



Active Learning Requires Learning - Not Just Activity

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Abstract

Does active learning yield better outcomes because of the learning value of the exercises, or because students simply “wake up” and become energized by an activity? To explore this, we compared undergraduate engineering/science students’ information recall in three lecture contexts. A pre-recorded lecture was punctuated with a) active learning exercises, b) sessions of light physical activity, or c) no breaks at all. Students who performed active learning exercises had a higher probability of answering exercise-related questions correctly, compared to the other two groups. However, students who performed active learning exercises did not exhibit better recall of information presented immediately after such breaks. Students who performed physical activity showed no difference in recall of information presented immediately after those breaks, compared to the recall of students who took no breaks. Our data suggest that *learning value*, not simple activity/wakefulness, is the critical element of active learning.

Introduction

“Active learning” is a term used to refer to situations in which an instructor requires students to actively engage in some form of learning activity – doing practice problems, combining previous knowledge with new knowledge, working on problems alone or in groups, *etc.*^{1,2} “Active learning” encompasses a wide variety of pedagogical situations in which students engage with information in some way other than passively listening to a lecture. The use of active learning techniques has been associated with positive outcomes – for example, an increase in the knowledge gained by students³, an increase in the proportion of students that pass a course^{4,5}, and a decrease in the number of students that drop out⁴. The goal of this study was to better understand why active learning breaks are effective – not to establish their efficacy, which many have already done^{1-3,6}. Specifically, we sought to explore the “active” portion of “active learning.” In Prince’s words, “The core elements of active learning are student activity and engagement in the learning process,” (Reference 1, page 1, emphases added). The active recall of information has been shown to increase information retention, compared to that resulting from passively reading the same material repeatedly⁶. It makes sense to break a long lecture into smaller units, punctuated by activities, given the conventional wisdom that students have an attention span of roughly 10 to 15 minutes⁷, and that student self-reported interest is highest at the beginning of a lecture and decreases throughout a lecture⁸. Might active learning breaks help students learn simply because the activity “wakes them up” and “resets” their attention? Or must the activity also require mental engagement with the material/skills to be learned? It has been established that activities which mentally engage students aid learning; might activities which energize students in another way yield similar effects? We decided to investigate the effects of light physical activity as a way of energizing students on information retention. Understanding why active learning works is important so that when designing new pedagogical techniques, we can incorporate the essential components⁹.

Methods

Participants and Educational Context Overview

Study participants were students enrolled in a freshman-level programming class for Applied Biology and Biomedical Engineering majors at Rose-Hulman Institute of Technology, who gave their informed consent to participate (IRB approval number RHS0154). The course instructors were not present during the experiment, and all participants were at least 18 years old. We used the three sections of this course to create the three educational contexts of this study: one in which students watched a lecture punctuated with short active learning exercises (“mentally-active breaks”); one in which students watched a lecture punctuated with short sessions of light physical activity (“physically-active breaks”); and one in which students watched a lecture without taking any breaks (“non-active”). Uneven student enrollment in the three sections of the course yielded uneven participation in the three educational contexts. Ultimately, (see the **Results: Data Validity** section for details), our analyses contained data from 23 students who participated in the mentally-active break context, 12 students who participated in the physically-active break context, and 9 students who participated in the non-active context.

Lecture Preparation

We videotaped a 40-minute, 42-slide PowerPoint presentation that was narrated and annotated (using a tablet PC) by an experienced college educator (Kay C Dee). The lecture material was a series of non-cumulative, discrete topics so that information recall at later times during the lecture would not depend on understanding information presented earlier in the lecture. The lecture topics were various aspects of plant biology (*e.g.*, plant evolution, avoiding desiccation during photosynthesis, plant roles as food sources in different ecosystems, *etc.*) since in the Applied Biology and Biomedical Engineering curricula, first-year students do not take a plant biology course and we anticipated that prior student knowledge of the topics would be low.

Educational Context Procedures

Students in the **mentally-active** learning context were given printouts of the PowerPoint slides so that they could take notes, if desired, as they watched the pre-recorded lecture. We paused the video at three points during the pre-recorded lecture - specifically, immediately after slides 21 (just over 17 minutes into the lecture video), 27 (just over 25 minutes into the lecture) and 33 (just over 32 minutes into the lecture). Each time the video was paused, we distributed a new worksheet to the students, and the experienced college instructor led the students through an active learning exercise. Each active learning exercise was designed to have students engage with the information that had been presented on the previous lecture slide (students were asked to recall and categorize information, create a memorization strategy, apply knowledge to evaluate the validity of given statements). During each active learning exercise, students worked in pairs or small teams on worksheet activities for two to three minutes, followed by a one to two-minute whole-group discussion/wrap-up facilitated by the instructor. Each individual active learning break therefore lasted a total of three to five minutes. We resumed the pre-recorded lecture immediately after each break.

Students in the **physically-active** learning context were also given printouts of the PowerPoint slides so that they could take notes while watching the pre-recorded lecture. For this group, we paused the pre-recorded lecture immediately *before* slides 21, 27, and 33. Each time the video was paused, students performed light physical activity that involved exiting the classroom and walking up and down flights of stairs, performing 10 jumping jacks, walking through the building hallways, *etc.* Each of the three physically-active breaks lasted a total of two and a half to four minutes. We resumed the pre-recorded lecture immediately after each break. We designed the timing of the physically-active breaks so that students in this group would be exposed to the lecture information covered on slides 21, 27, and 33 (*i.e.*, the same information that was the basis of the mentally-active breaks in the previous context) while these students were, in theory, maximally alert and refreshed from their physical activity.

Students in the **non-active** context were given printouts of the PowerPoint slides so that they could take notes, while watching the same pre-recorded lecture used in the previous two contexts. In this context we did not pause the lecture at any point. Although this caused the overall length of the experiment to be roughly 12 minutes shorter for this group, we chose this experimental design because it better approximated the experience of being immersed in a lecture-only environment, and because a simple pause in a lecture can be considered a break in itself¹⁰.

Exam Administration

In each of the educational contexts described above, we gave participants the same exam immediately following the conclusion of the entire pre-recorded lecture (not after each break), with no time allotted for studying. The 38-question exam was comprised of multiple-choice and short answer questions which were in the Knowledge, Comprehension and Application (or Remembering, Understanding, and Applying) levels of the cognitive domain of Bloom's Taxonomy^{11,12}. The questions on the exam were placed in an order that mimicked the order in which the information was presented during the pre-recorded lecture. The exam also asked participants to self-report their level of biology education and familiarity with plant biology. The exam took most participants between 10 and 20 minutes to complete. We subsequently graded each exam question as either correct (coded as '1') or incorrect (coded as '0') – no partial credit was given.

Data Analysis

To test for differences in the average score across educational contexts, we performed a one-way ANOVA on the proportion of students answering each question correctly within each educational context. To examine the effect of the time within the lecture that information was presented on recall, we performed a general regression on the proportion of students answering each question correctly against the time during the lecture that the information was presented, for each educational context. To measure the effects of the different educational contexts *and* the placement of break within the lecture, we used a generalized linear model with a binomial response distribution and a logit link function, repeated on subject (since subjects each answered multiple questions for each of the three breaks in each treatment group). For this analysis, scores on two relevant exam questions were used as an indicator of recall of the information presented

on slide 21 of the pre-recorded lecture (please see the **Results: Data Validity** section below for details). Scores on three relevant questions were used as recall indicators for slide 27 and for slide 33 of the lecture (so, three questions for each of these two slides). When appropriate, we used a Tukey-Kramer post-hoc pairwise comparison with an overall confidence level of 95% to determine which educational context had produced different exam scores. We hypothesized that information recall would be higher for the students in the mentally-active context, since we had reiterated material from the lecture. To test for the effects of students becoming more “energized” after mentally active breaks, we used a separate generalized linear mixed model to compare student retention of information that was presented immediately *after* the mentally-active learning breaks to retention of the same information by students in the non-active context (with a binomial response distribution and a logit link function, repeated on subject) where the factors were the context of the break and the placement of break within the lecture. We hypothesized that information recall would be higher for the students in the mentally-active context, since they had just completed a mental activity, possibly refreshing and refocusing their attention. Finally, we examined student performance across all of the educational contexts on each of the first 12 exam questions – corresponding to the initial 16 minutes of the pre-recorded lecture, during which students in all of the educational contexts simply watched the lecture without any break. To do this, we used a one-way ANOVA on the proportion of students answering each question correctly in each educational context.

Results

Data Validity

One participant completed the exam in less than five minutes, and their total exam score was only 11%. We deemed a score of less than 25% to indicate likely guessing/mischief, since most of the test was multiple-choice with four answer choices. This participant’s exam was therefore completely excluded from our analyses, resulting in the sample sizes reported in the **Methods: Participants and Educational Context Overview** section. None of the participants reported having previously taken a plant biology course, or having advanced familiarity with plant biology beyond what might be encountered in a high school biology course, which indicated that our choice of lecture topic was appropriate. The performance of participants across the educational contexts was not significantly different on exam questions regarding information that was presented before any breaks occurred (*i.e.*, the first 12 questions), indicating that prior knowledge and learning of participants was not significantly different with respect to those lecture topics ($p = 0.41$, one-way ANOVA, $F_{2,33} = 0.92$).

93% of the students across all of the educational contexts incorrectly answered one of the three exam questions regarding the material on slide 21 of the pre-recorded lecture. We therefore excluded that question from our analysis, and combined student scores on the remaining two relevant questions as an indicator of recall of the information presented on that slide (as noted in the *Data Analysis* section above). The total percentage of participants marking the correct answer was normally distributed for the remaining 37 exam questions ($p = 0.09$, AD = 0.638, Anderson-Darling normality test). There was no significant association between exam question number and the percent of participants marking the question correctly in the non-active

educational context ($p = 0.78$, $F_{1,37} = 0.08$, general regression), indicating that participants did not experience significant effects of testing fatigue.

Average Scores Across Educational Contexts

None of the experimental contexts produced overall exam average student scores that were significantly higher than any of the others. ($p = 0.539$, one-way ANOVA, $F_{2,108} = 0.62$). The number of questions answered correctly (mean \pm standard deviation out of 37 questions) within each context and combined were as follows: mentally-active: 26.05 ± 4.80 ; physically-active: 25.00 ± 6.11 ; non-active: 25.44 ± 4.48 ; combined: 26.05 ± 4.80 .

Effect of Presentation Time Within Lecture

We observed a visual trend of declining information retention, from the beginning of the lecture to a minimum occurring around 10 minutes into the lecture, in all three experimental constructs (Figure 1). There was no statistically significant relationship between the percentage of participants marking a question correct and the time that the information was presented for all students combined during the questions that occurred *before* the break ($p = 0.30$, $F_{1,34} = 1.12$, general regression, $n = 12$ exam questions). However, for students within the physically-active break context, we observed a statistically significant decline in recall of information presented later in the lecture ($p = 0.033$, $F_{1,35} = 4.90$, general regression, $n = 37$ exam questions). We did *not* observe a similar statistically significant decline in information recall in either of the other two educational contexts (mentally-active context: $p = 0.79$, $F_{1,35} = 0.072$; non-active context: $p = 0.726$, $F_{1,35} = 0.125$; general regression, $n = 37$ exam questions).

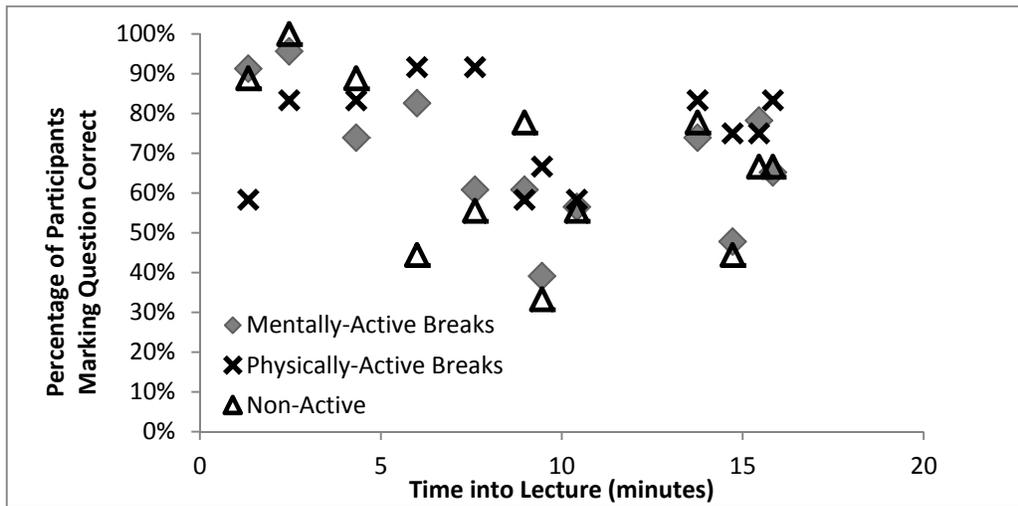


Figure 1. Percentage of participants answering exam questions correctly as a function of the time within the lecture when the information relevant to each question was presented. For students within the physically-active break context, we observed a statistically-significant decline in recall of information presented later in the lecture ($p = 0.033$, $F_{1,35} = 4.90$, general regression, $n = 37$ exam questions). There was no statistically significant relationship between the percentage of participants correctly answering a question and the time within the lecture at

which the information was presented within the other two educational contexts or pooled across all educational contexts. Note that the data presented in this figure were collected before the mentally-active and physically-active constructs participated in their first breaks. All of the students in all of the contexts were recalling information based simply on watching the pre-recorded lecture.

Effects of Mentally-Active Breaks

The effect of the educational context was statistically significant ($p < 0.0001$, $F_{2,320} = 13.57$; Table 1). Students in the mentally-active break group had the highest probability of correctly answering questions related to the material engaged with during their breaks, compared to the physically-active break and non-active contexts (Table 2). There was no statistically significant difference between the retention of information presented in the mentally-active context immediately *after* a mentally-active learning break and the retention of the same information by students in the non-active context ($p = 0.378$, $F_{1,128} = 0.78$, generalized linear mixed model; Table 3). The placement of a break within the lecture did not affect information recall in either the mentally-active or the physically-active contexts (Information presented within break: $p = 0.092$, $F_{2,320} = 2.40$; Table 1; Information presented after mentally-active breaks $p = 0.906$, $F_{2,128} = 0.10$; Table 3).

Table 1. Educational context of break, but not placement of break, affected the recall of information.

Factor	$F_{2,320}$	p -value
Educational Context of Break	13.57	<0.0001
Placement of Break	2.40	0.0921

Table 2. Mentally-active breaks, but not physically-active breaks, significantly improved information recall.

Educational Contexts Compared	t-value (df=320)	Adjusted p -value
Non-Active to Mentally-Active	-2.71	0.020
Non-Active to Physically-Active	1.02	0.566
Mentally-Active to Physically Active	5.19	<0.001

Table 3. Recall of information presented immediately *after* a mentally-active break did not improve in the mentally-active context, compared to the non-active context.

Factor	$F_{2,128}$	p
Educational Context of Break	0.78	0.378
Placement of Break	0.10	0.906

Effects of Physically-Active Breaks

Participants in the physically-active context showed no significant difference in recall of the information compared to participants in the non-active context ($p_{adj} = 0.566$, Tukey-Kramer post-hoc comparison, $t_{320} = 1.02$).

Discussion

The results of our study indicate that the component of “active learning” that makes this type of pedagogical approach effective is the actual learning that occurs during the activity. This is supported by two observations: 1) Students who participated in physically-active breaks showed no significant difference in recall of the information presented immediately after those breaks (when, in theory, they should have been maximally energized/alert), compared to the recall of students who took no breaks during the lecture. 2) Students who participated in mentally-active breaks did not exhibit significantly better recall of the information presented immediately *after* such breaks (when, in theory, they should still have been relatively mentally alert). These results suggest that simply “waking students up” does not significantly enhance information retention.

However, we draw this conclusion within the context of several limitations of our study. Since we were working with established course sections and schedules, we could not control either the time of day at which we created the educational contexts or the number of students participating in each context. We also did not control topic switching within the lecture. Switching topics may have affected participants’ attention and recall, either by reengaging with the material due to the novelty of a new topic, or because a particular topic may simply be more interesting to participants. Although we found that energizing students (through physical activity, or immediately after a mentally-active break) did not affect information recall, our small sample size may have led to this result if our analyses did not have sufficient power to detect small differences.

Some have questioned the level of rigorous research support for the often-cited 10 to 15-minute attention span⁷. Within the limitations of our study (which include assessing low levels of cognitive processing, and using an assessment with blunt “all or nothing” correct/incorrect questions) we observed a visual trend in which information presented at the beginning of the lecture was recalled better than information presented later in the lecture, with minimum recall occurring at approximately 10 minutes into the lecture. However, this trend was only marginally significant in the physically-active context; there was no statistically-significant trend in the other contexts or when data were pooled from all contexts and analyzed.

Although our results indicate that the placement or timing of the breaks did not affect information recall in our study, we cannot generalize this result to other potential situations. First, we had a relatively small sample size in some of the treatments, so this effect may be significant in a larger study. Second, we spaced the breaks relatively evenly during the lecture. We followed the principle that breaks should be strategically placed to prevent lapses in attention that may negatively impact learning later in the lecture period^{7,8}. Placing three breaks close together and having a large period of time without breaks may yield a different result.

Using active learning techniques in a classroom takes time. With limited lecture time, the trade-off for incorporating active learning breaks may be that less information can be presented to students overall. However, within the limitations of our investigation, our results suggest that active learning exercises helped students retain information. Furthermore, our data suggest that

student learning is influenced by the pedagogical design or learning value of active learning exercises, rather than by simply “waking students up” to become more alert or energized. In other words, our study provides evidence that active learning requires learning – not just activity.

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