get out of it what you put into it." The person most responsible for your learning is you.

Practicing – *applying* what you learn – is vital. You do not learn to drive a car by watching someone else do it. You learn to drive by driving – you have to practice. After a while, driving becomes second-nature. That is what you should be striving to develop in your problem-solving skills. The problems (roads, streets, traffic and weather) might change, but the problem-solving (driving) skills you develop will carry over.

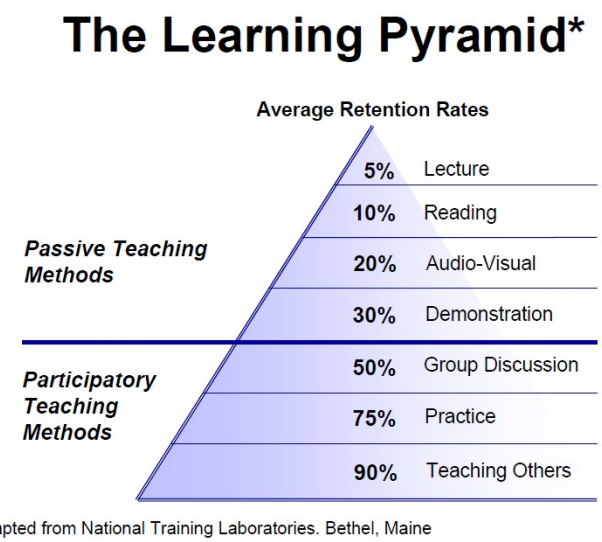


Figure 5. The Learning Pyramid. *Active Learning* (doing) is the most effective.

In AHC Engineering courses, each "weekly" assignment covers about one problem per day. This really should be considered a minimum. I suggest doing twice as many problems to really begin to master the material. Do not wait until the day before it is due to start a homework assignment; you either will not finish, or do a subpar job which will not help you actually learn. Do not "cram" your homework.

My sophomore-level Strength of Materials professor believed in continual practice. The class met Monday-Wednesday-Friday for 10 weeks. Homework was assigned every class meeting, due the next meeting: 3 problems due Wednesday; 3 problems due Friday, and 4 problems due Monday (as he would justify our fourth weekend problem: "What else are you going to do?"). Even at this rate – 1.5 problems/day due every-other day – I had to do at least twice as many problems to get a solid understanding of the material.

Working with groups is important and powerful. Effective group study is not just copying from others. Rather, each group member first works on problems individually. When the group meets, each member is then ready to *discuss* the problems, to work together at solving them (*practice*), to articulate what they do and do not understand, and to explain (*teach*) concepts to each other. Working through problems together helps everyone on the team.

What can you do to improve your learning and your grades? Can you study more? Can you study more effectively? Is your life set up so that you can best succeed?

Setting Yourself Up for Success – Allowing Yourself to Succeed

"But I don't have time to study more."

The AHC catalog states that students are expected to spend at least 2 hours outside of class per unit of a lecture class each week. Some college/university catalogues say 3 hours, and for STEM courses, 3 hours per unit per week is probably better. Are you able to devote that time?

To be a successful student, you must ***manage your time*** and ***set up your life to allow yourself to succeed***. This requires balancing any academic, family and work responsibilities that you have, as well as personal time to have some fun to ensure you do not burn out.

Managing your time is not always easy, but **bad time management is often the reason students fail**. Do you waste time? Do you have so much to do each week that your studies suffer? Are there obstacles in your path that prevent you from focusing enough on school? Are <u>you</u> putting obstacles in your path? Is school the right thing for you at this point in time? How many courses can you take and put quality effort into each of them?

In his introduction to engineering book *Studying Engineering*, Ray Landis recommends the *60-Hour Rule*. The 60-Hour Rule essentially states that the typical person has about 60 hours per week that they can perform activities that require some focus – going to class, studying and work. Sixty hours per week is about 9 hours per day, 7 days per week. Since a student is supposed to study 2 hours per unit (per lecture hour in class) per week, each unit is allotted 3 hours per week, while each work-hour is allotted 1 hour.

The 60-Hour Rule is as follows. The maximum number of units u a student should take is:

$$u = \frac{1}{3}(60 - w) \qquad (2)$$

where w is the number of work hours. Thus, a student working 20 hours per week should take at most about 13 units ([60–20]/3 = 13).

Written another way, someone with a schedule of u units and w work-hours should reach at most about 60 hours:

$$3u + w \approx 60 \qquad (3)$$

The 60-Hour Rule is a guideline. Some students can exceed 60, some cannot. But 60 hours of quality work is typical. You may think you can study and work 80 hours per week, but over the course of a semester, this is a recipe for burn-out and failure. If you get sick for one week, you may never catch up, and set yourself back a semester, if not a year.

Note that the 60-Hour Rule is for traditional students (singles in their late teens/early 20s). Students with a family should consider how many hours they need to meet their family responsibilities; w should include family time.

You should also think about scheduling your time by week, being consistent in what you do each week to get into a steady pattern. Transitioning into college can be difficult as life is less structured than in high school. If you make a weekly schedule with regular times set aside for quality studying (and for fun), you will be surprised by how much time you actually have to get things done. Remember, you make the schedule; you decide where and when (and with whom) to study. If your study schedule needs tweaking, change it so you are more productive.

Be smart about how you use your time. Work smart. The time you spend in college is generally considered the best in your life – you learn and experience many new things. College is also when you are investing in yourself so that you will have a better future. Spend your time wisely.

Author's Notes

I have wanted to write something like this article for my students for a number of years, and was finally motivated to make time to write it by attending a talk by Jeffrey Saikali at the CMC^3 conference in Monterey, CA, Dec. 2013. I attach Appendix I of Mr. Saikali's paper, "Advice to Student for Better Learning, Studying and Remembering" as an appendix to this document. Many of his points are exactly the same as those that I have been trying to get across to my students for years.

Sources

Texts and Articles

Landis, R. *Studying Engineering*, 4th Ed., Discovery Press, 2013.

Saikali, J., "Improving Learning by Understanding the Psychology of Human Memory", Paper presented Dec. 2013 at California Mathematics Council Community Colleges (CMC3) North Conference, Monterey, CA.

Images

Fig. 1 The "Forgetting Curve". From Stahl, et al, 2010: "Play it again: The master psychopharmacology program as an example of interval learning in bit-sized portions," *CNS Spectrums*, Vol. 15, No. 8, 491-501). http://www.cnsspectrums.com/userdocs/ArticleImages/Stahl_figure1.jpg Accessed July 29, 2014

Fig. 2 Leaking Buckets, the author.

Fig. 3 Effect of repetition of Forgetting Curve: a Remembering Curve. http://diogenesii.files.wordpress.com/2012/01/forgettingcurve21.png Accessed July 23, 2014.

Fig. 4 Calvin and Hobbes "I used to think you were smart". http://www.gocomics.com/calvinandhobbes/1995/03/25, Accessed August 11, 2014

Fig. 5 The Learning Pyramid. http://1.bp.blogspot.com/-egZAMUipWC0/TX1Y9fKof0I/AAAAAAAAAEY/bYyGMVQLCFw/s1600/learning%2Bpyramid.jpg Accessed July 29, 2014.

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