SMART STUDYING: TEACHING STUDENTS HOW TO STUDY THROUGH NEUROSCIENCE

By

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ABSTRACT

Students consistently report using primarily ineffective and inefficient study strategies when regulating their own learning. While some interventions have been shown to influence student study behaviors, we do not know what factors make these interventions successful or not. To investigate this question, we recruited seventy-five undergraduates in an introductory chemistry course that were randomly assigned to one of two video-based interventions. Both groups learned about four evidence-based study/test-taking strategies—retrieval practice, distributed practice, creating connections, and managing test anxiety—but only the experimental group received neuroscientific explanations for why these strategies work. To assess the intervention's effects, we examined its impact on exam scores, belief in strategy, and self-reported study behavior. Both interventions significantly changed self-reported study behaviors, but the neuroscience-based intervention did not significantly outperform the other intervention. These results support prior research suggesting that it is possible to design study strategy interventions to help college students regulate their learning more effectively, and serves as a pilot study for this new type of neuroscience-based intervention. These findings suggest that while neuroscience-informed framing has theoretical appeal, it may not offer additional benefit over evidence-based interventions without further refinement.

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INTRODUCTION

Educational psychology has well established that certain study techniques are more effective for student outcomes than others. These empirically supported (ES) study strategies have been researched in a variety of subjects and settings (Deslauriers et al., 2019; Cleary et al., 2006; Panadero 2017; Brown-Kramer, 2021). For example, self-testing and distributed practice are common ES study techniques that students are advised to practice in college and beyond.

However, despite overwhelming evidence in favor of these strategies, students generally continue to use non-ES study techniques (also called low-yield study strategies) that feel more fluent rather than ES techniques, and generally doubt their efficacy (Bjork et al., 2013; Yan XA et al., 2016). Some research suggests that we can teach students these ES study strategies through relatively simple interventions (e.g., Ariel & Karpicke, 2017). While there is a small and growing body of literature suggesting this, little research has compared the efficacy of different kinds of interventions, motivating us to investigate the issue.

Discussing a few of these ES study strategies in more detail, and how their bases and mechanisms are rooted in cognitive science and cognitive psychology, will help illuminate the context of the current study. Self-testing, one of the most commonly espoused ES study strategies, involves answering practice problems without the use of outside resources. Flashcards are a well-known method of self-testing, used for both memorization and assessment of understanding (Gurung et al., 2015; Carpenter, 2009). Self-testing has proved to be more effective than re-reading for recalling and applying information. Importantly, it's not by chance that self-testing (or, retrieval practice, as it's better known in cognitive science) is so effective. Instead, it's thought to be explained by the elaborative retrieval hypothesis (Carpenter, 2009, 2011; Endres & Renkl., 2015).

Distributed practice, another common ES study technique in which studying is spread out over time, can be contrasted with massed practice (better known as cramming). Spreading out studying a given topic, as opposed to doing it all at once, has been shown to increase long-term retention of material (Voice & Stirton, 2020; Cepeda et al., 2006). This effect has been attributed to memory consolidation and the greater cognitive load required to recall information after non-practice time (Lage GM et al., 2015; Litman & Davachi, 2008), although there remains no scientific consensus on an encompassing theory (Benjamin & Tullis, 2010).

Providing explanations like the ones just given, grounded in neuroscience (and even including pictures of brains), has been shown to increase people's beliefs in research (Im, Varma, & Varma, 2017). In addition, this approach is theoretically grounded in dual-process models of cognition (Kahneman, 2011), where elaborative understanding (System 2) may be more likely to change metacognitive beliefs than surface-level information (System 1), particularly when paired with mechanisms like the seductive allure of neuroscience explanations (SANE) (Im et al., 2017). Here, taking our inspiration from this research, as well as the slight gap in research comparing different types of study skill interventions, we compare the effects of two different study strategy interventions on learners: one that simply describes effective study techniques (as has largely been done in the past: Carpenter, 2023), while the other grounds those study strategies in the neuroscientific and cognitive psychology reasoning describing why they are effective. We hypothesize that grounding study strategies in neuroscientific research and clear explanations will increase learners' beliefs in those study strategies, increasing student usage, and ultimately improving their grades.

METHODS

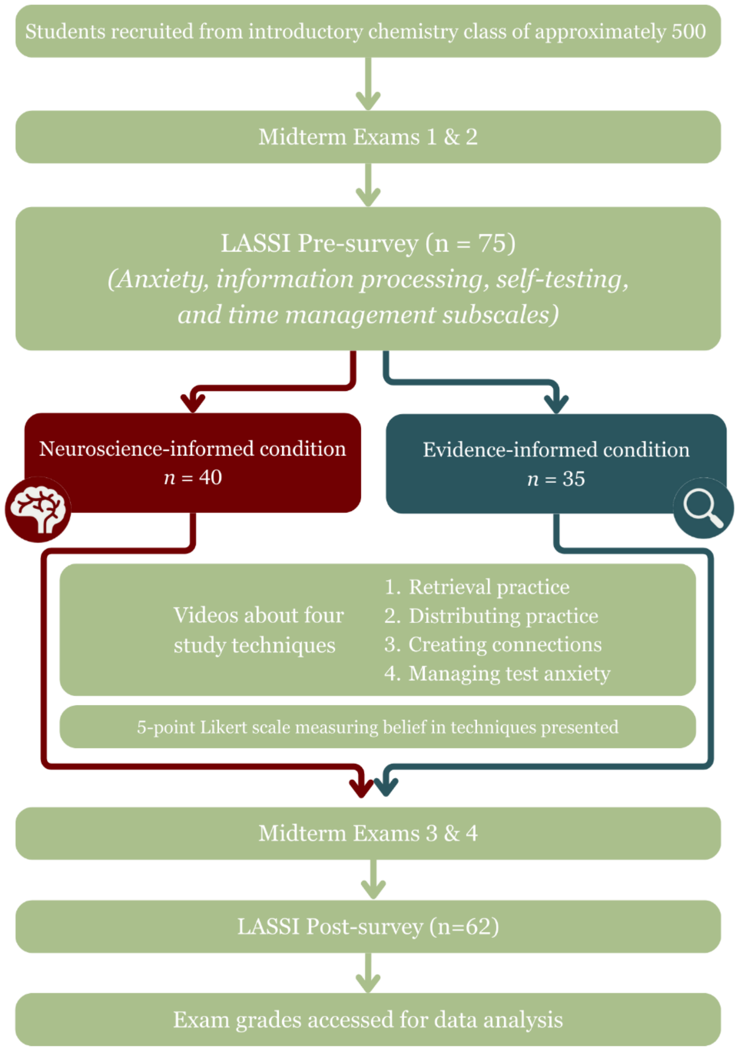


Figure 1: Overview of Methodology

Participants

We recruited 75 undergraduate students enrolled in CHEM 151, a large introductory chemistry course at the University of Arizona, during Fall 2024. Eligible participants were over 18 years old, fluent in English, and had completed the first two course exams. Demographic data are available in Table 1. Recruitment occurred via class announcements and follow-up emails. All participants provided informed consent and signed a FERPA release form to allow access to their exam scores.

Table 1: Participant Demographic Data

Variable	Category	N	Percent
Gender	Woman	59	78
	Man	17	22
Class Standing	First-Year	32	42
	Sophomore	38	50
	Junior	6	8
Major	Health/Life Sciences	32	42
	Psych/Cognitive Sci	9	12
	Pre-Med/Medicine	17	22
	Engineering/Comp Sci	14	18
	Other	6	8
Race/Ethnicity	White or Caucasian	42	55
	Hispanic or Latinx	33	43
	Asian American or Asian	11	14
	African American/Black	5	7
	Pacific Islander/Nat. Hawaiian	2	3
	American Indian/Alaska Native	1	1
	Multiple Selected	18	24
First Language	English	59	78
	Spanish	9	12
	English and Spanish equally	2	3
	Another language	6	8

Design and Materials

This study used a randomized controlled design with two intervention conditions: neuroscience-informed and evidence-informed. Participants in both groups received instruction on four empirically supported (ES) study techniques—retrieval practice, distributed practice, connecting ideas, and managing test anxiety—through brief instructional videos (see Supplemental Materials E).

Each video followed a standardized format consisting of an introduction, a condition-specific explanation, and a conclusion with actionable suggestions. Videos were matched for total length (5:51–6:47 minutes each). In the neuroscience-informed condition, the middle section explained the brain-based mechanisms behind each strategy. In the evidence-informed condition, this section instead presented behavioral studies demonstrating the technique's efficacy. Table 2 summarizes video timing.

Table 2: Video Time Breakdown by Study Technique

ES Study Strategy	Introduction	Condition-Specific Content	Conclusion	Total time
Retrieval Practice	3:03	2.29	1:15	6:47
Distributed Practice	2:58	2.79	1.22	6.19
Creating Connections	2:21	2:19	1:11	5:51
Managing test Anxiety	1:36	2.79	1:44	5:59

Procedure

After consenting, participants completed a pre-intervention survey that included four subscales of the Learning and Study Strategies Inventory (LASSI): anxiety, time management, information processing, and self-testing (Weinstein et al., 2016). They also responded to general questions about their study habits (see Supplemental Materials A).

Participants were then randomly assigned to one of the two intervention conditions and viewed the four study strategy videos. After each video, they wrote a brief summary of the strategy and described how they might apply it to their course learning. They then completed a set of belief and motivation questions on a 5-point Likert scale (see Supplemental Materials B).

At the end of the semester, participants completed a follow-up survey with the same LASSI subscales and general study questions. They also answered questions about their use of each study strategy and plans for future use (see Supplemental Materials C). Exam scores were collected at the end of the course.

Compensation

Participants who completed all phases of the study received 1% extra credit in the course and were entered into a raffle for two $250 prizes.

RESULTS

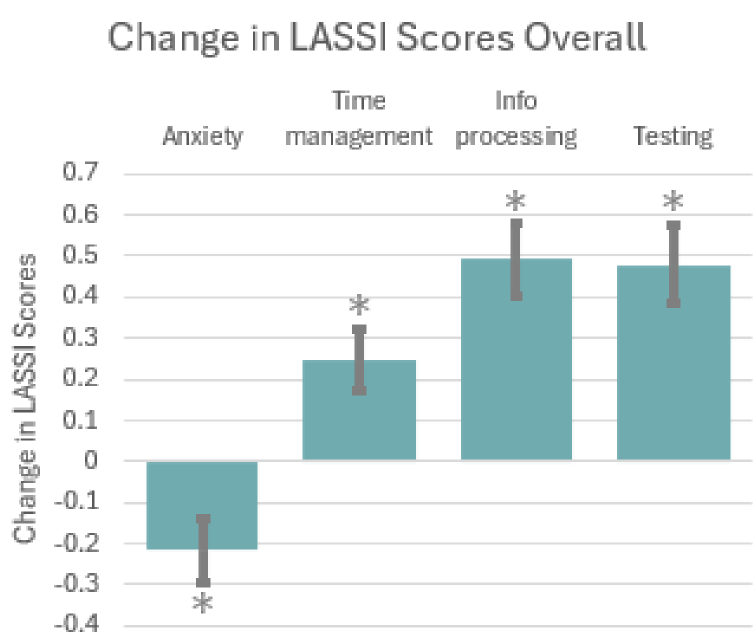
We evaluated the effects of the two interventions across three outcome categories: LASSI subscale scores, belief in study strategies, and exam performance. No significant difference was found between students in the neuroscience-informed and evidence-informed conditions.

LASSI Scores

We first examined pre-to-post changes in student scores on the four LASSI subscales. Across both conditions, students showed statistically significant improvement on all subscales.

Table 3: LASSI Subscale Scores Overall

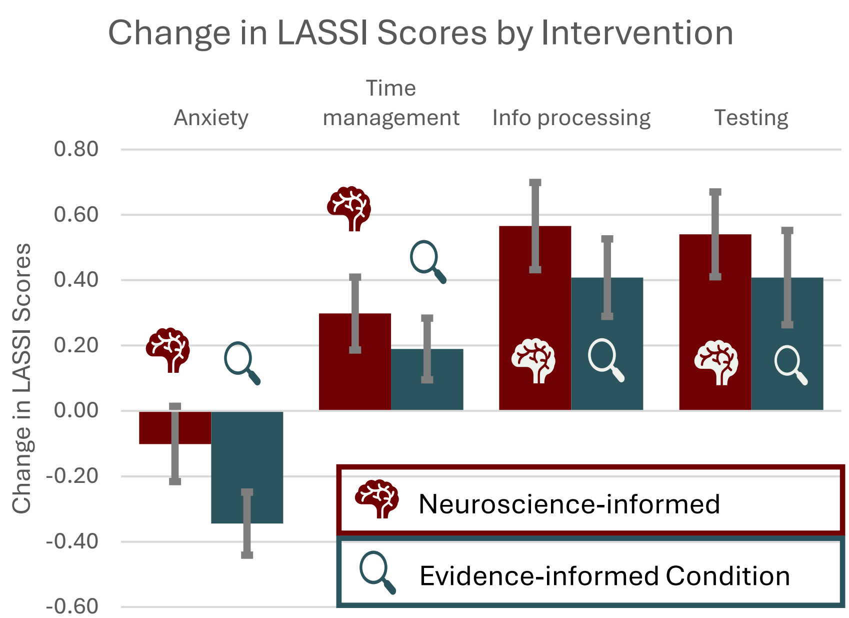
	Anxiety Subscale	Time Management Subscale	Information Processing Subscale	Self-Testing Subscale
Score Change Across Conditions	-0.345	0.190	0.408	0.408
P-value	< 0.01	<0.0001	<0.0001	<0.0001



For LASSI scores separated by condition, no statistically significant differences were found between the two groups for any subscale (all $p > .05$).

Table 4: LASSI Subscale Scores by Condition

Score Change from Pre- to Post-Test	Anxiety Subscale	Time Management Subscale	Information Processing Subscale	Self Testing Subscale	p-value
Neuroscience-informed Condition Score Change	-0.101	0.298	0.566	0.540	ns
Evidence-informed Condition Score Change	-0.345	0.190	0.408	0.408	ns

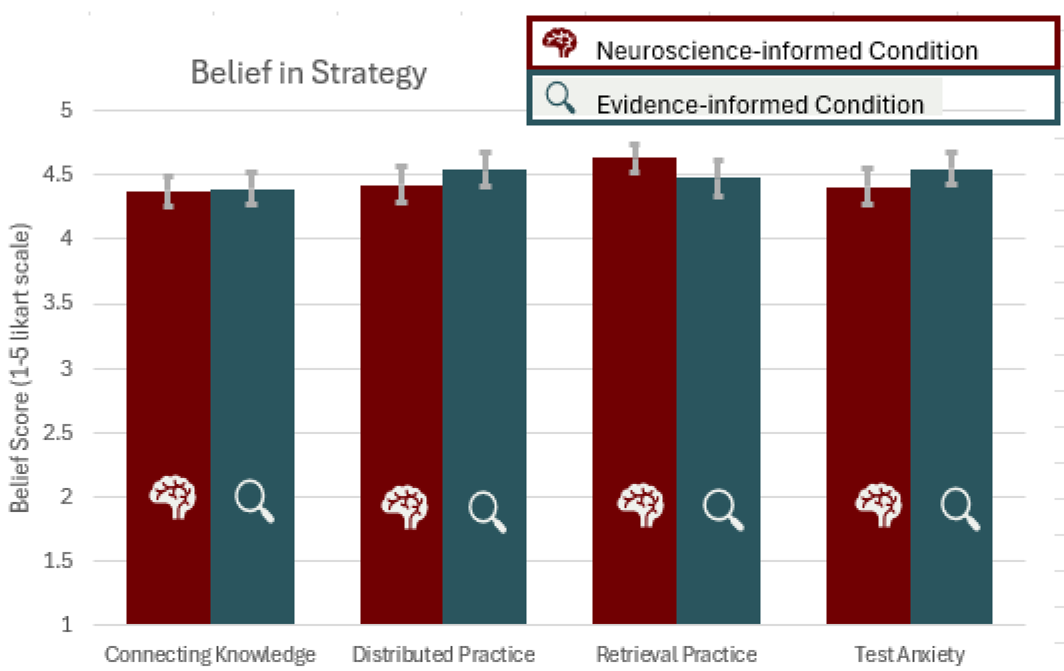


Belief in Study Strategies

Participants in both conditions reported high belief in the efficacy of the study strategies, with mean ratings near or above 4.4 out of 5 for all techniques. Belief scores did not significantly differ between groups.

Table 5: Belief in ES Study Strategies Presented by Condition

	Belief in Test Anxiety Strategy	Belief in Connecting Knowledge Strategy	Belief in Distributed Practice Strategy	Belief in Retrieval Practice Strategy
Neuroscience-informed Intervention	4.406	4.372	4.421	4.628
Evidence-informed Intervention	4.545	4.391	4.541	4.476
Average	**4.472**	**4.381**	**4.479**	**4.558**

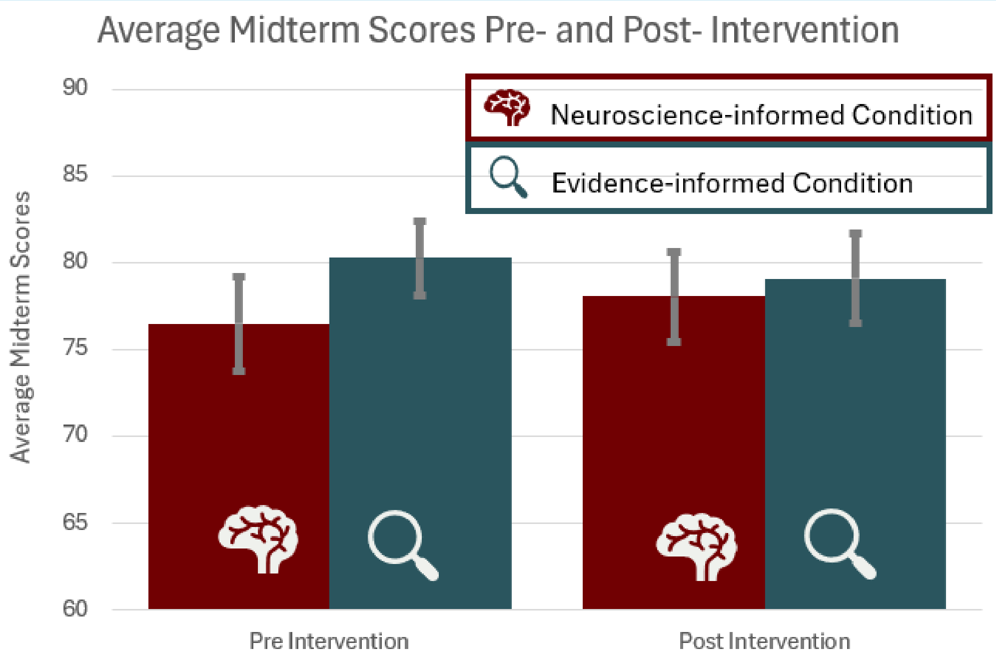


Exam Scores

Students in the evidence-informed group had slightly higher average scores on the first two exams (pre-intervention), but post-intervention differences between groups diminished and were not statistically significant.

Table 6: Exam Scores Pre- and Post- Intervention by Condition

	Average Midterm Score Pre-intervention	**Average Midterm Score Post-Intervention**
Neuroscience-informed Intervention	76.46	78.05
Evidence-informed Intervention	80.26	79.08
Average	**78.26**	**78.54**



ANALYSIS AND LIMITATIONS

This study reinforces the growing body of literature suggesting that short, targeted interventions can meaningfully improve students' beliefs and self-reported use of effective study strategies. While embedding cognitive science explanations into study skills interventions has theoretical appeal, grounding strategies in neuroscience did not significantly enhance student outcomes relative to standard explanations, contrary to our hypothesis. One possible explanation is that participants in both groups already held strong beliefs about the utility of these techniques, resulting in a ceiling effect. Alternatively, it is possible that the neuroscience content, though promising in prior work, was not sufficiently clear, relevant, or detailed, to meaningfully affect student outcomes in this context. In addition, a larger sample size may be needed to detect the effect of our intervention on learners.

These findings suggest that while embedding cognitive science explanations into study skill interventions has theoretical appeal, they may require more clarity, length, or repetition to be effective practically. In addition, given that we did not find any evidence of the neuroscience-based intervention impacting student grades, behavior, or belief in a negative way, educators could consider implementing these changes prior to more research. For example, they could informally direct students to websites or videos that explain the neuroscience behind study techniques, or assign research projects on the topic. Meanwhile, future research should continue to explore how to refine study skills interventions like these, especially neuroscience-based ones, for more significant changes in learner behavior and grades.

SUPPLEMENT A: Demographic Questionnaire

This survey was administered at the beginning of the study to collect participant background information.

With which race/ethnicity do you identify? (Select all that apply)

- African American or Black
- American Indian or Alaska Native
- Asian American or Asian
- Hispanic or Latinx
- Middle Eastern or North African
- Pacific Islander or Native Hawaiian
- White or Caucasian
- I prefer to self-identify as [short answer box]
- Prefer not to answer

What was the first language you learned to speak as a child?

- English
- Spanish
- Another language
- English and Spanish equally
- English and another language equally

With which gender(s) do you identify? (Select all that apply)

- Woman
- Man
- Trans Woman
- Trans Man

- Genderqueer or gender nonconforming

- Two-spirit

- Non-binary

- Agender

- Questioning

- Prefer to self-identify as [short answer box]

- Prefer not to answer

What is your academic class standing?

- First Year

- Sophomore

- Junior

- Senior

- Other [short answer box]

What is your major? [short answer box]

How old are you? [short answer box]

SUPPLEMENT B: General Study Habits Survey

This survey was administered before and after the intervention to assess the frequency of participants' study behaviors.

On a 5-point Likert scale (1 = Never, 5 = All the time), rate how frequently you use each of these strategies when studying:

- Practice testing myself

- Cramming the night before a test

- Studying a little bit each day
- Making connections between new knowledge and existing knowledge
- Re-reading the textbook

SUPPLEMENT C: Study Strategy Belief Questionnaire

This questionnaire was administered after each video to assess belief in each strategy presented.

Please summarize the [study strategy] in a sentence or two. [long answer box]

Describe how you might use [study strategy] to support your learning in Chem 151. [long answer box]

Rate your agreement with the following statements on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree):

- I believe that using [study strategy] would improve my learning and grades in Chem 151.
- I think [study strategy] would be useful for my specific learning needs in Chem 151.
- I trust the information provided about [study strategy].
- I understand why [study strategy] helps learning.
- I understand the benefits of [study strategy] for learning.
- I am confident that I could explain [study strategy] to someone else.
- I intend to use [study strategy] in the future to help my learning in Chem 151.
- I am motivated to try [study strategy] to improve my learning in Chem 151.

SUPPLEMENT D: Post-Intervention Strategy Use Survey

This follow-up survey was administered at the end of the semester to assess continued use and intention to use study strategies.

Thinking about [study strategy], please rate your agreement with the following statements on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree):

- I used [study strategy] to support my learning this semester.

- Using [study strategy] improved my learning and grades in Chem 151.

- I will continue to use [study strategy] in future classes.

SUPPLEMENT E: Intervention Video Links

Each participant viewed the following four videos depending on their randomly assigned condition. Videos are approximately 6 minutes each in length.

Neuroscience-Informed Condition:

- Video 1: Retrieval Practice (https://www.youtube.com/watch?v=UiGjcn9uuLU)

- Video 2: Distributed Practice (https://www.youtube.com/watch?v=MSgpZ-UxJoc)

- Video 3: Creating Connections (https://www.youtube.com/watch?v=idZPqgW3vmc&t=15s)

- Video 4: Managing Test Anxiety (https://www.youtube.com/watch?v=8bumQl_QZS0&t=15s)

Evidence-Informed Condition:

- Video 1: Retrieval Practice (https://www.youtube.com/watch?v=uxrS9e56WHI&t=274s)

- Video 2: Distributed Practice (https://www.youtube.com/watch?v=oVG5EKQEOiE&t=1s)

- Video 3: Creating Connections (https://www.youtube.com/watch?v=yyEtlC4KsQ8)

- Video 4: Managing Test Anxiety (https://www.youtube.com/watch?v=XL3RG5yfuqU)

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