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A Multicourse, Multisemester Investigation of the Impact of Cognitive Reappraisal and Mindfulness Instruction on Short- and Long-Term Learning in the College Classroom

Sarah R. Cavanagh and James M. Lang
Assumption College

Jeffrey L. Birk
Columbia University Irving Medical Center

Carl E. Fulwiler
University of Massachusetts Medical School

Heather L. Urry
Tufts University

Emotions impact learning, in part by affecting cognitive resources like attention and working memory. Clinical literature suggests that cognitive reappraisal and mindfulness can benefit emotional experiences. However, evaluations of whether we can leverage these tools to improve student learning in the classroom are limited. We evaluated whether brief training in cognitive reappraisal and mindfulness, compared with an informational control condition, would impact same-day and semester-end learning in 226 undergraduates in art history, mathematics, and economics courses. On each of these intervention days, participants were randomly assigned to one of the three interventions. All students thus completed all three interventions over the course of the semester. At the end of the semester, students completed another assessment which measured class learning of material covered on the intervention days and a variety of control days on which there were no interventions. The interventions did not result in better same-day learning, but students performed better on the final exam items from intervention days, particularly the cognitive reappraisal day, $F(2, 139) = 4.495$, $p = .013$, $\eta_p^2 = .061$. Future research should examine the mechanisms by which cognitive reappraisal might influence learning.

Keywords: Learning, Emotion, Reappraisal, Mindfulness

The college classroom, like life, is permeated by emotion. Confusion upon the presentation of a new concept, frustration with a difficult problem, the glow of pleasure as a skill is mastered—these are but a few of the affective states students experience during their time in the classroom (D'Mello & Graesser, 2012; Immordino-Yang & Damasio, 2007). Some of these affective states are likely to encourage learning (Cavanagh, 2016), but others, like anxiety, clearly detract from learning (Götz & Hall, 2013; Moore, McAuley, Allred, & Ashcraft, 2014). And of course, students are not

Sarah R. Cavanagh, Department of Psychology and D'Amour Center for Teaching Excellence, Assumption College; James M. Lang, Department of English and D'Amour Center for Teaching Excellence, Assumption College; Jeffrey L. Birk, Department of Medicine, Columbia University Irving Medical Center; Carl E. Fulwiler, Departments of Psychiatry and Medicine, Center for Mindfulness, University of Massachusetts Medical School; Heather L. Urry, Department of Psychology, Tufts University.

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Correspondence concerning this article should be addressed to Sarah R. Cavanagh, Department of Psychology, D'Amour Center for Teaching Excellence, Assumption College, 500 Salisbury Street, Worcester, MA 01609. E-mail: sarah.rose.cavanagh@gmail.com

solely focused on their work. Affective states related to their personal lives, other classes, and the buzzing smartphones in their laps can also distract them. In this multisemester, multidiscipline, randomized, blind-to-the-instructor, within-subjects, preregistered research study, we evaluated whether offering students tools to manage potentially disruptive affective states would benefit their learning.

Emotions Impact Learning

Emotions evolved to prepare an organism for action, to encourage approach of evolutionarily beneficial situations and avoidance of evolutionarily costly situations (Shiota & Kalat, 2017). Information that is surprising, anomalous, and/or goal relevant evokes emotion and is particularly important for people to attend to, prioritize processing of, and store for future recall—that is, to learn about (Bower, 1992). As such, emotional information is prioritized by attentional (P. J. Lang & Davis, 2006) and memory (Kensinger & Schachter, 2008) systems in the brain, suggesting that teaching practices that tap into the affective domain might yield benefits in learning (Immordino-Yang & Gotlieb, 2017).

Research by Reinhard Pekrun and colleagues (Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz. 2017) suggests that positive activating emotions (e.g., curiosity, pleasure) enhance academic motivation and achievement, whereas negative deactivating emotions (e.g., boredom, hopelessness) interfere with learning. In his control-value theory of achievement emotions, Pekrun (2006) suggested that the best route to optimizing student motivation and achievement is to facilitate their appraisals of classwork and assignments as having high levels of both control (autonomy) and value (relevance for personal present, personal future, or societal goals), and that relationships between emotions and achievement are mediated by changes in motivation, cognition, and self-regulation. Supporting the importance of these appraisals for achievement, other important work illustrates the critical role of autonomy (Black & Deci, 2000) and highlights the relevance or utility of the work (Harackiewicz & Hulleman, 2010) in enhancing learning. In other words, maximizing control and value appraisals yield affective states like curiosity and enjoyment, which elicit greater levels of attention, motivation, and memory consolidation, which, in turn, yield better learning (and vice versa for states like boredom or anxiety).

Focusing less on affect and more on the distribution of cognitive resources, cognitive-load theory (Chandler & Sweller, 1991) argues that attention and working memory are limited resources, and thus are distributed among several competing demands during the process of learning. These respective demands are intrinsic (pertaining to the task or skill, related to its complexity and number of elements), extraneous (pertaining to processing related to presentation style and/or distractions), and germane (pertaining to changing knowledge structures, a requirement for learning).

Huk and Ludwigs (2009) point out, however, that freeing up cognitive resources by reducing extraneous load does not guarantee that learners will automatically dedicate the extra resources to learning. They may well use their freed-up resources to daydream, to text their friend, or to study notes for an upcoming exam in another class. These authors propose a theoretical framework of *augmented* cognitive-load theory, which incorporates the additional layer of cognitive and affective support that encourages the dedication of resources to learning.

Combining the control-value and augmented-cognitive-load theories, providing students with tools to decrease their negative emotional reactivity and refocus their attention on their academic goals may decrease the resources absorbed by distracting emotions like anxiety and direct any freed-up resources to the task of learning. If students dedicate more resources to germane demands, this should benefit learning and yield better academic outcomes.[1]

Cognitive Reappraisal and Mindfulness Impact Emotion

If emotions can impact learning in both positive and negative ways, giving students some tools to regulate their emotions could potentially benefit their learning. *Emotion regulation*

[1] Applying new skills to regulate emotions will also use resources. We estimate that the benefits will be superior to the cost of applying the strategies, but we may be mistaken, in which case we would observe either no effect or a negative effect on learning.

refers to any process by which a person attempts to change their emotions in order to bring their experience in line with a perceived goal (Gross & Thompson, 2007). Strategies for regulating emotion are numerous (Gross, 2015; Webb, Miles, & Sheeran, 2012), from modifying the situation, to manipulating attentional focus, to suppressing one's emotional response. An evaluation of the clinical and affective literature yields two regulatory strategies with the most empirical support: cognitive reappraisal (Gross & Thompson, 2007) and mindfulness (Kabat-Zinn, 1990).

Cognitive Reappraisal

One of the most effective emotion regulation techniques is *cognitive reappraisal* (Webb et al., 2012), in which one reinterprets the meaning of a situation in order to alter its emotional impact (Gross & John, 2003)—for instance, reframing a job loss as an opportunity for career exploration. Use of cognitive reappraisal is linked with higher levels of well-being and fewer symptoms of psychopathology (Gross & John, 2003; Preece, Becerra, Robinson, & Gross, 2019).

Emotion regulation processes are highly relevant in the classroom, in which emotions are pervasive and the social norms for behavior are typically strict. A few studies have investigated emotional interventions in the classroom and found no (Kim & Hodges, 2012) or marginal (Strain & D'Mello, 2015) support for effects on learning. Neither of the studies used an active control, however, and both were conducted in online environments. It is not clear the extent to which online learning environment research will translate to face-to-face classroom settings, and more work is clearly indicated before we can make conclusions about the impact of emotion interventions in the classroom.

Mindfulness

Mindfulness is a multifaceted mental state that blends focused awareness of moment-to-moment experience with an attitude of acceptance, curiosity, and affection (Kabat-Zinn, 1990). Mindfulness-based interventions successfully reduce symptoms of numerous psychiatric disorders and yield many benefits for psychologically healthy people (Chiesa & Serretti, 2011; Hofmann, Sawyer, Witt, & Oh, 2010). In the laboratory, a focused breathing intervention benefited performance on timed mathematics tasks in participants with high math anxiety (Brunyé et al., 2013); however, it is unclear whether these effects would generalize to actual classrooms and whether mindfulness would benefit not only task completion but also learning new skills. Preliminary evidence suggests that mindfulness-based activities at the start of class can yield emotional and cognitive benefits (Calma-Birling & Gurung, 2017; Ramsburg & Youmans, 2014; Waters, Barsky, Ridd, & Allen, 2015; Yamada & Victor, 2012), but many of the studies to date are partially limited because of lack of random assignment and/or instructor awareness of the intervention (Waters et al., 2015). Studies of the effects of mindfulness on learning in the classroom in which participants in the same class are randomly assigned and in which the instructor is not aware of the manipulation are indicated. This need for more extensive empirical evaluation is particularly necessary because mindfulness interventions in the classroom are increasingly popular (Felver, Celis-de Hoyos, Tezanos, & Singh, 2016)—the practice is outpacing the empirical support.

Synthesis and Conceptual Frameworks: Impacting Emotion via Cognitive Reappraisal and Mindfulness May Benefit Learning

We know that emotions are ubiquitous in the classroom and important for learning, and we know that mindfulness and cognitive reappraisal are among the most effective strategies to benefit emotional experiences and outcomes. However, we do not yet have extensive real-classroom evidence to support the idea that we can implement these tools to improve student learning. Simply put, we do not know whether exercises that are effective at improving *emotional* outcomes *outside* the classroom are also effective at improving *learning* outcomes *inside* the classroom.

Here, we extend the augmented-cognitive-load theory to examine how adaptively responding to emotion may allow students to direct more cognitive resources to the process of learning. We propose that by providing support for students to reduce their negative emotional re-

activity (through the application of mindfulness and cognitive reappraisal), we may reduce their extraneous load and maximize learning. This possibility is consistent with research on math anxiety, which has suggested that such anxiety is associated with an "affective drop" in performance (Moore et al., 2014). Namely, reducing negative affective states like boredom, frustration, and anxiety may decrease extraneous load by reducing physiological arousal and worrisome, distracting thoughts. Our goal was not to eradicate negative emotions. Rather, we aimed to help students find ways of interpreting negative emotions in the classroom in ways that have been linked to lower reactivity and to more adaptive emotional states, which would ideally reduce extraneous load and benefit learning.[2]

This synthesis of control-value and cognitive-load theories is also consistent with a recently proposed model of emotion regulation in achievement situations (Harley, Pekrun, Taxer, & Gross, 2019). This model integrates the control-value theory with the process model of emotion regulation. It suggests that the classroom is a specific setting in which both emotions and goals are salient, and integrates the importance of appraisals of control and value within the larger family of cognitive change strategies of emotion regulation. Within this model, the instructional interventions aimed to help students make adaptive appraisals of their experiences in the classroom. The cognitive appraisal intervention focused on appraisals related to value (of the process of learning, of their instructor's care for their progress, of the sometimes-beneficial nature of negative states like frustration when learning something new), and the mindfulness intervention focused on appraisals related to acceptance.

Aside from the emotional benefit that we hoped the students would gain from the instructional interventions, cognitive-load theory would also suggest that practices that focus cognitive resources on the task of learning rather than extraneous distractions should benefit subsequent learning. Beginning a college class with a transitional activity that focuses the class on the task of learning is a commonly recommended pedagogical tool (e.g., J. M. Lang, 2016) that has, to this date, received little empirical evaluation.

Whether small interventions at the start of class can benefit student learning (either by impacting emotions or establishing a greater focus on learning) represents an important research question, because should these interventions be found effective, they could be easily implemented in real-life classrooms to better students' educational experiences. Cognitive reappraisal is little studied and little used in the classroom; knowing its benefits would thus represent untapped potential to better student experience. Mindfulness is heavily studied and often practiced in the classroom, but empirical support in higher education is equivocal; knowing more about its effects may impact practice.

Present Study

In the current work, we evaluated whether giving students tools from cognitive reappraisal and mindfulness at the start of class would benefit short-term and long-term learning of the material that followed the interventions (compared with a control condition).

We presented cognitive reappraisal, mindfulness, and informational control interventions (described in detail in the Methods section) using a brief web application presented on tablet devices (iPads) that included text, images, and examples of how the regulatory strategies could be applied during class. We manipulated the intervention condition on a within-subjects basis, in which each condition was deployed on 3 different class days during the semester (see Figure 1 for a full depiction of the study design).

Presenting these interventions and control condition using headphones and iPads allowed us to randomize participants so that a subset of participants on each of the 3 test days received each intervention or the informational control, and meant that the instructors were blind to participant condition. Participants interacted with the web application at the start of class and then put aside the iPads while the instructors taught them a lesson. At the end of class, participants picked up the iPads and completed a brief multiple-choice quiz on the lesson. Partic-

[2] We would like to acknowledge that these brief instructional interventions are unlikely to be powerful enough to ameliorate negative emotions surrounding many of more serious levels of distress students may be experiencing because of challenges like food insecurity, trauma, and/or clinically significant levels of depression or anxiety.

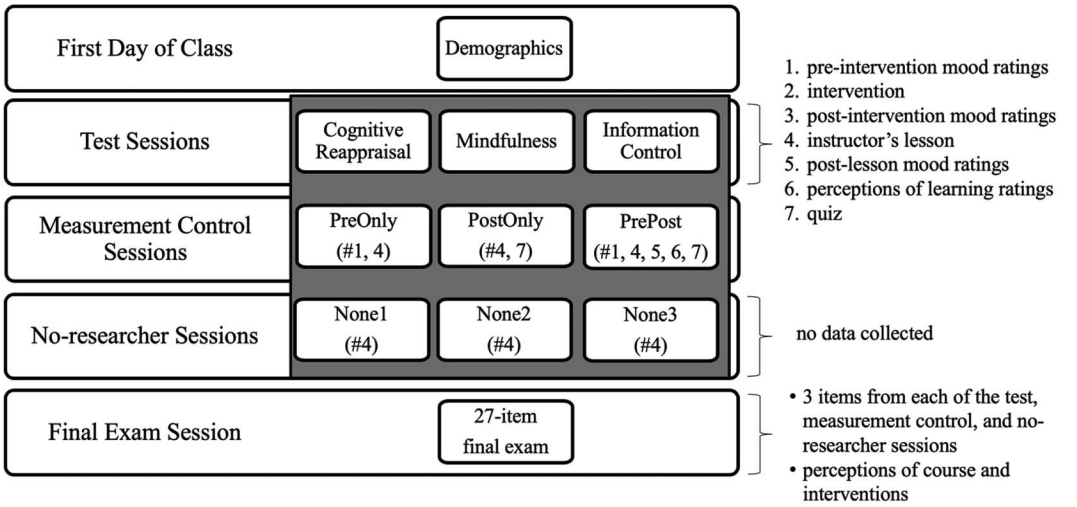

Figure 1. Overview of study design and measurements collected at each session.

ipants rated their moods before and after the intervention, and then again after the lesson but before the quiz. They also took a final exam at the end of the semester containing questions from these days and a variety of measurement control days.

We conducted this experiment over two different semesters in introductory courses in three disciplines (one science, technology, engineering, or math, one humanities, and one social science).

Hypotheses

We tested five primary hypotheses. Compared with the informational control intervention, we anticipated the following:

Hypothesis 1 (H1): Mindfulness and cognitive reappraisal interventions will result in improvements in mood (H1a: There will be an increase in same-day positive emotions; H1b: There will be a decrease in same-day negative emotions).

Hypothesis 2 (H2): Mindfulness and cognitive reappraisal interventions will result in better academic performance (H2a: The interventions will result in improved same-day perceptions of learning; H2b: The interventions will result in improved same-day quiz performance; 2c: The interventions will result in improved end-of-semester "final exam" performance).

Hypothesis 3 (H3): Intervention-based improvements in academic performance (H3a: same-day perceptions of learning; H3b: same-day quiz performance, or H3c: end-of-semester final exam performance) will be mediated by improvements in mood.

Hypothesis 4 (H4): Given that all three interventions engage focusing of attention at the start of class, all three interventions, whether aimed at regulating emotion (cognitive reappraisal and mindfulness interventions) or not (informational control intervention), will boost end-of-semester "final exam" performance.

Hypothesis 5 (H5): As they represent novel, potentially arousing activities, simply providing mood ratings at the start of class (5a) or taking a quiz at the end of class (5b) will boost end-of-semester "final exam" performance. The latter effect would also be suggested by extensive research on retrieval practice (Roediger & Butler, 2011).

As both mindfulness and cognitive reappraisal have been demonstrated to have beneficial effects on emotion, we did not have a priori predictions regarding whether mindfulness or

cognitive reappraisal would be superior with respect to their impact on the relevant outcomes.

Method

All procedures, stopping decisions, measurement variables, hypotheses, and data analysis plans were preregistered on the Open Science Framework before data collection commenced (https://osf.io/92vuh).

Participants

The sample consisted of all students enrolled in the specific courses taught by our recruited faculty over the Spring 2017 and Fall 2017 semesters at a small liberal arts Catholic college in New England: an Art History course (71 students across three classes), a math class in Elementary Functions (81 students across three classes), and an Introduction to Microeconomics course (74 students across four classes). Across all of these courses, we thus recruited 226 participants (124 women, average age = 19.23 years, $SD = 1.07$). Reflecting the general demographics of the school we were recruiting from, the majority of participants were White (77%), with the next largest racial identifications being Black or African American (8%) and Asian or Asian American (2.2%). The proportion of participants reporting Hispanic or Latino heritage was 9.7%. In our preregistration, we estimated recruiting 190 participants. According to the pwr package in R, this gives us sensitivity to detect paired within-subjects effect sizes of $d = .20$ or higher (Champely, 2018).

The college's institutional review board reviewed the protocol and approved it as exempt from review, as the procedures were deemed typical educational practices. Indeed, several instructors on campus were already implementing mindfulness exercises in their classes and quizzes following a lesson, practices that have been demonstrated to improve learning (e.g., Roediger & Butler, 2011). Because the instructors embraced the interventions and the associated quizzes on the material as part of the educational practices within their classes, we did not offer incentives to the students for their participation.

Procedure

On each of 3 intervention days, participants rated their emotions, completed their assigned intervention, rated their emotions again, and then put the iPads aside while the instructor presented the planned lesson. At the end of class, the participants picked up the iPads again, reported on their emotions and perceived learning, and then took a short multiple-choice quiz on the material they had just learned. We included several additional control days to test for the effect of emotion rating at the start of class, taking a quiz at the end of class, and the combination of the two (see Figure 1 for a full depiction of the study design).

Participants also took a final exam at the end of the semester containing questions from these days and a variety of measurement control days. Thus, the primary dependent measures were the emotion ratings, the quiz scores, and the final exam scores.

Students provided data on the first day of class and on each of 7 additional class days over the semester, one of which was scheduled just prior to the end of the semester. The activities associated with all sessions are described in the next section. Note that the sessions were spread throughout the semester. The study registration, intervention randomization, and study data collection were all performed using an Angular web app with backend services written in Java, hosted on Amazon Web Services.

First week of class. At the start of the semester, students established a unique identification number designed to be nonidentifiable but easily remembered, learned about the study, and provided demographic information.

Test sessions. At the start of class, students received headphones and iPads, which cued them to rate their current mood as a preintervention measurement. Next, they completed the tasks associated with one of three conditions (order randomized over test sessions, with researchers and instructor blind to condition):

1. a cognitive reappraisal condition, in which students were guided through a training aimed at encouraging helpful interpretations of the learning experience and their emotional response;
2. a mindfulness condition, in which students were guided through a training aimed at

promoting a state of focus, acceptance, and lower emotional reactivity; and

3. an informational (control) condition, in which students were guided through an SAT-style reading comprehension passage—the demands of this exercise matched the visual and motor aspects of the other two conditions but without engaging mindfulness or cognitive reappraisal.

The full text of all three interventions (one course's informational control as an example) is provided in Appendix. These interventions were guided instructions on how to apply cognitive reappraisal and mindfulness during the class to come rather than emotional induction followed by guided practice.

Cognitive reappraisal intervention. The cognitive reappraisal intervention consisted of a series of pictures overlaid by explanatory text, followed by three opportunities to commit to/practice using reappraisal during the lesson to follow. The intervention began with a discussion of how the college experience is full of emotions, both positive and negative, and that these are experiences that the participants share with their peers. It then described what cognitive reappraisal was, gave an example of it, and shared that research has demonstrated its effectiveness in regulating emotion. Following all of this psychoeducational material, we presented to students three scenarios that might arise during the lesson to follow—that they may become bored with the material, that they may start feeling anxious, and that they may become frustrated.

Each of these scenarios (boredom, anxiety, frustration) were accompanied by three (equally representative of reappraisal) possibilities for ways that the student could reframe or rethink the emotion or the situation were it to arise (nine total reappraisals). These were presented in an if–then structure, similar to implementation intentions (e.g., "IF I find myself losing interest and focus, becoming tempted to think about or do things unrelated to class, THEN I will instead think about . . ."). Implementation intentions make automatic the link between goal-relevant situations and one's preferred goal-directed response (Gollwitzer & Sheeran, 2006). In summary, the intervention raised the issue of emotions during the college experience, described cognitive reappraisal and its effectiveness at length, and then asked students to imagine three emotional scenarios that could arise in the lesson to follow and to commit to using reappraisal in response. For example, the following is the leading scenario with one of the three completion prompts for the frustration scenario:

> IF I find myself becoming irritated and frustrated with my progress, my professor, or my peers, or find myself feeling lost and confused, THEN I will instead think that the best rewards in learning occur by working through initial confusion.

Mindfulness intervention. The mindfulness intervention mirrored that of the cognitive reappraisal intervention, in that it began with normalizing emotions in the college and classroom experience, then defined mindfulness, then described some research demonstrating its effectiveness, and then moved into the scenarios with the three options, which represented mindful ways of approaching emotional experience rather than techniques for reappraisal. Participants were asked to commit to one mindful approach per scenario. For example, the following is the leading scenario with one of the three completion prompts for the anxiety scenario:

> IF I find myself becoming nervous about my performance in answering questions in class or on quizzes or tests, or about my grade in the class, THEN I will instead let this nervousness be, accepting it as it is, not trying to change it or make it go away.

Informational control. Each of the three classes had a different informational control task, which used the same structure as the emotional interventions (images and explanatory text followed by three multiple choice options) but which presented information sourced from example SAT and GRE reading comprehension texts. In art history, students were presented with information about watercolor painter Dong Kingman. In economics, students read information about the role of ethics in economics. In math, students read information about the changing proportions of philosophy majors over time. Each of the passages was selected from one of three possibilities per class (nine total passages), which were to be as closely matched as possible on variables like reading complexity, interest level, and number of multiple-choice questions correct,

based on ratings by pilot participants on Amazon Mechanical Turk.

Control sessions. Participants completed a number of additional control sessions so that we could systematically evaluate the effect of aspects of the test sessions that were unrelated to the actual content of the interventions.

Measurement control sessions. The measurement control sessions paralleled the test sessions, with the exception that students did not complete an intervention; instead, they received a tablet and (a) provided prelesson mood ratings (PreOnly) plus received their instructor's lesson, (b) received their instructor's lesson and took a quiz afterward (PostOnly), or (c) provided mood ratings before and after their instructor's lesson, provided ratings of perceptions of learning, and took a quiz afterward (PrePost).

No-researcher sessions. On these 3 days, students did not use a research tablet or provide any data and researchers were not present. Instructors simply delivered their planned lesson and provided us with three items to be included in the research "final exam" (None1, None2, None3).

Final exam session. To assess long-term retention of material, near the end of the semester, students completed a brief "final exam," which contained material from the test, measurement control, and no-researcher sessions. Test sessions, measurement control sessions, and no-researcher sessions were yoked together and occurred over approximately a week and a half toward the beginning, middle, and end of the semester, respectively. Order of control sessions was pseudorandomized across the three disciplines. For instance, in one section, in September, students completed one test session, PrePost, and None1; in mid-October, they completed one test session, PostOnly, and None2; and in late November, they completed the final test session, PreOnly, and None3. The "final exam" was held either on the last day or secondto- last day of the semester, according to professor preference.

Measures

Mood ratings. Participants provided mood ratings on 12 measurement occasions: three times during each of three test sessions, and once during the PreOnly and twice during the PrePost measurement control sessions. On each occasion, they provided ratings of how they felt using 10 items adapted from previous work by Tamir, John, Srivastava, and Gross (2007). We used items that we thought would be most relevant in the classroom. Each item was composed of a set of three emotion adjectives; participants rated how they felt based on each set as a whole on a scale from 0 (*not at all*) to 6 (*very much*), with a midpoint anchor at 3 (*moderately*). Items were presented in alphabetical order of the first word in each set. The negative emotions were *anxious*, *worried*, *fearful*; *bored*, *indifferent*, *uninterested*; *confused*, *puzzled*, *lost*; *frustrated*, *exasperated*, *impatient*; and *judged*, *scrutinized*, *evaluated*. The positive emotions were *active*, *alert*, *keyed up*; *affectionate*, *loving*, *connected to others*; *curious*, *interested*, *engrossed*; *happy*, *pleased*, *contented*; and *self-confident*, *capable*, *worthwhile*. We calculated two subscale scores by computing an average, one for the positive emotions (five items) and one for the negative emotions (five items), for each of the 12 measurement occasions.

Perceptions of learning (subjective). On each of the days that contained a quiz and mood ratings after the lesson (i.e., the three test sessions and PrePost), participants also rated the following items on a 5-point scale with anchors at each point (*minimal*, *below average*, *average*, *above average*, and *substantial*): degree of interest in the lesson, degree of challenge presented by the lesson, extent of learning, and extent of mastery of the perceived goal of the lesson.

Assessments of same-day learning (objective). A quiz was administered on five measurement occasions (three test sessions, two measurement control sessions [PostOnly, PrePost]). Each quiz contained five multiple-choice items with four response options (one correct answer and three incorrect distractors) and was provided by the instructors.

Assessment of long-term learning (objective). The "final exam" was administered once at the end of the semester. It contained 27 items—three items from each of nine class days (three test sessions, three measurement control sessions, and three no-researcher sessions). All items were multiple choice with four response

options, and the exam was provided by the instructors.

Perceptions of the course and interventions (subjective). After the "final exam" on the last day of the study, students and professors both completed some evaluative questions about the course and the interventions (see Table 1, which reports students' and professors' perceptions of the course and interventions).

Demographics. On the first study day, students provided demographic information and ratings of their feelings about the course, including age, gender identity, race, ethnicity, year in school, major, current grade point average, reason for taking the course, and the extent to which they considered themselves to be a strong student in this subject, were excited for the course, and intended to work hard.

Reliability of Test Score Measures

Regarding the reliability of the quiz and final exam scores, we computed the total omega coefficient using polychoric correlation matrices. We used this approach because Cronbach's alpha assumes *tau equivalence*, such that the items in a scale each contribute equally to the scale total (McNeish, 2018), which is likely not the case for the five-item quiz and three-item final exam scores, for which the items tapped different aspects of the day's lesson and therefore should not be expected to load equally on a higher order factor. Second, the items were dichotomous (1 = correct, 0 = incorrect), in which case Gadermann, Guhn, and Zumbo (2012) recommended calculating reliability using polychoric (as opposed to Pearson) correlation matrices to account for truncated variance.

We computed the reliability indices using the psych library (Revelle, 2018) in R (R Core Team, 2018) for each of the three classes, two semesters, and sessions. There were five sessions for quiz scores (ID1: Intervention Day 1, ID2: Intervention Day 2, ID3: Intervention Day 3, PostOnly, and PrePost) and nine sessions for final exam scores (the five sessions noted previously plus PreOnly, None1, None2, and None3). For the quiz scores, the coefficient omega total ranged from 0.33 to 1 (Mdn = 0.86) for the quiz scores and from 0 to 1 (Mdn = 0.64) for the final exam scores. Thus, reliability varied a great deal between semesters, classes, and sessions. Median values for coefficient omega total suggested that the five-item quiz scores were at least moderately reliable. Unsurprisingly, the three-item final

Table 1
Student and Professor Self-Reported Perceptions of Study

	M	*SD*	Range
Student ratings			
Study was interesting	2.23	1.46	0–5
Study detracted from learning	1.15	1.37	0–5
Study helped learning	1.62	1.35	0–5
Study was a negative experience	.91	1.26	0–5
Cognitive reappraisal was helpful	1.56	1.34	0–5
Mindfulness was helpful	1.74	1.35	0–5
Quiz was helpful	2.60	1.49	0–5
iPads helped transition to class	1.60	1.39	0–5
Reminder of negative emotions was unhelpful	1.28	1.35	0–5
Professor ratings			
Students more interested than usual	1.00	1.00	0–2
Study detracted from learning	.67	.58	0–1
Study was a refreshing change of pace	1.67	1.53	0–3
Students seemed to like the study	2.33	.57	2–3
Students made positive comments about study	1.33	1.15	0–2
Students didn't seem to care for study	1.33	1.15	0–2
Students made negative comments about study	.00	.00	0–0
Students seemed more focused than usual	1.67	.58	1–2
Students seemed more emotional than usual	.00	.00	0–0

Note. All student ratings were on a 6-point scale from *not at all* (0) to *extremely* (5). All professor ratings were on a 7-point scale from *not at all* (0) to *extremely* (6). As depicted, most professor ratings for most variables were centered around 2, which corresponded to *slightly* on the rating scale.

exam scores were less reliable than the five-item quiz scores. However, overall, although reliability would ideally be higher, the pattern herein suggested that the quiz and final exam scores were tenable for use as dependent variables. We have provided all omega total and traditional Cronbach's alpha coefficients using polychoric correlations (see Table 2) and Pearson correlations (see Table 3).

Results

Data Preparation

All analyses were performed using SPSS. We inspected the distribution of all measured variables and found them suited to the proposed analyses that assume a normal distribution.

Prior to calculating scores across mood and perceptions of learning rating items, we examined whether their internal consistency was acceptable (judged by a Cronbach's $\alpha \geq .70$). The mood ratings all met these criteria. However, the "perceptions of learning" variable fell below this threshold. Examining the individual items, the item relating to the perceived challenge of the material seemed to be driving these lower consistencies. Upon consideration, it seems reasonable that the degree to which one found material difficult or stimulating would be qualitatively different from the other items, which all related to the degree of understanding, learning, or mastery of the material. We decided to formulate the overall perceptions of learning score leaving out the challenge item, which raised the internal consistency of the scale to acceptable levels (Cronbach's $\alpha = .723$).

For Hypotheses 2 (2a, 2b, and 2c), 4 (4a and 4b), and 5 (5a and 5b), we set alpha at .05 for determining whether the single a priori contrast of interest is surprising if the null hypothesis is true. For H1a and H1b and H3a, H3b, and H3c, we used a Bonferroni correction to adjust the alpha to .05/k, where $k = 2$ a priori contrasts each for H1a and H1b, and $k = 8$ effects each for H3a, H3b, and H3c.

Hypothesis Testing

Hypothesis 1. To test the hypothesis that mindfulness and reappraisal interventions would result in improvements in mood, we computed a mixed-model general linear model (GLM) with positive and negative mood ratings as the dependent variables. This analysis included two within-subjects factors—Condition (cognitive reappraisal, informational, mindfulness) and Time (preintervention, postintervention, postlesson)—and two between-subjects factors—Course (art history, economics, mathematics) and Semester (Spring 2017, Fall 2017). Of primary interest, we tested H1a and H1b with two a priori contrasts each. Each contrast compared postintervention (or postlesson) mood with preintervention mood to determine whether change over time was bigger in the cognitive reappraisal and mindfulness conditions than in the informational condition. We inferred full support for H1a or H1b if one or both contrasts were different from zero in the expected direction.

For positive mood, cognitive reappraisal and mindfulness did not impact mood differentially from the information control condition as reflected by mood measured preintervention and postintervention, $F(1, 139) = .066$, $p = .798$, $\eta_p^2 < .001$, or preintervention compared with postlesson, $F(1, 139) = 1.402$, $p = .238$, $\eta_p^2 = .010$. For negative mood, cognitive reappraisal and mindfulness did not impact mood differentially from the information control condition as reflected by mood measured before and after the intervention, $F(1, 139) = .043$, $p = .837$, $\eta_p^2 < .001$, or preintervention compared with postlesson, $F(1, 139) = 1.609$, $p = .207$, $\eta_p^2 = .011$ (see Figures 2 and 3).

On the overall GLM, we did observe a nonanticipated main effect of time, $F(4, 136) = 22.149$, $p < .0001$, $\eta_p^2 = .394$. As this finding did not relate to the hypothesis, we did not follow it further.

Hypothesis 2. To test whether mindfulness and cognitive reappraisal interventions would result in better academic performance as measured by same-day perceptions in learning (2a), same-day quiz performance (2b), and end-of-semester "final exam" performance (2c), we computed repeated measures GLM with one factor, condition (cognitive reappraisal, informational, mindfulness), and the measures of learning as the dependent variables. These analyses each included one a priori contrast. This contrast compared the cognitive reappraisal (coded 1) and mindfulness (coded 1) interventions with the informational (coded −2) intervention. A contrast greater than zero would indicate full support for the contrast.

Table 2
Internal Consistency Reliability for the Quiz and Final Exam Scores in Each Session, Class, and Semester Calculated With Polychoric Correlation Matrices

		Quizzes			Final exam		
Day and class	Semester	Alpha	Omega total	*n*	Alpha	Omega total	*n*
Post only							
Art	Fall	.44	.72	26	−.11	.00	27
Art	Spring	.50	.84	35	−.22	.45	30
Economics	Fall	.45	.65	40	.41	.62	38
Economics	Spring	.69	.90	39	.59	.80	35
Math	Fall	.86	.95	46	.41	.58	42
Math	Spring	.47	.91	24	.17	.37	23
PrePost							
Art	Fall	.32	.77	24	.34	.64	27
Art	Spring	.58	.75	32	.60	.66	30
Economics	Fall	.46	.79	34	−.53	.00	38
Economics	Spring	.69	.92	37	.36	.60	35
Math	Fall	.76	.96	46	.34	.54	42
Math	Spring	.87	1.00	22	.58	.68	23
ID1							
Art	Fall	−.78	.74	27	−.16	.16	27
Art	Spring	.68	.91	39	.06	.74	30
Economics	Fall	.77	.88	36	.74	.76	38
Economics	Spring	.68	.86	33	NA	NA	NA
Math	Fall	.56	.89	28	.09	.41	42
Math	Spring	.72	.87	23	.63	.64	23
ID2							
Art	Fall	.25	.75	28	.59	.79	27
Art	Spring	.27	.77	32	.52	.85	30
Economics	Fall	.71	.89	36	.43	.50	38
Economics	Spring	.71	.79	37	.73	.74	35
Math	Fall	.60	.89	45	−.43	.08	42
Math	Spring	.30	.78	18	.49	.88	23
ID3							
Art	Fall	.23	.33	22	−.02	.10	27
Art	Spring	.75	.85	31	.47	.71	30
Economics	Fall	.65	.89	33	.34	.56	38
Economics	Spring	.71	.85	35	.49	.65	35
Math	Fall	.62	.89	42	NA	NA	NA
Math	Spring	.86	.93	21	.84	.87	23
Pre only							
Art	Fall	—	—	—	.58	1.00	27
Art	Spring	—	—	—	−.31	.00	30
Economics	Fall	—	—	—	.62	.70	38
Economics	Spring	—	—	—	−.30	.05	35
Math	Fall	—	—	—	.61	.91	42
Math	Spring	—	—	—	.58	.64	23
None1							
Art	Fall	—	—	—	−.47	.00	27
Art	Spring	—	—	—	.55	.77	30
Economics	Fall	—	—	—	.30	.71	38
Economics	Spring	—	—	—	.74	.77	35
Math	Fall	—	—	—	.58	.60	42
Math	Spring	—	—	—	.31	.44	23
None2							
Art	Fall	—	—	—	.52	.80	27
Art	Spring	—	—	—	−.55	.01	30

(*table continues*)

Table 2 (*continued*)

Day and class	Semester	Quizzes			Final exam		
		Alpha	Omega total	*n*	Alpha	Omega total	*n*
Economics	Fall	—	—	—	.15	.53	38
Economics	Spring	—	—	—	.57	.74	35
Math	Fall	—	—	—	.53	.54	42
Math	Spring	—	—	—	.24	.96	23
None3							
Art	Fall	—	—	—	.29	.63	27
Art	Spring	—	—	—	.62	.68	30
Economics	Fall	—	—	—	.34	.36	38
Economics	Spring	—	—	—	.71	.72	35
Math	Fall	—	—	—	.74	.84	42
Math	Spring	—	—	—	.46	.80	23

Note. There were no quizzes administered in the Pre only, None1, None2, or None3 sessions; thus, no reliability values are reported. Otherwise, "NA" is noted when the coefficient could not be computed. Post Only refers to the measurement control day where the only study procedure was taking a quiz at the end of class. PrePost refers to measurement control day in which participants rated their moods before class and took a quiz at the end of class but did not complete an intervention. ID1, ID2, ID3 refer to the three randomized intervention days. Pre Only refers to the measurement control day where the only study procedure was rating moods at the start of class. None1, None2, None3 refer to the measurement control days in which there were no study procedures but for which the instructors provided final exam questions.

Hypothesis 2a. For this test, perceptions of learning was the dependent variable. These contrasts did not provide support for this hypothesis, $F(1, 139) = .047$, $p = .828$, $\eta_p^2 < .0001$.

Hypothesis 2b. For this test, quiz scores were the dependent variable. These contrasts did not provide support for this hypothesis, $F(1, 134) = .106$, $p = .745$, $\eta_p^2 = .001$.

Hypothesis 2c. For this test, final exam subscores were the dependent variable. These analyses did not provide support for this hypothesis, $F(1, 140) = 1.734$, $p = .190$, $\eta_p^2 = .012$. However, inspection of the marginal means led us to examine the main effect of condition, which was significant, $F(2, 139) = 4.495$, $p = .013$, $\eta_p^2 = .061$. Examination of the pairwise comparisons revealed that this pattern of results was related to cognitive reappraisal leading to better final exam performance than either mindfulness ($p = .015$) or informational control ($p = .012$). Mindfulness and informational control did not differ from each other in final exam performance ($p = .978$). Figure 4 provides a depiction of these results.

Hypothesis 3. Given that the GLM analyses for H1 revealed no evidence of improvements in mood, we did not pursue the hypothesis that changes in academic performance would be mediated by changes in mood further.

Hypothesis 4. To test the hypothesis that all three interventions would boost end-of-semester "final exam" performance, we computed a repeated measures GLM with one factor of condition, which has nine levels (cognitive reappraisal, informational, mindfulness, PreOnly, PostOnly, PrePost, None1, None2, and None3) with final exam scores for each day as the dependent variable. The analysis included four a priori contrasts that test H4. Each contrast compared the intervention days cognitive reappraisal (1), mindfulness (1), informational (1), with one of the measurement control days (PreOnly, PostOnly, or PrePost, each coded −3) or to the average of the no-researcher days (None1, None2, None3, each coded −1). We inferred full support for the hypothesis when any of the contrasts were greater than zero.

Custom hypothesis tests revealed that the intervention days were superior to the days that the researchers did not come into the classroom at all (i.e., Intervention compared with None), $F(1, 140) = 12.756$, $p < .0001$, $\eta_p^2 = .084$. The intervention days were not significantly superior to PreOnly ($p = .878$) or PostOnly ($p = .255$). Interestingly, PrePost led to better final exam scores than the interventions considered together, $F(1, 140) = 17.008$, $p < .0001$, $\eta_p^2 = .108$ (although as noted in the next section, PrePost did not lead to final exam scores that were better than cognitive reappraisal; see Figure 5).

Table 3
Internal Consistency Reliability for the Quiz and Final Exam Scores in Each Session, Class, and Semester Calculated With Pearson Correlation Matrices

		Quizzes			Final exam		
	Semester	Alpha	Omega total	*n*	Alpha	Omega total	*n*
Post only							
Art	Fall	.33	.54	26	−.03	.17	27
Art	Spring	.34	.56	35	−.11	.22	30
Economics	Fall	.31	.44	40	.29	.44	38
Economics	Spring	.50	.68	39	.44	.59	35
Math	Fall	.69	.80	46	.07	.25	42
Math	Spring	.30	.69	24	.10	.22	23
PrePost							
Art	Fall	.11	.50	24	−.14	.09	27
Art	Spring	.58	.75	32	.23	.36	30
Economics	Fall	.29	.53	34	−.28	.00	38
Economics	Spring	.53	.71	37	.12	.34	35
Math	Fall	.62	.80	46	.19	.31	42
Math	Spring	.87	1.00	22	.26	.48	23
ID1							
Art	Fall	−.37	.58	27	−.09	.09	27
Art	Spring	.53	.70	39	.04	.48	30
Economics	Fall	.57	.74	36	.56	.58	38
Economics	Spring	.68	.86	33	NA	NA	NA
Math	Fall	.40	.65	28	−.32	.00	42
Math	Spring	.72	.87	23	.40	.41	23
ID2							
Art	Fall	.16	.43	28	.35	.61	27
Art	Spring	.14	.48	32	.34	.63	30
Economics	Fall	.71	.89	36	.30	.35	38
Economics	Spring	.54	.64	37	.56	.57	35
Math	Fall	.43	.61	45	−.17	.17	42
Math	Spring	.30	.78	18	.36	.64	23
ID3							
Art	Fall	.23	.33	22	−.30	.00	27
Art	Spring	.75	.85	31	.30	.57	30
Economics	Fall	.33	.64	33	.22	.35	38
Economics	Spring	.51	.64	35	.33	.44	35
Math	Fall	.43	.64	42	NA	NA	NA
Math	Spring	.74	.85	21	.65	.69	23
Pre only							
Art	Fall	—	—	—	.44	.75	27
Art	Spring	—	—	—	−.15	.00	30
Economics	Fall	—	—	—	.38	.43	38
Economics	Spring	—	—	—	−.21	.02	35
Math	Fall	—	—	—	.45	.64	42
Math	Spring	—	—	—	.39	.44	23
None1							
Art	Fall	—	—	—	−.21	.00	27
Art	Spring	—	—	—	.45	.49	30
Economics	Fall	—	—	—	.21	.44	38
Economics	Spring	—	—	—	.55	.59	35
Math	Fall	—	—	—	.37	.38	42
Math	Spring	—	—	—	.20	.28	23
None2							
Art	Fall	—	—	—	.43	.63	27
Art	Spring	—	—	—	−.30	.00	30
Economics	Fall	—	—	—	.14	.42	38
Economics	Spring	—	—	—	.41	.54	35
Math	Fall	—	—	—	.33	.34	42
Math	Spring	—	—	—	.19	.65	23

(*table continues*)

Table 3 (*continued*)

		Quizzes			Final exam		
	Semester	Alpha	Omega total	*n*	Alpha	Omega total	*n*
None3							
Art	Fall	—	—	—	.18	.37	27
Art	Spring	—	—	—	.48	.55	30
Economics	Fall	—	—	—	.23	.25	38
Economics	Spring	—	—	—	.54	.55	35
Math	Fall	—	—	—	.54	.63	42
Math	Spring	—	—	—	.11	.41	23

Note. There were no quizzes administered in the Pre only, None1, None2, or None3 sessions; thus, no reliability values are reported. Otherwise, "NA" is noted when the coefficient could not be computed.

Hypothesis 5. To test the hypothesis that simply providing mood ratings at the start of class (H5a) or taking a quiz at the end (H5b) would boost end-of-semester "final exam" performance, the GLM analysis Identified in H4 included two additional contrasts that test whether (a) providing mood ratings at the start of class (PreOnly coded 3) or (b) taking a quiz at the end of class (PostOnly coded 3) boosted performance relative to no-researcher days (None1, None2, None3, each coded −1). We inferred full support for Hypothesis 5 when the corresponding contrast, one for each, was greater than zero.

Providing mood ratings at the start of class did boost performance above the days the researchers did not come into class, $F(1, 140) = 6.023$, $p = .015$, $\eta_p^2 = .041$, but taking a quiz at the end did not reach significance ($p = .107$). Interestingly, pairwise comparisons revealed that the PrePost condition yielded better final exam performance than any of the conditions

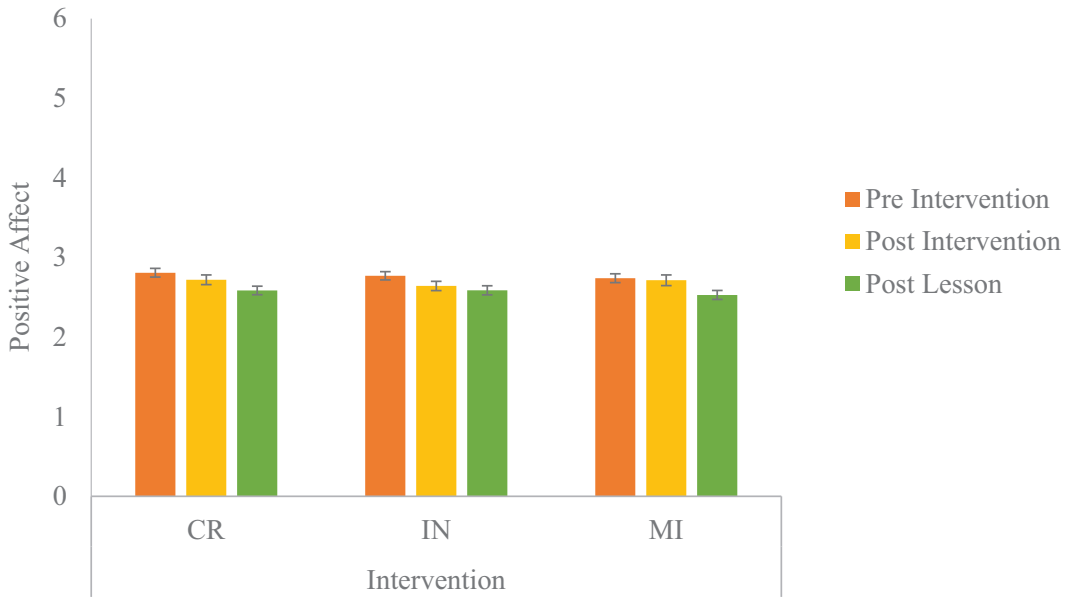

Figure 2. Mean scores for negative (see Figure 2) and positive (see Figure 3) affect, by time of data collection (preintervention, postintervention, and postlesson), depicted separately by intervention condition. Cognitive reappraisal (CR) and mindfulness (MI) did not impact mood differentially from the information control (IN) condition. See the online article for the color version of this figure.

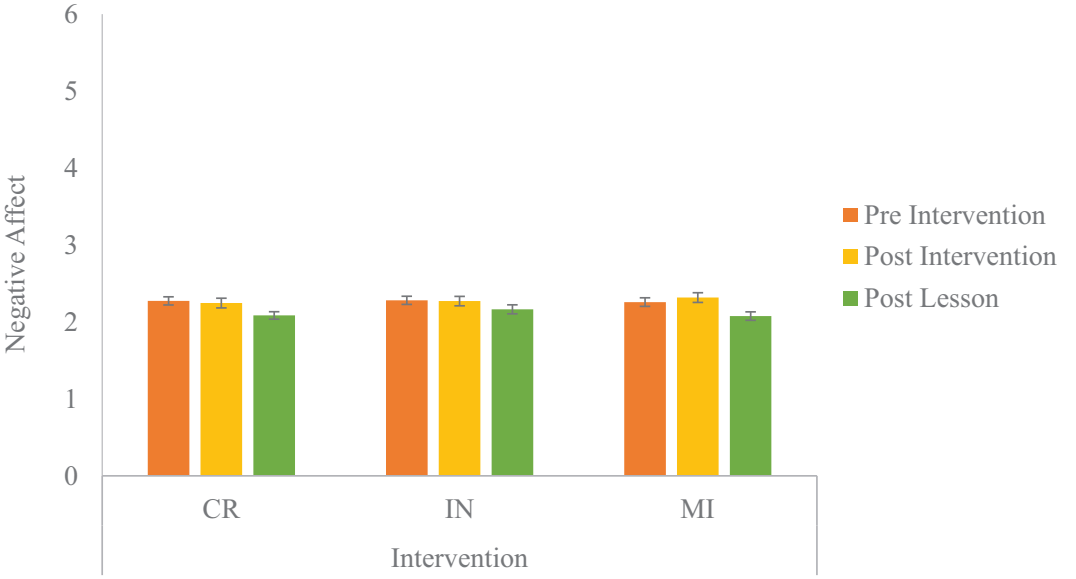

Figure 3. Mean scores for negative (see Figure 2) and positive (see Figure 3) affect, by time of data collection (preintervention, postintervention, and postlesson), depicted separately by intervention condition. Cognitive reappraisal (CR) and mindfulness (MI) did not impact mood differentially from the information control (IN) condition. See the online article for the color version of this figure.

except cognitive reappraisal, from which it was statistically indistinguishable (mean difference .099, $p = .310$).

Discussion

In this rigorously controlled design across multiple courses and semesters, we found evidence that brief focusing activities at the start of class, and cognitive reappraisal in particular, were effective in increasing longer term learning.

Cognitive Reappraisal and Mindfulness Did Not Significantly Impact Emotions

In contrast to our hypothesis, when compared with the informational control condition, neither of the strategies the researchers offered students to help regulate their emotions significantly impacted their self-reported emotions before and after the interventions. Our hypothesis may have been incorrect for several different reasons. First, most work on reappraisal, in particular, first introduces an emotional state (through the use of emotionally evocative stimuli, like pictures or video clips) and then asks participants to regulate the emotion via reappraisal. In contrast, the students in this study entered class in a variety of emotional states and had not yet begun the class and encountered learning-relevant emotions. Second, both of the emotion interventions began by acknowledging that the college experience can be a heady time full of anxieties and frustrations, before moving on to suggest strategies for dealing with these emotions. The three implementation intentions that concluded both the reappraisal and mindfulness interventions were situated in the future ("IF I become anxious during class, THEN I will . . .") rather than in the present. Thus, the interventions themselves may have introduced a mixed emotional state and done little to regulate in-the-moment emotions. As we noted in the introduction, the intervention instructions focused at least as much on acceptance of negative emotions as it did regulation of these emotions, and so rather than reducing negative emotions, the instructions may have helped students focus on learning despite the presence of negative affective states. Of course, it could also be that the

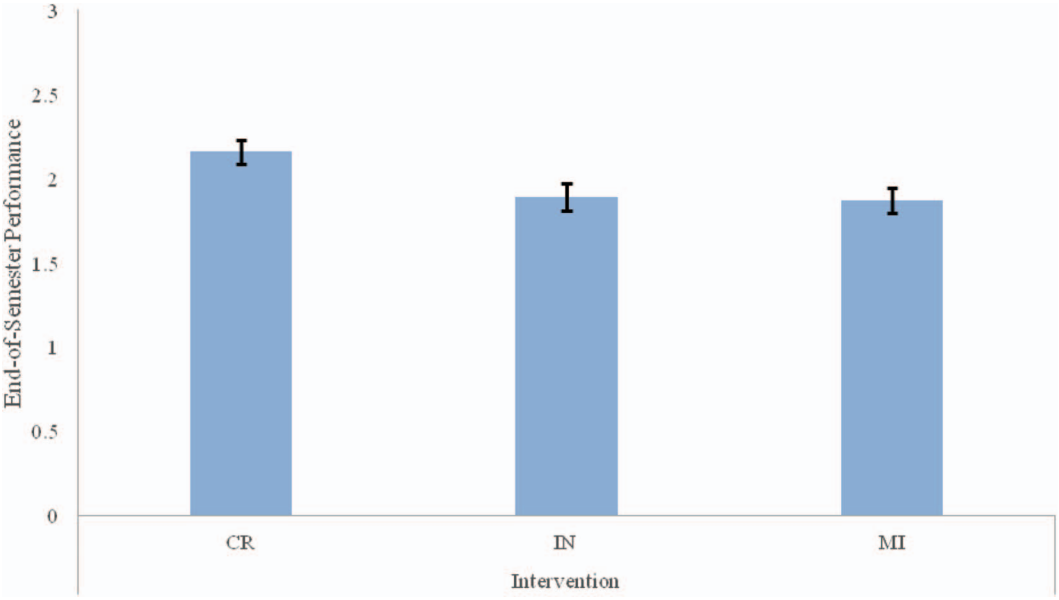

Figure 4. Final exam subscores separately by intervention condition. Cognitive reappraisal (CR) led to significantly higher scores than either informational control (IN) or mindfulness (MI). Asterisk indicates statistical significance $p < .05$. See the online article for the color version of this figure.

interventions were ineffective and did not successfully convey meaningful information to participants about how to regulate their emotions.

Focusing Activities at the Start of Class Increased Long-Term Learning

All three interventions, whether they provided tools from cognitive reappraisal or mindfulness or simply presented information relevant to the domain the class was studying, yielded better performance on the final exam questions compared with days that the researchers did not come into the class. As the interventions were multidimensional, it is impossible to ascertain the precise mechanisms behind the beneficial effect of the intervention days. However, several candidate mechanisms should be considered.

First, settling into class mode and entering a state of focus may have set the stage for better learning. Students enter the classroom from their busy lives, and their heads may be full of the stressful exam they just finished or a recent fight with their dating partner. Putting on headphones and being reminded of the importance of their academic goals may have assisted their ability to learn the material that followed in a deeper way.

Another possibility is that the disruption of ordinary classroom activities could have yielded a state of greater arousal, which, in some circumstances, facilitates memory consolidation (Mather & Sutherland, 2011). The researcher visits were marked by new social presences, the use of technology, and the unpredictable nature of which activities would be run that day. Any of these attributes of the learning study could have resulted in slightly greater physiological arousal, which, in turn, could have benefited long-term memory consolidation.

It is also possible that the context of participating in a research study aimed at facilitating learning served as a reminder of learning goals. Being prompted by goal reminders can fuel motivation (Prestwich, Perugini, & Hurling, 2010), and so the study days could have resulted in greater attentiveness during the lesson. Consistent with this interpretation, the one classroom day that did not result in better learning

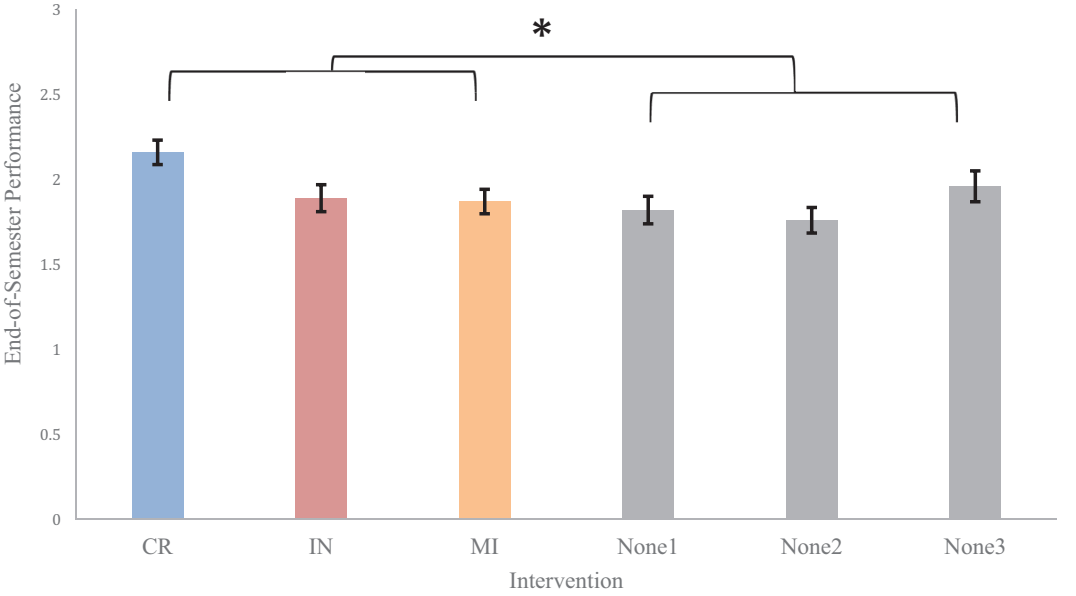

Figure 5. Final exam subscores separately by intervention condition compared with days the researchers did not visit the classroom at all. Collectively, students had better scores on the material from the intervention days compared with the no-researcher days (None1 – None3), even despite the higher scores for None3, which, for all students, represented some of the most recently learned material. CR = Cognitive reappraisal; MI = mindfulness; IN = information control. See the online article for the color version of this figure.

than the no-researcher days was the day that the researchers only showed up at the end of the class to administer the quiz. The goal reminders could have also impacted postclass behavior, perhaps in terms of students being more likely to review their notes after class or study the material in the evening that followed. Because the instructors knew they would have less time than usual to accomplish the day's learning goals on the study days, they may also have planned their lessons more carefully.

Finally, all days except the quiz-only day also involved a mood rating at the start of class, and it is possible that reflecting on one's emotional state prepared students well for learning. Past research has demonstrated that mentally labeling emotional experiences can lessen their impact (Lieberman et al., 2007).

Future research should evaluate these possibilities by manipulating or measuring some of these possible mechanisms, for instance, by including measurements of physiological arousal or collecting data on self-reported intentions to study after class.

Cognitive Reappraisal Increased Long-Term Learning

Learning how to mentally reframe boredom, frustration, and anxiety appeared to particularly benefit long-term retention of newly learned material. Interestingly and unexpectedly, reappraisal had this effect without having a differential effect on student emotions compared with the mindfulness or informational control interventions. Thus, cognitive reappraisal may have been effective at increasing learning, but not for the reason we hypothesized.

The proffered reappraisals had much in common with attributional retraining and other "targeted interventions" aimed at increasing student effort and motivation (Dweck, 2006; Harackiewicz & Priniski, 2018; Hulleman & Barron, 2015), and may have operated by a similar mechanism. These interventions tend not to target student emotions but rather the attributions or interpretations students make for their successes and failures. The intervention, although intended to impact student emotions, nonethe-

less asked students to reappraise their instructor's care for their learning, their frustration as an indicator of the process of learning new skills, and their anxiety as a sign of their prioritization of their own learning. These shifts in appraisal may have served to put students in this mind-set (Dweck, 2006) of focusing on their own efforts toward learning.

Mindfulness Did Not Impact Learning

This study did not replicate previous research (e.g., Bellinger, DeCaro, & Ralston, 2015; Brunyé et al., 2013; Calma-Birling & Gurung, 2017) indicating that mindfulness has at least some beneficial effects on learning in college students. There may be several possible reasons for this lack of replication. It may be that practicing mindfulness in the college classroom does not yield benefits in learning, as was the conclusion of one recent large, well-controlled study of executive function and critical thinking (Noone & Hogan, 2018). However, we would hesitate to overgeneralize from the current findings. First, and most critically, while the researchers described mindfulness and gave students several examples of how they might apply mindfulness during the lesson that followed, unlike previous work, they did not explicitly lead students in focusing on their present experience, engaging in deep breathing, relaxing their muscles, or approaching their experience with curiosity and affection. It would be more accurate to say that the intervention was a mindfulness instruction rather than a guided practice, the latter of which is what has been found to have some beneficial effects on learning (e.g., Calma-Birling & Gurung, 2017). It may well be that it is more straightforward to reinterpret or reappraise one's emotions (as in the reappraisal condition) than to independently engage in the multifaceted response that mindfulness requires with no guided practice. It may also be that for students to benefit from mindfulness, they would need to engage in more regular practice in and out of the classroom before beneficial effects could be observed.

Interventions Did Not Affect Same-Day Learning

All of the significant findings concerned longer term (end of semester) rather than short-term (same day) memory. This result was unexpected, as we hypothesized that we would observe effects on both initial learning and then the degree to which the information would be successfully retrieved over a longer period of time. Instead, participants appeared to learn the day's lesson equally well initially, but then successfully remembered the material from the intervention days, and particularly cognitive reappraisal, best in the long-term assessment. Thus, the effect may have less to do with the comprehension of the material and more to do with longer term memory. Supporting this interpretation, the interventions also did not result in significantly different *perceptions* of learning—at the end of the lessons, students reported understanding the material to the same degree across the interventions. As noted previously, this superior longer term memory may be explained by either better memory consolidation or motivated practices like better note-taking or postclass studying behavior.

Limitations of the Research Design

The study design had several limitations. First, we wanted an objective assessment of learning that was similar across the very different courses, and so the quizzes and the final exam were all multiple-choice questions. Multiple-choice questions have limitations as assessments of knowledge (Roediger & Marsh, 2005), but more importantly, none of the participating instructors typically used multiple choice in their classes. Thus, we were evaluating students using an assessment method that was unfamiliar to them in that classroom setting and likely not ideal assessments of learning in these contexts.

Second, the interventions had several components, and thus it is difficult to know which were driving the observed effects. Both the reappraisal and mindfulness interventions presented similar information normalizing the emotional aspects of the college experience, gave some information about the nature of the two tools, and then provided participants with nine examples (three each for anxiety, boredom, and frustration) of how they could implement these strategies. We also asked participants to endorse three of these strategies in a format that mimicked implementation intentions. We do not know if, for example, cognitive reappraisal's beneficial effects on long-term learning were related to one, some, or all of these

components. The intention was to provide an early, important test of whether such interventions could be effective, and then follow it up with future work to better tease out mechanisms.

Third, as the data were collected in actual classes over a semester, conditions were not ideal. In analyses that included only participants with complete data, we lost one third of the sample. Participants were absent or showed up late, and we had to shuffle some planned data collection days because of snowstorms and the Amazon server collapsing. This limitation was unavoidable, as we wished to test real-world classroom learning. It does, however, raise the possibility that the beneficial effect of reappraisal that we observed may only be applicable to students with good attendance—which could mean that the intervention would fail to reach the students who might need it the most. Future research testing the applicability of this intervention to all types of students is warranted.

Fourth, although we hoped that participants would enjoy the study and that interacting with the iPads in class would be a novel, fun experience, the self-reports of the participants and participating instructors somewhat contradicted this view. Although the average ratings for the study were not alarming—participants reporting middling ratings for both enjoyment of, and frustration with, the study—we did not see evidence that the participants or instructors reflected fondly on the study. Reflecting on our experience during data collection, we now feel that sequestering students into independent spheres with headphones and iPads, although appealing for the rigorous experimental control it offered, may have been poor for pedagogical reasons. The classroom is a rich social environment, and much of learning is relational—both academic learning and learning how to implement multifaceted techniques like mindfulness. For instance, bidirectional emotional transmissions between students and the instructor are likely to have a great impact on learning (Frenzel, Becker-Kurz, Pekrun, Goetz, & Lüdtke, 2018). Interventions that use technology to isolate students and professors from each other may be contraindicated.

Finally, the interventions targeted everyday negative emotional scenarios like worrying about test scores or feeling confused by the class material. As noted in the introduction, many students grapple with negative emotions surrounding far more serious challenges like food insecurity (Goldrick-Rab, 2016), trauma, and clinical levels of depression and anxiety. It is unlikely that the instructional interventions would effectively address emotions relevant to these challenges.

Strengths of the Design and Future Research

The study design had several compelling strengths, including the randomized, controlled, within-subjects design; the real-world data collection environment; the cross-disciplinary and multisemester structure; the inclusion of multiple control days; and the use of an active control condition.

There are a number of promising directions for future research. As discussed, future research should evaluate the mechanisms by which cognitive reappraisal may impact long-term learning. Second, emotion-sensitive intelligent tutoring systems adjust the pace of learning and offer supports based on students' affective states (Malekzadeh, Mustafa, & Lahsasna, 2015), and the field of affective computing and online learning environments has much to offer face-to-face classrooms (Graesser & D'Mello, 2012). Future research should explore the extent to which research in these domains extends to more traditional learning environments (and vice versa).

Third, a growing literature (Brady, Hard, & Gross, 2018; Jamieson, Peters, Greenwood, & Altose, 2016) has provided evidence that cognitive reappraisal can also be effective in down-regulating anxiety prior to taking assessments, particularly in mathematics, and that this down-regulation is associated with better scores. Future work should tease out the extent to which cognitive reappraisal can affect initial learning of material versus retrieval of learned material, and whether targeted interventions might provide reappraisal training for both emotions related to the process of learning and to the challenge of performance and assessment.

In sum, we observed significant effects of focusing activities and cognitive reappraisal at the start of class on long-term learning. It may be that offering these tools in the context of the shared social environment of the classroom would be even more powerful. We plan to test this intriguing possibility in future research.

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Appendix

Text of Interventions

Text for Reappraisal

College is an exciting time full of opportunity and novel experiences. You are encountering new ideas, new experiences, and new friendships.

But it can also be an intimidating time. You may have doubts about how well you perform, how you measure up against your fellow peers, and what your professors think of your abilities.

You may also find the process of learning to be occasionally confusing, frustrating, boring, and even discouraging.

And these are just the academic concerns. You might also have concerns about your friendships, about your romantic relationships, or about how you fit in with your social circle.

As you deal with these emotions in and out of the classroom, it may become difficult to focus on your work. Distractions may become tempting both in the classroom and when you are studying.

All of this is natural, and your peers are going through it too. Learning is incremental, gradual, often frustrating, and it is WORK. The point isn't getting it right away, or absorbing it all like a sponge.

The point of this exercise is to acknowledge these emotions and reassure you that they are a natural part of the college experience and the learning process. The point of this exercise is *also* to give you some tools to manage emotions and distractions when they arise during class so that you can focus on learning.

(*Appendix continues*)

One method you can use to manage these emotions is to **think differently** about the situation you're in, the challenges that you are facing, and/or your emotional response to them. Research shows that people who choose to reframe emotional situations and responses by thinking differently about them can successfully change their emotional experiences and the impact they might have on performance. The regular practice of this sort of rethinking is associated with lower levels of depression and anxiety and higher levels of psychological well-being.

For instance, you might tell yourself that your classmates are also facing the same sorts of challenges. You could remind yourself that part of the process of learning is first trying and failing, and so feelings of frustration are actually signs of progress. You might also remember your professor wishes to challenge you and thus values your learning.

We are going to present three scenarios to you and then some options for how you might think differently in order to manage your emotional response.

Please read the scenario, and then click next.

Afterward please read the three options, and choose the one you plan to implement most often or most strongly in class today.

(Boredom Condition)

IF I find myself losing interest and focus, becoming tempted to think about or do things unrelated to class, THEN I will instead think about . . .

❏ the value of my education and how it will contribute to a bettering of my mind and life.

❏ that I chose this class and this degree program, and that both will help me achieve my long-term goals.

❏ that focusing now will help me on my later homework and exams, and thus be better in the long run.

(Frustration/Confusion Condition)

IF I find myself becoming irritated and frustrated with my progress, my professor, or my peers, or find myself feeling lost and confused, THEN I will instead think about . . .

❏ the fact that frustration actually means I'm making progress in learning.

❏ that the best rewards in learning occur by working through initial confusion.

❏ that I am being challenged, and that means that both my professor and I care about my learning.

(Anxiety Condition)

IF I find myself becoming nervous about speaking in class, about my performance in answering questions in class or on quizzes or tests, or about my grade in the class, THEN I will instead think about . . .

❏ how everyone gets nervous sometimes, and that my nervousness means this class and my progress is important to me.

❏ the fact that the best performances arise from a manageable level of nervousness.

❏ that this is just one day, and if I don't perform well I'll have other opportunities to work hard and change my grade.

Text for Mindfulness

The college experience is one that is exciting and full of new experiences and new opportunities for growth–both intellectual and social.

But new experiences can also carry challenges, and be overwhelming. You may worry about your performance in class, your relative progress compared with your peers, and your professors' opinions about your skills.

In doing classwork and homework, you may sometimes be confused, frustrated, bored, and even discouraged.

And that is just on the classroom side. You may also have doubts about how you are fitting in socially, whether you can rely on your friends, and how your romantic life is going.

As you confront feelings about all of these academic and social matters, you may have trouble focusing on your work. You may become easily distracted when attempting to do work in the classroom or study at home.

This is all normal. Your peers are experiencing it too. The process of learning is incremental, gradual, often frustrating, and it is WORK. The point isn't getting it right away, or absorbing it all like a sponge.

(*Appendix continues*)

The point of this exercise is to acknowledge these emotions and reassure you that they are a natural part of the college experience and the learning process. The point of this exercise is *also* to give you some tools to manage emotions and distractions when they arise during class so that you can focus on learning.

One such method is to approach these emotions with mindfulness. Mindfulness is a practice and a skill everyone is capable of that allows us to be present from moment to moment with a nonjudgmental, compassionate awareness.

People who practice mindfulness report feeling calmer and less overwhelmed by difficult thoughts and emotions.

For instance, when you find yourself becoming distracted by uncomfortable emotions, you could bring your attention back to the present moment by focusing on your breath.

You could also try to let these feelings pass through you without judging them or trying to change them.

By increasing our awareness in this way we become less reactive to challenges and even investigate and accept our experiences with curiosity and kindness.

We are going to present three scenarios to you and then some options for how you might notice and accept your emotional response.

Please read the scenario, and then click next.

Afterward please read the three options, and choose the one you plan you would be likely to implement most often or most strongly in class today.

(Boredom Condition)

IF I find myself losing interest and focus, becoming tempted to think about or do things unrelated to class, THEN I will instead . . .

❏ simply notice that I am thinking about topics unrelated to class without trying to do anything about it.

❏ be really curious about this experience, noticing as much as I can about these thoughts, and any feelings and/or body sensations that are also present.

❏ accept and be with whatever I'm thinking and feeling without reacting to it, judging it as good or bad, or trying to change it.

(Frustration/Confusion Condition)

IF I find myself becoming irritated and frustrated with my progress, my professor, or my peers, or find myself feeling lost and confused, THEN I will instead . . .

❏ get really curious about how I'm feeling, noticing as much as I can about the frustration and how it feels in my body without trying to do anything them.

❏ just notice the confusion and/or frustration as I normally would.

❏ acknowledge and accept these feelings as much as possible, without reacting to them, engaging in them, or judging them as good or bad.

(Anxiety Condition)

IF I find myself becoming nervous about my performance in answering questions in class or on quizzes or tests, or about my grade in the class, THEN I will instead . . .

❏ let this nervousness be, accepting it as it is, not trying to change it or make it go away.

❏ Pay close attention to this nervousness and any related body sensations and notice how it changes from moment to moment.

❏ notice the feeling of nervousness without trying to do anything about it.

Text for One-Sample Informational Control (Math)

Long viewed by many as the stereotypically useless major, philosophy is now being seen by many students and prospective employers as a very useful and practical major, offering students a host of transferable skills with relevance to the modern workplace.

In broad terms, philosophy is the study of meaning and the values underlying thought and behavior. But more pragmatically, the discipline encourages students to analyze complex material, question conventional beliefs, and express thoughts in a concise manner.

Because philosophy teaches students not what to think but how to think, the age-old discipline offers consistently useful tools for academic and professional achievement.

(*Appendix continues*)

A 1994 survey concluded that only 18 percent of American colleges required at least one philosophy course. Therefore, between 1992 and 1996, more than 400 independent philosophy departments were eliminated from institutions.

More recently, colleges have recognized the practicality and increasing popularity of studying philosophy and have markedly increased the number of philosophy programs offered. By 2008 there were 817 programs, up from 765 a decade before. In addition, the number of four-year graduates in philosophy has grown 46 percent in a decade.

Also, studies have found that those students who major in philosophy often do better than students from other majors in both verbal reasoning and analytical writing. These results can be measured by standardized test scores. On the Graduate Record Examination (GRE), for example, students intending to study philosophy in graduate school scored higher than students in all but four other majors.

These days, many students majoring in philosophy have no intention of becoming philosophers; instead they plan to apply those skills to other disciplines. Law and business specifically benefit from the complicated theoretical issues raised in the study of philosophy, but philosophy can be just as useful in engineering or any field requiring complex analytic skills.

That these skills are transferable across professions makes them especially beneficial to twenty-first-century students. Because today's students can expect to hold multiple jobs—some of which may not even exist yet—during their lifetime, studying philosophy allows them to be flexible and adaptable. High demand, advanced exam scores, and varied professional skills all argue for maintaining and enhancing philosophy courses and majors within academic institutions.

Question One

According to this piece, over time the popularity of philosophy as a major

A) was high, then declined, is now increasing again.
B) was low, then rose, is now declining again.
C) has remained steady over time.

Question Two

As used in the sentence "But more pragmatically, the discipline encourages students to analyze complex material, question conventional beliefs, and express thoughts in a concise manner," the word "discipline" most nearly means

A) a way of behaving that shows a willingness to obey rules or orders.
B) area of scholarly study.
C) methods implemented to reduce a behavior.

Question Three

Philosophy is again becoming popular as a major because

A) more students want to be philosophers for a living.
B) the media has recently portrayed successful philosophers.
C) analytical thinking and argumentation are highly relevant in the modern workplace.

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