# The Science of Learning Initiative at Colorado State University

**Anne M. Cleary & Matthew G. Rhodes**

**Colorado State University**

## Impediments to Practicing Effective Learning Strategies in Education

Surveys of college students indicate that they are often unaware of or unlikely to use optimal learning strategies (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; McCabe, 2011; Morehead, DeLozier, & Rhodes, 2016). Indeed, students often report using low-utility methods of learning. For example, students frequently mass, or "cram" their study before an exam and regularly re-read material instead of testing themselves (Karpicke et al., 2009). Such misapprehensions about optimal methods of learning may have significant consequences, hindering students' likelihood of graduating and diminishing academic achievement. A further challenge with respect to implementing optimal learning strategies is that students and instructors alike can be easily fooled by their intuitions and impressions about learning (Bjork, 2018). In fact, a major impediment to implementing long-established effective learning strategies is the pervasive disconnect between learner and instructor impressions during learning and actual learning outcomes (Bjork, 2018; Roediger & Karpicke, 2018). The bottom line is that people do not have intuitive access to what helps their learning, and worse, strategies that intuitively seem to be the least helpful are often the most helpful for learning. The fact that learning is not intuitive underscores the need to turn toward the scientific research on learning and to use well-established methods of improving learning rather than the subjective impressions of students or instructors during the learning process.

## The Science of Learning Course at Colorado State University

We sought to not only remedy students' gaps in knowledge about learning, but also to train students to rely on what the science suggests helps learning rather than their own subjective impressions while learning. Toward this end, with funding for course development from the Colorado State University Provost's office, we developed a course in the Science of Learning (PSY 152) in 2014. The current offering can be found here: https://www.online.colostate.edu/courses/PSY/PSY152.dot and its ongoing offering is funded by the Department of Psychology.

In the Science of Learning, we translate the large research literature on learning into practical recommendations and skills that all students can apply, with an emphasis on teaching students specific methods of incorporating effective study strategies into their everyday habits. A significant barrier to adopting and implementing evidence-based strategies is the substantial disconnect between individuals' subjective impressions of learning and actual learning outcomes. For instance, most instructors have had the experience of being approached by a student making sincere claims of mastery of material when no such mastery is evident.

One potential reason for this disconnect is that the student has engaged in ineffective methods of learning that temporarily elevate the accessibility of information and confidence, but without changing underlying knowledge (cf., Rhodes, 2016; Soderstrom & Bjork, 2015). We approach this disconnect in several ways in the Science of Learning course. First, there is a strong emphasis on the value of science and critical thinking as a means of apprehending the world. Students frequently practice these skills in class and apply it to understanding learning. For instance, students are frequently asked to consider this question: "What is the evidence that Method X helps learning?". Second, the course provides specific instruction on best practices in evaluating and assessing learning (i.e., instruction in metacognition; see e.g., Dunlosky & Metcalfe, 2009; Dunlosky & Tauber, 2016). Thus, students should leave the course with generalizable skills that allow for accurate assessment of learning and knowledge, regardless of the content knowledge. Third, the course provides ample opportunity, via low-stakes quizzes, cumulative testing, writing assignments, and discussions to practice these approaches to learning and to consider outcomes.

Although many institutions provide general orientation courses to college or university life, our approach can be distinguished by its specific focus on critical thinking and scientifically supported learning strategies. Indeed, the approach is sufficiently unique that we were unable to identify a textbook that met the needs of the course and thus we have written a textbook (tentatively titled "*Improving Learning Skills: Insights from the Science of Learning*) that is currently in production with Oxford University Press. In what follows, we provide an illustration of how a key topic in learning (spacing) is covered in the course.

## An Example: Spacing

One of the simplest methods of enhancing learning is to distribute that learning over time. Such spacing can be contrasted with massing, whereby all learning occurs in a single block of time. For example, consider a student who will study for approximately 5 hours in advance of an exam. All other factors being equal, learning will be far more robust if that studying is spread across 1-hour sessions over 5 days rather compacted into long sessions over one or two days. These recommendations regarding the benefits of spacing are supported by a voluminous laboratory literature on spacing (e.g., Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006) as well as numerous classroom trials (e.g., Blaisman, 2017; Yazdani & Zebrowski, 2006). Research suggests many reasons why this is, including memory consolidation processes that take place during sleep between sessions to help solidify the learning that has already occurred (Born, Rasch, & Gais, 2006; Rudoy, Voss, Westerberg & Paller, 2009), and to connect the newly-learned information to other bits of information in the person's knowledge-base (Lewis, Knoblich & Poe, 2018; Wagner, Gais, Haider, Verleger & Born, 2004).

Although the benefits of spacing for learning are legion, they are not intuitive. For example, one study (Kornell, 2009) had participants learn a set of complex vocabulary words over four different days. Participants were exposed to each vocabulary word eight times; for half of the words, all of the exposures occurred within a single learning session (massing). The remaining half of the words were studied just as frequently, but these study exposures were spread out over four different study sessions. As would be anticipated by prior work, information studied via spacing was much more likely to be correctly recalled on a later test than words studied on a massed schedule. However, when participants had been asked to judge how well the information had been learned, they consistently favored words studied on massed schedules. That is, participants' subjective impression was that the massed information was better learned than the spaced information.

Accordingly, when describing the benefits of spacing, we are mindful of the fact that distributing study sessions does not tend to feel like it is going to have the benefit that it does. Instead, students must seek out the science and trust the conclusions reached via those approaches (e.g., Bjork, 2018). We further emphasize that the benefits of spacing are multiplicative, giving them more value for their time than a massed approach. For instance, for the same overall amount of time spent studying, more learning will be achieved when dividing the sessions across days than lumping them all into one or two days (or studying just prior to an exam). These multiplicative benefits are not intuitively accessible, so must be taught to learners based on the scientific research. One approach that has proven effective with students is to use the following analogy. Consider playing a sport or a musical instrument. And suppose further that one has an important "test" in the next 7 days, a game or a recital. Would it be effective to, say, avoid playing piano for an entire week and then to practice furiously the night before a recital, in that hope that performance would be optimal? Students immediately grasp the absurdity of this approach and note that a person must engage in regular practice to become skilled. With that insight achieved, the question can then be asked: Why do we expect to achieve long-last learning if we choose to do all of our learning in a single, long session or the night before an examination? Although anecdotal, our experience is that this is an effective prompt to encourage students to reconsider their approach to scheduling studying.

When teaching the benefits of spacing or any method of learning, we generally adhere to the following approach. First, we often do a demonstration of the key concept. Several simple demonstrations of spacing are available and can be easily implemented in the classroom. Moreover, we can demonstrate with the students' own data from these demonstrations that their impressions while learning do not map onto their actual learning performance. Next, we identify the key concepts. In the case of spacing, we would provide clear definitions of spacing with an emphasis on the idea that students should consider how learning is scheduled. Concepts in hand, students are introduced to the science behind the method, with a strong emphasis placed on methods, findings, and general conclusions from the literature, illustrated by several key studies. This approach furthers our goal of enhancing students' comfort with science, highlights the value we place on science, and further demonstrates the types of information necessary to critically evaluate claims. With this foundation in place, the class turns to discussion of practical strategies of implementing the method of learning into their everyday habits. For example, for the discussion of spacing, the students engage in a class activity whereby they schedule spaced study sessions into calendar apps on their devices and then later report on their adherence to these spaced schedules in written, reflective exercises.

Our course emphasizes many other science-based learning strategies beyond spacing. However, the example of spacing as an effective study strategy that we emphasize in this course is a particularly good one, as the benefits of spacing can be found in nearly every conceivable type of learning. Importantly, spacing is a good example of a strategy that does not merely benefit memorization or learning of facts. Spacing benefits acquiring skills like playing a musical instrument, playing a sport, or learning a surgical skill. Spacing also benefits inductive learning, such as learning of artists' genres from paintings. Spacing also benefits understanding, creative problem solving, and innovation. When a person is faced with a difficult problem or complicated material that is difficult to grasp or understand, repeatedly spacing out one's attempts at trying to understand, or trying to solve the problem, improve one's trajectory toward eventually arriving at a critical insight. Research suggests a number of reasons why spacing out one's thinking about a problem or attempts at understanding something facilitates insight, creavivity and innovation, including a role of sleep in the neurological processes that occur during episodes of sleep to facilitate the formation of critical connections between newly-learned material and existing knowledge (Lewis, Knoblich & Poe, 2018). Another reason has to do with the mechanisms of memory retrieval and access to relevant knowledge; by spacing out one's attempts at understanding or solving something, one can approach the problem fresh each time, escaping the grip of the wrong mindset that may have prevented access to the relevant knowledge on a previous attempt (Beda & Smith, 2018; Beeftink, Van Eerde, & Rutte, 2008; Kounios & Jung-Beeman, 2009; Kounios & Beeman, 2015). Yet another has to do with the role of continuing to have a problem on the mind over time in preparing the mind by facilitating detection of relevant information when it comes along (Siefert, Meyer, Davidson, Patalano, & Yaniv, 1995; Seifert, & Patalano, 1991). In short, spacing is a critical component of enhancing understanding, creativity and innovation.

## Successes and Remaining Challenges

As one method of evaluating the Science of Learning course, we have collected survey data the beginning and end of the course. These data show that students who have completed the course are far less likely to endorse poor approaches to learning and are far more likely to endorse evidence-based practices than before taking the course. For example, Figure 1 depicts the percentage of students who endorsed the statement “Adherence to a student’s learning style (such as visual learner, auditory learner, etc.) is very important to effective learning,” on the first day of class versus on the last day of class. This example illustrates how student beliefs about what helps their learning can be very out of line with what the research suggests. In a survey taken on Day 1 of the Science of Learning course, 81.5% of the students indicated a belief that adherence to their learning style is an important factor in how well they will learn. This is out of line with the scientific consensus regarding the notion of learning styles. The current scientific consensus is that although people generally do have preferences regarding their preferred modality of presentation of information, adherence to these preferences does not impact actual learning (e.g., Pashler, McDaniel, Rohrer, & Bjork, 2009; Riener & Willingham, 2010).  Note that by the end of the course, on the last day, very few students continue to endorse the idea that adherence to their learning style is an important factor in how well they will learn.

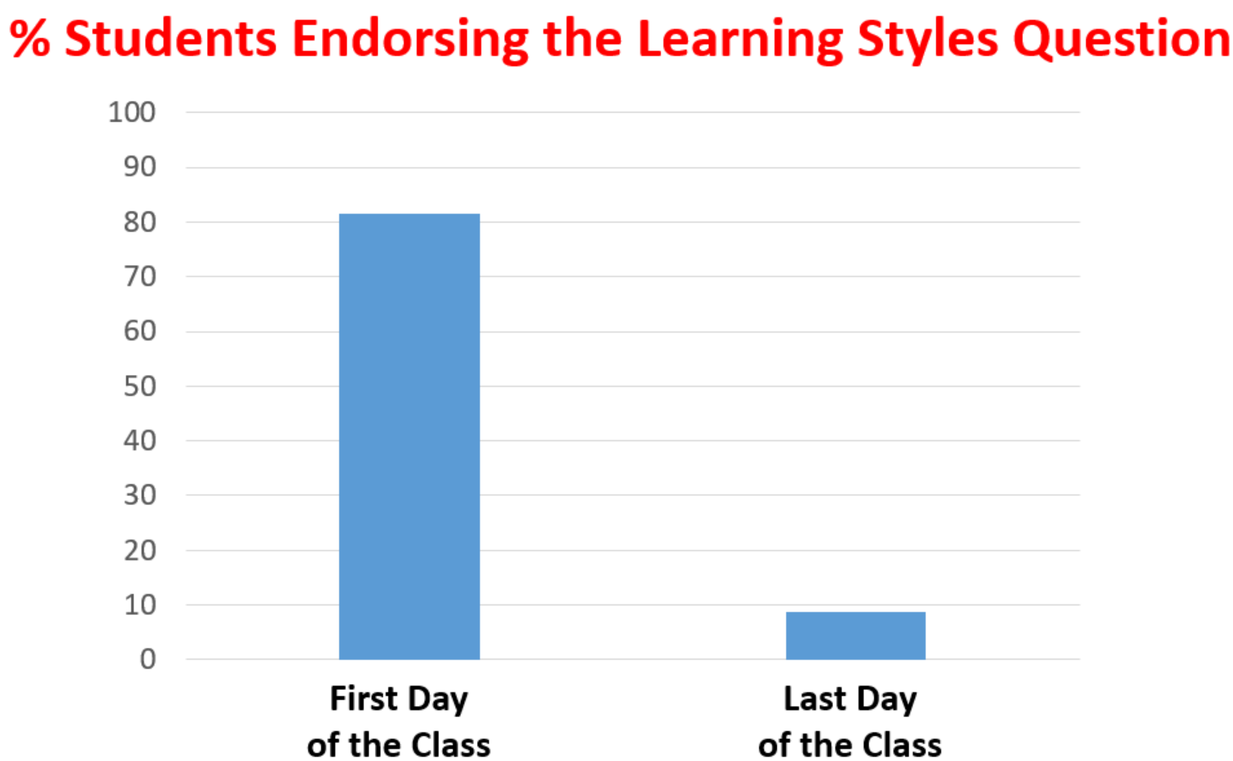


Figure 1. The percentage of students in Science of Learning who endorsed the statement “Adherence to a student’s learning style (such as visual learner, auditory learner, etc.) is very important to effective learning,” on the first versus the last day of the class.

This example illustrates that our course is having an impact on students’ beliefs about learning regarding what is and is not effective. Thus far, several hundred students have taken the Science of Learning course (PSY 152) at CSU and thus been impacted in this way. The course continues to be offered every semester. In future semesters, we will seek to better understand how the course may impact student learning and student success. For example, a key question to address is whether, relative to a control group who have not taken the course, students who have taken the Science of Learning have superior learning outcomes, operationalized via grade point average, retention, and time to graduation.

Despite these successes, barriers to practicing evidence-based methods remain. For example, although students who have taken our course endorse the value of spaced testing, they still report irregularly implementing this highly effective strategy. Therefore, we have taken our own bench science in learning to study ways of overcoming barriers to implementing effective learning strategies in students' daily lives. We are currently researching ways of overcoming barriers to successful implementation of effective study strategies in students' daily lives. In particular, research on the benefits of spaced testing on learning (e.g., Dunlosky & Rawson, 2015; Kornell, Klein & Rawson, 2015), drove our current research study on implementing spaced testing with smartwatches and smartphones. In ongoing research funded by the Center for Analytics on Learning and Teaching (C-ALT) at Colorado State University, we have devised and begun to test a method that enables students to easily implement pre-scheduled spaced testing prompts from a smart watch or smart phone. Preliminary data indicate that this method produces significant learning benefits, and may be one of several viable methods of reinforcing the continued daily practice of the basic strategies from the Science of Learning course in students' everyday lives.

## Conclusion

Our course in the Science of Learning is intended to fulfill two major goals: To make students better consumers of information and to teach high-impact, robust learning strategies that can support life-long learning. Indeed, we argue that creating effective learners who are capable of adapting and flourishing in any environment is not just a goal of our course, but a key goal of higher education. Prior data suggests that knowledge of effective learning cannot be assumed—students harbor a number of inaccurate beliefs about learning and infrequently engage in evidence-based strategies (e.g., Morehead et al., 2016). For this reason, we believe a course in the Science of Learning should be a foundational component of any undergraduate education. That is, just as students should have fundamental skills in writing, math, and other domains, so should they also have core competencies in learning. Our course is an effort to meet this goal and improve student learning and student success.

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## Primary Contact

Anne Cleary: Anne.Cleary@colostate.edu