

# Recent Research in Science Teaching and Learning

Sarah L. Eddy\*

Florida International University, Miami, FL 33199

## ABSTRACT

The *Current Insights* feature is designed to introduce life science educators and researchers to current articles of interest in other social science and education journals. In this installment, I highlight three studies drawing on psychology and learning sciences to understand how to increase student motivation to engage in scientific writing, how drawing can enhance learning, and whether spacing, or distributed practice, matters in actual classes.

## HELPING STUDENTS SEE VALUE IN WRITING LAB REPORTS

Curry, K. W., Jr., Spencer, D., Pesout, O., & Pigford, K. (2020). Utility value interventions in a college biology lab: The impact on motivation. *Journal of Research in Science Teaching*, 57(2), 232–252.

Communicating in writing is a highly valued skill among science professionals, but college students do not necessarily perceive that value. This can lead to low motivation to engage meaningfully in writing tasks and may limit the development of writing skills in our students. In this article, Curry and colleagues test three implementations of an intervention to determine how best to increase the value students see in a common college-level writing task: lab reports.

As described in the introduction, Curry and colleagues designed their interventions around the expectancy value theory of motivation. Expectancy value theory posits that, to engage in a task, an individual must 1) see enough value in the task that the value overcomes any costs to engagement and 2) expect to be able to accomplish the task. The intervention in this paper focuses on the value of the task. In expectancy value theory, there are multiple types of value: attainment (importance of mastering or being successful at a task), intrinsic (enjoyment of a task), and utility (usefulness of task). This study manipulates the utility value of scientific writing. The researchers chose to focus on utility value over other types of value, because prior research has shown it is the most malleable. In addition, higher perceived utility value is tied to multiple desirable outcomes in education contexts, including persistence, performance, and increased intrinsic interest.

What makes this study stand out is that the researchers not only explore *whether* a utility value intervention can impact the value and interest students see in lab reports, but also *how* to optimize such an intervention for maximum benefit. The researchers designed three interventions to manipulate the utility value of lab reports. The first intervention, “directly-communicated,” involved providing students information on why writing lab reports is valuable. Specifically, students watched short videos about different types of utility value of lab reports. The second intervention, “self-generated” asked students to come up with the value of the lab reports for themselves. Students in this condition brainstormed the value of lab reports related to a specific theme. The third intervention, “hybrid,” had students engage in both the directly communicated and self-generated activities. First, they watched the video, and then they wrote a reflection on the utility value of lab reports. In the control group, students watched videos about biology content and took a brief comprehension quiz related to that content.

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This feature is designed to point CBE—Life Sciences Education readers to current or noteworthy articles for life science educators and education researchers. We invite readers to suggest current themes or articles of interest in life science education as well as influential papers published in the more distant past or in the broader field of education research to be featured in *Current Insights*. Please send any suggestions to Julia.Gouvea@tufts.edu.

\*Address correspondence to: Sarah L. Eddy (seddy@fiu.edu).

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More than 1000 ( $n \sim 250$  per treatment) students were recruited from 43 lab sections of introductory biology at one institution. The majority of students who participated in this study were first-year science majors. Students taught by the same teaching assistant (TA), who may have taught more than one section, were all randomly assigned to the same treatment group or to the control group. TAs completed a measure of self-reported teaching competency as an attempt to control for differences between TAs that could impact the value students saw in lab reports. Across the semester, each lab section experienced five 5-minute interventions. Each intervention highlighted a different utility value for lab reports or different content (control). Surveys were administered to students three times in the semester to measure the impact of these interventions: week 1 (pre-intervention), week 7, and week 12 (post-intervention). These surveys measured aspects of value from the expectancy value framework (utility, attainment, and intrinsic value as well as perceived costs) and interest in writing lab reports. The researchers used repeated-measures analyses of covariance, controlling for student initial interest and TA self-reported competency, to determine the impact of the intervention on these outcomes. The researchers did not relate the interventions to the quality of lab reports submitted or course performance overall.

The researchers found that both the hybrid and self-generated groups perceived higher utility value for lab reports both at week 7 and at week 12. The self-generated group also had higher interest at week 12. Thus, the self-generated intervention seemed to have the most potential to increase motivation for scientific writing. One hypothesis for this finding is that students developed a more personal connection to lab reports, because they generated their own values rather than being told the value.

Thus, this study suggests that instructors can improve student motivation for academic tasks by providing an opportunity for students to brainstorm about why the task is useful to them and then write a reflection on that value.

### SYNERGISTIC BENEFIT OF DRAWING AND EXPLAINING

Fiorella, L., & Kuhlmann, S. (2019). Creating drawings enhances learning by teaching. *Journal of Educational Psychology*, 112(4), 811–822. <https://doi.org/10.1037/edu0000392>

In many science classes, students struggle to produce quality explanations of course content, focusing more on restating the material than connecting it to their prior knowledge and, thus, deeper learning. One strategy for helping students create better explanations is asking them to teach others, particularly orally. Yet the quality of student explanations seem to moderate the learning gains observed when students explain content to each other (Roscoe and Chi, 2007; Roscoe, 2014). In this study, Fiorella and Kuhlmann tested whether a drawing task paired with a verbal explanation could help students generate better explanations and experience deeper learning. As reviewed in their introduction, learning by drawing typically involves depicting course content, presented to students in words, in images. Drawing is thought to benefit students by encouraging them to identify the most relevant information, organize it, and integrate it with what they already know. It may also benefit learning, because drawing involves different mental mecha-

nisms than verbal explanations and the use of multiple mechanisms should improve learning over the use of one. Thus, Fiorella and Kuhlmann predicted that students who have to explain and draw would outperform students that do one or the other.

Fiorella and Kuhlman tested the synergistic effect of drawing and explaining together through three treatments and a control: explain-only, draw-only, draw-while-explaining, and a restudy control. Thirty undergraduates were randomly assigned to each of the four conditions. Participants in the three treatments were told by researchers that they were going to create an 8-minute video lesson to teach a peer about the respiratory system by 1) orally explaining, 2) creating a drawing, or 3) orally explaining while drawing. Participants in the control were told to study in a way that would help them perform well on a test. Across all these treatments, participants then read a short explanation of the human respiratory system and studied it for 20 minutes. Students in the three treatments then recorded their videos without access to any notes or the original material. One week later all participants completed a free-response posttest on the respiratory system that included knowledge, application, and drawing items.

The strength of this study lies in the analysis. The researchers analyzed not only the posttest data patterns, but also the quality of the explanations and drawings students generated in the teaching conditions. Specifically, the researchers coded the explanations for evidence of knowledge (individual ideas from the lesson); elaborative statements, in which students expressed ideas from beyond the unit, showing they were incorporating the new content with their existing knowledge; and monitoring statements, in which students reflected on their own thought process while explaining. For the drawings, the researchers measured the number of elements of the respiratory system represented and the number of respiratory processes illustrated. By collecting these measures of students' representations of the material, the researchers could determine whether the quality of the explanation or drawing mediated the impact of the teaching condition on the posttest score.

Using a one-way analysis of variance with planned contrasts, the researchers found that the explain-and-draw group performed better on all the question types on the posttest than the explain-only group and better on knowledge items than the draw-only group, with a trend in the same direction for the application and drawing questions. All three teaching conditions performed better than the study condition. Interestingly, the draw-only and explain-only groups did equally well on the posttest.

To understand these finding, the researchers turned to the quality of the explanations and drawings. They found that the explain-and-draw group explanations had more elaborative statements than the explain-only group, but that they did not differ in knowledge or monitoring statements. This difference in elaborative statements is important, because it was the only measure of explanation quality correlated with posttest score. On the other hand, the explain-and-draw group had lower drawing-quality measures than the draw-only group. However, no measure of drawing quality was correlated with posttest scores.

Finally, the researchers formally tested whether the number of elaborative statements mediated the impact of treatment on posttest score. They found a partial mediation, meaning that

the number of elaborative statements did partially explain the difference in posttest performance between teaching conditions, but there still may be other mechanisms involved.

Altogether, this study demonstrates that prompting students to draw can help them generate better explanations and leads to increased learning. This effect can be partially explained by students producing better explanations that involve incorporating learned information with prior knowledge. However, if instructors are only able to use one method (explaining or drawing), each is equally useful for student learning.

### SPACING EFFECT EVALUATED IN A REAL COURSE SETTING

Carvalho, P. F., Sana, F., & Yan, V. X. (2020). Self-regulated spacing in a massive open online course is related to better learning. *NPJ Science of Learning*, 5(1), 1–7.

One of the most robust strategies for learning found in cognitive psychology is the spacing effect: long-term memory is enhanced when study is spread out over time rather than done all at once (Dunlosky *et al.*, 2013). The vast majority of the evidence for this effect, however, comes from lab studies. Very little work has been done in real-world courses where students dictate their own study patterns and where they are tested on complicated assessment exams that require more than recall. In this study, Carvalho and colleagues explore the impact of the spacing effect on learning in a massive online open course for general psychology. They further delve into whether the spacing effect's impact varies based on student ability or how students engage (passively or actively) with the material as they are learning.

An online course has an advantage over an in-person course for this type of study, because many course management software programs track when students engage with the different course elements. Because of this, Carvalho and colleagues have a record of each time a content page was loaded by each student in the study and how long the student spent on that page. The authors defined “spacing” as the number of different times a student loaded a given unit. The more times the student revisited a unit, the more spaced the learning. Total study time per unit was calculated by summing the total time a student spent on the unit across every time the student loaded it. The researchers also calculated a retention interval: the time between when a student last loaded a unit and when the student took the unit quiz. Finally, as each unit had a series of embedded activities, the authors collected an activity completion rate to account for how engaged students were when they learned the content. On average, students engaged in four sessions over 2 days to complete each unit, and they usually took the unit quiz within 48 hours. In addition to study behaviors, the researchers collected a measure of each student's prior knowledge of psychology (a pretest) and the student's performance on unit quizzes and the final.

The researchers employed mixed-effects models to explore the relationship between spacing and unit quiz performance. A

random effect for unit accounted for differences between the material in the units and a random effect for student allowed the researchers to look at how variation in student study behaviors across units, but within a student, impacted performance. Fixed effects included pretest score to control for prior knowledge and total study time so this variable did not confound the results (i.e., the more sessions a student took could mean greater total study time). A final control was the retention interval and an interaction between retention interval and spacing. Carvalho and colleagues found an impact of spacing on unit quiz performance. Specifically, within a student, in the units for which students spaced out their learning more, they performed better. The final exam revealed a similar pattern of increased spacing increasing performance.

An interesting, but possibly confounded follow-up analysis used final exam score as a measure of student ability to look at the impact of spacing on performance for different “ability” students. This is challenging, because the variable they cared about, spacing, was correlated with final exam performance, and this relationship could confound the results of this analysis. Nevertheless, they did find results that would be worth following up on in future studies: Spacing seems to be more important for the performance of lower-ability students than for higher-ability students.

Finally, the researchers explored the relationship between spacing and engagement: If students are more actively engaged in the units, is spacing still important? They found that active engagement can buffer against use of cramming: When students completed fewer activities, the relationship between spacing and quiz performance was stronger than when students completed more activities in the unit. The researchers propose this moderation may occur because both active practice and spacing act through the same mechanisms: retrieval of prior knowledge and generating connections between old and new knowledge.

These results from a study of natural student behaviors in a real course suggest that encouraging students to spread out their learning of course content can increase their performance and may be especially important for struggling students. Most interestingly, the results also seem to imply that, as instructors, we may be able to help make up for our students' tendency to cram by engaging them more actively with the material. Alternatively, spacing out learning can buffer students from the negative effects of a passive class.

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