Common Learning Techniques: Using #scienceoflearning to Make the Most of Your Study Time

Andy Dosmann and Geneva Stein
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Introduction

The fact that you are in this class shows you have been at least fairly effective at studying in your academic career so far. However, most people develop some study habits that are less than ideal by this point in their academic career. In fact, most students use ineffective study techniques that they incorrectly believe are effective (Bjork et al., 2013). Our goal in this paper is to evaluate commonly used study techniques to first give you the knowledge of what research shows is effective, and second to guide you on how to use these techniques to develop better study habits. In many cases, this will only require a few small changes to how you currently study, but the effort to establish those habits will be rewarded throughout your academic and professional career.

Because college classes are more demanding and variable, more efficient and effective study skills and habits are required. These independent study habits become even more important for learning outside the classroom in jobs later on in life. There's even a non-academic argument to learn more efficient and effective study habits. If you can master the material in less time, then you'll have more opportunity to do whatever you enjoy in your free time.

One way experts are more efficient and effective is to study with purpose (Wyatt et al. 1993). Before reading a text, experts often identify specific information to look for and what sections they can ignore, or simply skim through. While experts base this way of studying on previous knowledge and experience, students can still take advantage of this method to study more efficiently and effectively. You should use the study guide to help you identify what each reading may contribute to the learning goals for a class. As time goes on, you can also learn more about the specific dynamic of the classroom and what current and previous topics are likely to come up in discussion. Importantly, you should also read to fulfill your own curiosity and interests in the material. This allows you to connect more deeply with the topic and enhances your ability to discuss topics in class and in assignments. Finally, if you want more clarity on how to identify what to focus on in class readings, go to office hours and discuss this with the Professor.

Before we evaluate commonly used study techniques, it's important to dispel some common misconceptions. First, many students incorrectly believe that they have a particular "learning style", such as being a visual learner. Despite decades of research on the topic, there is no evidence that students have different learning styles (Kosslyn, 2017; Willingham, 2018). Second, many students incorrectly believe that some people are just naturally good at coding, writing, art, or some other particular subject. Believing that you inherently have a high or low ability in a subject is known as a "fixed mindset" (Dweck, 2006). Believing that you can improve at a subject is known as a "growth mindset" (Dweck, 2006). You may not have mastered a subject, like writing. If you hold a fixed mindset and say that you're just not a good writer, you likely won't put in the work to become a better writer. However, if you have a growth mindset and say that you're not a good writer *yet*, and you work hard to employ the tools to improve, you will improve your writing. The learning techniques we evaluate in this paper are the tools that can produce mastery of a subject with hard work.

There are a huge number of study techniques, and many different ways to employ each technique. In this paper we will limit our discussion to: 1) a subset of study techniques that are most commonly used by students and 2) those techniques researchers have found are most effective. Some study techniques are better suited to particular material, but the best techniques are effective for a range of material, whether you are learning Korean, coding, writing, biology, economics, or Renaissance art history.

Learning Techniques

A simple definition of a learning technique (aka a study technique) is that it is an action a learner can engage in on their own to acquire a piece of knowledge or master a skill.

Technique 1: No strategy

"No strategy" may not seem like much of a learning/study technique, but we'll treat it as one because it is probably the most common technique used by students. If you merely read the material for class and then go participate in class, we will refer to that as "no strategy". You have taken some action to learn the material, but you have done no independent work. It may seem obvious that this technique is ineffective. However, it is deceptively easy to fall into this strategy because other techniques require more time and effort.

Take home: Do something! Read with a goal, and use the study guide. Study material before class *and* after class, because simply showing up for class is insufficient.

Technique 2: Re-reading

The re-reading technique is straightforward. For example, if you are assigned a book chapter on political theory for a class, you may choose to read it more than once when you study, which constitutes “re-reading”. While the technique is very straightforward, it can be implemented various ways that may make it more or less effective. You may re-read the book chapter immediately after you finished your first reading, or you may wait for a period of time. You may re-read the entire chapter, or only particular sections. You may re-read the book chapter once, or you may re-read it many times. Miyatsu et al. (2018) found that 78% of students reported using re-reading as a study technique, which made it the most common of the techniques they evaluated. They hypothesized that re-reading is commonly used because it is relatively passive and does not require substantial effort (Miyatsu et al., 2018). Despite being relatively easy to employ, re-reading can be a very time consuming study technique, especially if you re-read every word of the assigned reading.

While re-reading is better than “no strategy”, Dunlosky et al. (2013) identified it as one of the less effective techniques. There is evidence that rereading gives students a false sense of knowledge, perhaps by producing familiarity without sufficiently encoding material so that it can be successfully retrieved. Roediger and Karpicke (2006) gave students multiple rereadings or one reading and multiple tests. Students given multiple rereadings reported feeling more confident that they would remember the material, but in fact did worse when asked to recall the material.

However, despite the fact that rereading is one of the less effective study techniques (Dunlosky et al. 2013), there are particular ways that it should be used (Miyatsu et al., 2018). Rothkopf (1968) found that two readings led to a greater than 10% increase in correct responses compared to a single reading, but four readings led to virtually no increase over two readings (Figure 1). The duration of the lag between readings also changes re-reading’s impact on recall. A 30-minute lag was better than an immediate lag (Glover and Corkhill, 1987) and a 4-day lag was better than a 3.5 week lag (Verkoejian et al., 2008). This fits with the recommendations of Case (2018) that the ideal is to return to the material just as you are starting to forget it. Most forgetting occurs in the first 24 hours after trying to learn something, so if you study in the morning, return to the material that afternoon or the next day. Subsequent study sessions should then be spaced out with increasing gaps.

Take-home: Re-reading should be used sparingly, but it has a place in your study practice. If you re-read whole texts many times cramming before a class, test, or assignment, you are simply wasting your time. However, rereading assigned material once at a slight time lag produces more learning. Additionally, re-reading portions of a text with a specific goal or purpose in mind has been shown to help students delineate important information (Kaakinen et al., 2002, 2003).

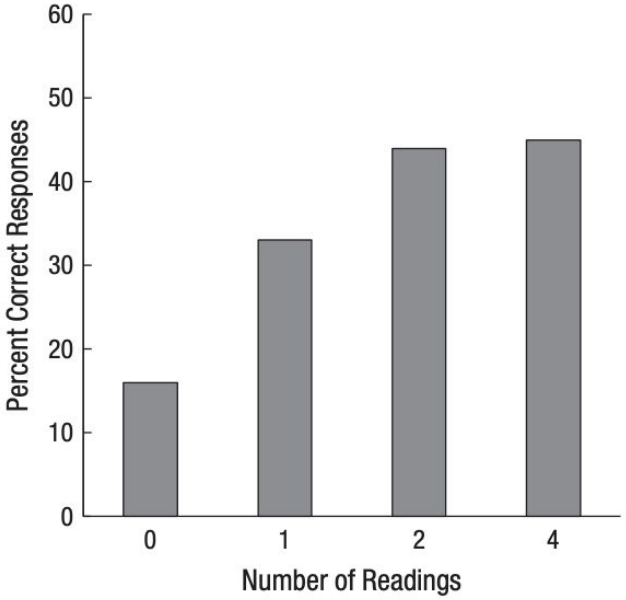

Figure 1. Mean percentage of correct responses on a test for learners who read a text zero, one, two, or four times in Rothkopf (1968). Note the substantial increase from reading 1 to 2 and the minimal increase from reading 2 to 4. This figure is copied from Dunlosky et al. (2013).

Technique 3: Self-explanation

The self-explanation technique entails thinking of the reasons a fact to be learned or a problem that you've solved are correct. For example, you may determine if a deductive argument is valid or not. If you reason to yourself that the argument is valid because the truth of the premises guarantees the truth of the conclusion, and go over why the truth of those premises guarantees the conclusion, then you have used the self-explanation technique. The implementation of self-explanation will depend on the material you're learning, but general self explanation prompts (e.g., "Explain what this sentence means to you and how does that relate to what you already know?") that apply to logic, biology, history, and other subjects can be useful (Dunlosky et al., 2013). When you use this technique, you could give the self-explanations while you are completing a problem or after you've completed a problem or answering a prompt. A related technique called elaborative interrogation in which you ask yourself a series of "Why?" questions could also be considered a variant of self-explanation.

Dunlosky et al. (2013) identified self-explanation as a moderately useful learning technique. They argue that self-explanation facilitates the integration of new material with material that students already know (Dunlosky et al., 2013). Importantly, self-explanation can be particularly effective at helping students pick up concepts rather than simple rote

memorization of facts. Berry (1983) found that the benefits of self-explanation were more pronounced for abstract transfer problems as opposed to concrete practice problems. Interestingly, for both types of problems, students who gave self-explanations while they were solving the problems did better than those who gave self-explanations after they had solved the problem (Berry 1983; Figure 2).

Take home: Self-explanation can be beneficial. Use it when you are aiming for conceptual knowledge you can transfer, and implement it so you are providing your self-explanations while you are going through the material you're learning instead of after.

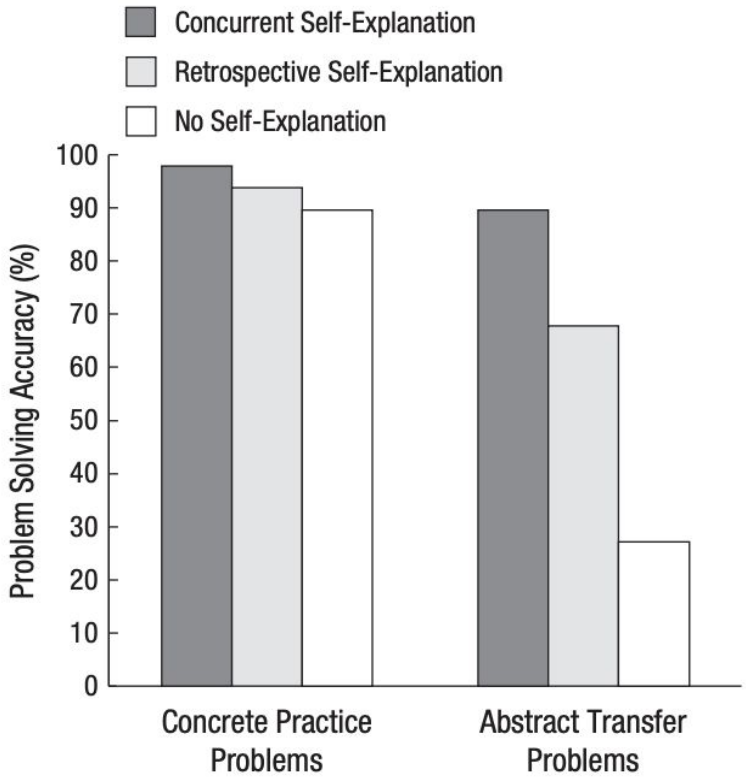

Figure 2. Mean percentage of logical reasoning problems answered correctly for concrete practice problems and subsequently administered abstract transfer problems in Berry (1983) depending on whether they gave a self-explanation while solving a problem, after solving a problem, or not at all. This figure is copied from Dunlosky et al. (2013).

Technique 4: Practice testing

Practice testing involves actively recalling information, answering a question, or solving a problem by responding to some sort of prompt (Dunlosky et al., 2013). Case (2018) advocates "spaced repetition", which is essentially practice testing repeated over time. A way of implementing practice testing is to answer a question provided to you, such as

Case's question asking, "The best way to space out your recalls is…". Then you check to see if your answer of, "...with increasing gaps," is correct. Another way of implementing practice testing is to create your own questions.

One of the main points Case (2018) made was that memory facilitates creativity and critical thinking. You could create a very simple question asking,
Q: "What facilitates creativity and critical thinking?".
A: Memory facilitates creativity and critical thinking.

You could create a more challenging question, such as,

Q: "What are two examples that show you need memorization for creativity and critical thinking?"
Case (2018) gives the example answer to imagine writing an essay if you know no words. You could generate your own example answer, such as imagining a pharmaceutical researcher trying to come up with a cure for mitochondrial disease without knowing what a mitochondria does. In addition to these types of fact-based practice tests, you could also write your own problems that you then solve, such as a coding task (or find existing problem sets to use!).

Dunlosky et al. (2013) reviewed a wealth of research on the topic of practice testing and found it to be one of the very best learning techniques students can use. It is effective and broadly applicable for a range of subjects (Miyatsu et al., 2018). It is particularly useful for remembering discrete facts, but multiple studies also show that it goes beyond rote memorization and improves retention of concepts and comprehension and inferential abilities (Butler, 2010; Dunlosky et al., 2013; Figure 3). Practice testing is even more effective when combined with other study methods (Rawson and Dunlosky, 2012). Retention of facts and skills is improved by practice testing because it entails active retrieval of previously encoded information. Practice testing activates the neurons involved in a memory or skill, and the efficiency of communication between those neurons is improved when they are activated together, making later recall easier and more accurate (Young, 2015).

Most implementations of practice testing are successful, but Miyatsu et al. (2018) identified an important pitfall to avoid. Students often stop studying a practice test question too soon, and this results in lower learning gains than if the student continued to practice the material after they could correctly answer the question or problem (Karpicke and Roediger, 2007; Kornell and Bjork, 2008). Longer lags in between practice test repeats is better than short repeats (Dunlosky et al., 2013). Case (2018) says that the best way to space out your recalls is with increasing intervals. Traditionally, students have given themselves (and their friends) practice tests by creating flashcards or answering questions included at the end of a textbook chapter. In addition to those implementations, students can use app-based

systems. Whatever technological platform you choose, your practice test questions should be s_ _ _ _, c_ _ _ _ _ _ _ _, and
m_ _ _ _ _ _ _ _ _ (refer to Case (2018) if you don't remember those three qualities). The fill-in-the-blank format I just used is effective, but free-recall is better (Glover, 1989). That means a better practice test question would be, "According to Case (2018), what are the three qualities a set of practice test questions should have?"

Take home: Use practice testing a lot! Repeat questions with increasing gaps, and don't stop until you get the answers right a bunch of times. Combine practice testing with other study techniques.

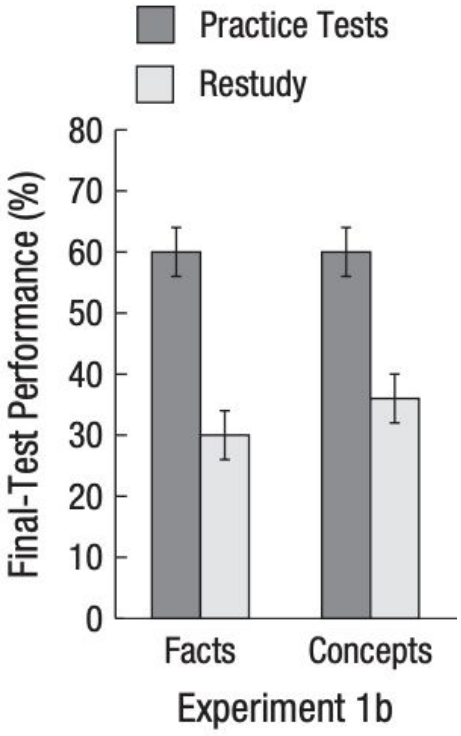

Figure 3. Accuracy on final tests that consisted of inference-based transfer questions tapping key facts or concepts, administered one week after a learning session that involved either practice tests or restudy, in Butler (2010). Error bars represent standard errors. This figure is a copy of a portion of a figure from Dunlosky et al. (2013).

Technique 5: Highlighting/underlining

Highlighting involves marking important parts of a text. Over 50% of students report using this technique, likely because it is relatively easy to use (Miyatsu et al., 2018). For example, later this semester you will read a *Scientific American* paper on global food security, and you might highlight the main solutions to different aspects of the overall problem. This simple learning technique could be done the first time you read through the paper, or you could

highlight during the second time you read the paper. A variant on this example where you generate your own highlights (termed *active highlighting*) is for instructors or textbook writers to highlight material for learners to pay closer attention to (termed *passive highlighting*). It is often assumed that students will review the highlighted material as part of the technique.

Dunlosky et al. (2013) found highlighting to be one of the least effective techniques, despite the fact that it is so commonly used. However, Miyatsu et al. (2018) were more positive on the technique, arguing that it is effective in certain situations. They identified that highlighting can benefit learning because students select what information is important and distinguish the material in a way that makes it easier to store (Miyatsu et al., 2018). Dunlosky et al. (2013) cited multiple studies showing that students assigned to active or passive highlighting did not outperform control groups. Interestingly, in those studies that found no broad benefit of highlighting, the researchers did find that students better remembered material that they had highlighted (Dunlosky et al, 2013). **This means the success of highlighting depends on whether students can properly identify and highlight important information (Miyatsu et al., 2018), but unfortunately students generally do not do so (Nist and Kirby, 1989).** Additionally, even successful highlighting does not produce higher order comprehension and inferential abilities for material (Miyatsu et al., 2018).

While the way students usually use highlighting is ineffective, there are relatively easy ways for students to make their use of the technique more effective. First, short hour-long training sessions have helped students learn to highlight appropriate material (Miyatsu et al., 2018). In addition to some subject specific knowledge to guide highlighting, focusing on how a text is organized helps students highlight the right material (Meyer et al., 1989). Second, it is crucial that students do not highlight text during their first reading (Miyatsu et al., 2018). The understanding of the material generated through the first reading helps students highlight the right information without marking too much or too little. An unfortunate finding from the literature is that students who prefer highlighting actually derive less benefit from the technique than those who don't prefer it (Annis and Davis, 1978; Yue et al., 2015), which calls for even more caution when implementing the technique. If you like highlighting and choose to use it, make the extra effort to ensure you are highlighting the right material.

Take home: Beware! If you choose to use highlighting, make sure you have gone through some training to properly identify what to highlight, and don't mark during the first reading of a passage.

Technique 6: Note-taking/summarization

Note-taking is a very broad category of study technique that encompasses writing down parts of a lecture, outlining a lecture or textbook chapter, and summarizing portions of a textbook reading. We will focus on summarization here, because this class does not have lectures and outlining is only effective in narrow contexts students rarely encounter (Miyatsu

et al., 2018). To summarize a reading, or a portion of it, you identify the main points of the text and exclude minor details and repetitive information. Summarization does not entail copying portions of the text, but rather boiling things down into your own words. The summaries are then used for later study.

Dunlosky et al. (2013) identifies summarization as a relatively ineffective technique. The technique is argued to be useful because when students summarize they must extract meaning and use organizational processing to pull out important parts of the text and connect them, but the technique often ends up ineffective because students are unable to write quality summaries (Dunlosky et al., 2013). Likewise, the technique is largely ineffective if you review other students' notes or summaries because you do not engage in the generative processing of the material (Miyatsu et al., 2018).

Despite the ineffectiveness of the technique as commonly employed, both Dunlosky et al. (2013) and Miyatsu et al. (2018) reviewed studies that found note-taking can be useful when properly employed. Putting the summarized information into fewer words make students more likely to remember the material compared to students who used more words (Howe, 1970), and reviewing the notes or summaries after taking them is particularly important gaining benefit from the technique (Kobayashi, 2005; Kobayashi, 2006).

Take home: Though note-taking is not the best technique, you can do a few things to make it more effective. First, digest the material into short summaries. Second, double check the original text to make sure that your summaries are accurate. Third, review the summaries.

Technique 7: Distributed Practice

Distributed practice is quite possibly the most beneficial learning technique to employ (Dunlosky et al., 2013; Kosslyn, 2017). Hundreds of studies on thousands of students have reliably found a benefit to returning to your study materials multiple times with time in between (Cepeda et al., 2006). You may notice that Distributed Practice is a way to make many of the previous techniques more effective, such as repeating practice testing at increasing intervals, reviewing summaries, and putting time in between re-readings. In general, longer lags are better, though Cepeda et al. (2008) found that performance was best when the lag between sessions was 10-20% of the time you intend to retain the material. This fits with the recommendation of Case (2018) that to remember something forever(ish), you should continually increase the interval.

Even though the details of how your practice is spaced matters, what is really important is developing the habits and time management skills to facilitate spaced practice. Habits and time management are two topics that could fill an entire textbook, so our treatment here will inevitably be incomplete, but we will introduce two key concepts that should help you successfully employ spaced practice as you begin your college career.

1. Give yourself rewards when you do engage in spaced practice, and don't give yourself rewards if you procrastinate and end up cramming right before class or an assignment. For example, if you really like Premier League soccer (or football), then give yourself a little time to watch some highlights or read an article after you have studied. The intrinsic reward of learning and working hard can help establish good study habits, but a few external rewards help, too.
2. Reserve extra time when you make your schedule. Humans underestimate the time tasks will take. When you plan your study, and when you plan other activities that might take time away from your studies (e.g., going to the grocery store), double or even triple the amount of time you hold to complete that activity. If you end up with extra time, then you can use that to reward yourself in some way for completing your studies.
3. Acknowledge that your schedule is a work in progress. A schedule should be viewed as a draft that you are continually revising. Often, students give up on schedfules as soon as they misjudge the time needed for a task or when unexpected circumstances arise. They believe this means they failed at scheduling. But, schedules are educated guesses that, over time, become more accurate. As you learn more about your own study habits and the demands of different college classes, you will improve your ability to stick to a weekly schedule or study plan.

Take home: Prioritize spaced practice, develop habits that will enable spaced practice, and continue to refine your schedule.

Conclusion

Some learning techniques are better than others. You should incorporate practice testing and distributed practice. When you use less effective techniques, such as highlighting or rereading, revise how you use them to make sure you're getting some benefit from them. For example, if you tend to only reread when you study, you don't need to totally throw that out in favor of practice testing. Instead, add some practice test questions for yourself before and after you reread the material once, and make sure you are goal-oriented when you reread. If you highlight, you don't need to totally throw that practice out in favor of self-explanation. Instead, highlight after you've read the material once, and add some marginal notes to each highlight to explain to yourself why those highlighted sections are important.

The beginning of your first year in college is an ideal time to establish quality study habits, but anytime is a good time! Take the information in this paper and from this lesson, and start employing it in other classes. Extensive research shows that your academic performance will improve. I also argue that improved study habits will help your experience outside the class. More efficient class preparation will leave you more time to explore the city with your

friends, and will leave you less stressed when you do take the time to do the non-academic things you love, whatever that may be.

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