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A preliminary study of the educational benefits of conducting replications in the classroom

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Abstract

Some have argued that having students conduct rigorous replications of published studies would provide benefits to both psychological science and to the students themselves. However, while it seems clear that replications are beneficial to psychological science, there is little empirical evidence that having students conduct replications provides benefits to students. In this study, I conducted a preliminary test ($N = 37$) of one purported benefit to students of conducting a classroom replication: the development of scientific critical thinking skills. Students completed a one-term research methods course centered around a class replication project. I assessed students' critical thinking development after completing the course. The results were largely inconclusive, showing no significant change in performance between a pre-test ($M=11.00$, $SD=3.44$) and a post-test ($M=10.30$, $SD=2.62$), $t(36) = -1.21$, $p = 0.23$. This study highlights the need for additional research on the question of whether having students conduct replications provides educational benefits beyond those offered by other pedagogical methods.

Keywords: research methods, replication, reproducibility, critical thinking

A preliminary study of the educational benefits of conducting replications in the classroom

In response to recent calls for more replication in psychology (Bakker, van Dijk, & Wicherts, 2012; Koole & Lakens, 2012; Roediger, 2012; Open Science Collaboration, 2015), some have suggested that the task of carrying out replications could fall to students, particularly undergraduates (Frank & Saxe, 2012; Grahe et al., 2012; Grahe, 2017). Perhaps in response to these calls, the practice of conducting classroom replications has gained in popularity (see Standing, 2015; Standing, Astrologo, Benbow, Cyr-Gauthier, & Williams, 2016; Lenne & Mann, 2016; Janz, 2016, for several published examples). Possibly the largest organized effort of this kind is the Collaboration Replications and Education Project (CREP; Grahe, Brandt, IJzerman, & Cohoon, 2014; Grahe et al., 2017). CREP identifies high-impact studies that have not been replicated and encourages teams of students to carry out replications. The results are then publicly shared and combined.

It seems indisputable that efforts like CREP are beneficial to psychological science. However, several authors have also claimed that having students conduct replications could provide multiple benefits to the students themselves, such as motivating them with the knowledge that they are contributing to science (Frank & Saxe, 2012; Janz, 2016), giving them a deeper understanding of statistics (Standing et al., 2016; Janz, 2016), and developing their scientific critical thinking skills (Standing et al., 2016). For example, Standing et al. (2016) write that having psychology students in research methods courses conduct replications “may substantially benefit both [their] skills and critical thinking”. Despite claims like these, there have been no empirical tests of these benefits. In this paper, I focus on one particular asserted benefit: developing critical thinking skills. I describe the results of a test of students’ psychological critical thinking development after completing a one-term research methods course centered around a class replication project.

The course

I taught a 10-week psychology research methods course. The content of the course was mostly typical of research methods courses: lectures on research design, discussions of research articles, and an independent research project. The primary difference was that the course had a thematic focus on reproducibility in science¹. For example, students learned how employing questionable research practices when analyzing data can dramatically inflate the false positive rate with null hypothesis significance tests (Simmons, Nelson, & Simonsohn, 2011). Consistent with this theme, approximately half of the course was centered around a class replication of a memory experiment (Thomas & Jacoby, 2013). I chose this experiment because the methods and materials (text-based questions and answers on a computer) were simple enough that students could reproduce them nearly exactly.

Near the beginning of the term, students read the original article and completed an exercise in which they had to identify the information they would need to exactly reproduce the experiment in the article, as well as the information they would need that was not specified in the article. This exercise helped them to understand how many potentially influential decisions go into the design of every study. Later, students worked together to generate the stimuli for the experiment. Through a series of exercises and assignments, students individually implemented the experiment using PsychoPy software (Peirce, 2007). They collected data from participants outside of class. Finally, they processed the data and analyzed it by performing the key statistical tests from the original study. The results of the replication were published on PsychFileDrawer.org. In sum, students were directly involved in every aspect of carrying out a nearly exact replication under my close supervision.

My primary goal was for students to learn basic research concepts and skills. In addition, consistent with past authors (e.g., Standing et al., 2016), I hypothesized that

¹ Course syllabus and materials are available at osf.io/7jj5t.

conducting the replication and learning about problems of reproducibility in science more generally would help students develop better scientific critical thinking skills compared to practices used in more traditional research methods courses. Specifically, compared to reading and critiquing a study, I hypothesized that the process of replicating an experiment would require students to recognize additional limitations of published research.

Additionally, compared to finding a null result in a new independent study, the possibility of finding a null result after conducting an exact replication requires students to more seriously grapple with the possibility that the underlying hypothesis is flawed because such null results are harder to explain away by the limitations of the methods. In short, I expected students who completed the course to become more critical consumers of science.

Methods

Participants

I taught two sections of the course during the Winter 2017 quarter. By the end of the quarter, 26 undergraduate students (1 first-year student, 2 second-year, 10 third-year, 13 fourth-year and above) were enrolled in one section and 19 undergraduate students (10 first-year students, 4 second-year, 2 third-year, 3 fourth-year and above) were enrolled in the other section. Although this sample size was small, I expected a large effect size. Specifically, the main dependent measure was performance on the Psychological Critical Thinking Exam (PCTE; Lawson, 1999; Lawson, Jordan-Fleming, & Bodle, 2015). Lawson et al. (2015) compared performance on the PCTE between junior and senior psychology majors and found an effect size difference of $d = 1.60$. A power analysis reveals that detecting an effect size half as large as this with power equal to 0.8 would require approximately as many students as were enrolled in my course.

Compared to psychology research methods courses at most institutions, one unusual feature of this student population is that there were no psychology majors. Additionally, the course did not have any psychology pre-requisites; six students had not taken a

psychology course before.

Materials and Procedure

Students completed a pre-test and a post-test. Both tests were composed of questions from the PCTE. Each question describes a study and a conclusion drawn from the study. The instructions read: “State whether or not there is a problem with the person’s conclusions and explain the problem (if there is one).” The PCTE consists of 14 questions. There is one question on each half of the test related to each of seven critical thinking questions. Lawson et al. (2015) reported high reliability ($r = 0.88$) between the two halves of the test. I therefore split the test in half to create two seven-question versions of the test: Version A and Version B. One section of students completed Version A as the pre-test and Version B as the post-test. The second section completed the tests in the reverse order. At the end of the post-test, I also asked students how many psychology courses they had taken previously, how many statistics and/or probability courses they had taken previously, and asked them to rate how effective the replication project had been for helping them to learn about behavioral research, on a scale from 1 (not effective) to 7 (very effective).

All students completed the pre-test in class on the first day of class and the post-test on the last day of class. Students completed the tests on their laptops. I made no effort to teach students the specific content on the PCTE. However, over the course of the quarter, students read and critiqued research articles and repeatedly discussed limitations of their own and others’ studies.

Results

Due to technical problems, and because the tests were voluntary, not all students submitted both tests. Students who failed to submit at least one test were excluded. This left 24 students in the first section and 13 students in the second section (final $N = 37$).

All identifying information from students’ responses, including course section, were removed. I then scored their responses using the scoring rubric provided by Lawson et al.

(2015). According to the rubric, each question is scored on a scale from 0 to 3. The highest score, 3, is assigned when only the main problem with the study is identified. After scoring, the responses were unblinded so the scores could be linked to sections and to the additional questions described above.

Contrary to expectations, students overall did not perform better on the post-test ($M = 10.30$, $SD = 2.62$, 95% CI [9.45, 11.14]) than the pre-test ($M = 11.00$, $SD = 3.44$, 95% CI [9.89, 12.11]). The highest possible score on each test was 21. A paired-samples t-test revealed that the difference in scores was not statistically significant, $t(36) = -1.21$, $p = 0.23$. Although students' scores did not improve, their scores are comparable to those of similar populations reported by Lawson et al. (2015). In their study, senior biology majors earned a mean score of 8.45 and junior psychology majors earned a mean score of 11.47 (these means are halved in order to make them comparable to the halved version of the PCTE I used). Thus, these scores are consistent with past research and do not suggest that the student population in my course was unusual.

To test whether other factors, like educational background, may have affected student performance, I analyzed students' PCTE scores by fitting a linear mixed-effect regression model using test timing (pre-test or post-test), number of previous psychology courses taken, number of previous probability or statistics courses taken, and response to the question about the effectiveness of the replication project as predictors. Several students did not answer these additional questions and were omitted, leaving $N = 33$ students. I included course section as a random effect². Consistent with the paired-samples t-test, timing was not a statistically significant predictor of score ($\beta = -0.85$, 95% CI [-2.34, 0.64], $p = 0.27$). Of the remaining factors, number of previous psychology courses was the best predictor of score ($\beta = 0.61$, 95% CI [0.02, 1.19]), consistent with Lawson et al. (2015), followed by number of probability and statistics courses ($\beta = 0.42$, 95% CI [-0.51, 1.35]), and ratings of how effective the replication project was ($\beta = -0.26$, 95% CI

² The script used to run this analysis is available at osf.io/7jj5t.

$[-0.95, 0.43]$). As this analysis was exploratory and I had no specific predictions regarding these predictors, I have omitted p-values.

Discussion

The results were largely inconclusive. Contrary to expectations, students' mean scores on the PCTE declined, but this difference was not statistically significant. One explanation for this null effect was the small sample size: only 37 students completed both tests, which may not have been enough to reliably detect small performance differences in either direction. However, the enthusiastic claims that some have made about the benefits of conducting classroom replications suggests that they would have expected a large effect size. Thus, even if this explanation is correct, it would mean that the level of enthusiasm some have expressed for conducting classroom replications may need to be tempered.

An alternative possibility is that the PCTE is a poor assessment tool in this context. For example, the PCTE focuses primarily on identifying flaws in study designs, which is not a primary skill that is developed by conducting a replication. This does not mean that conducting replications does not develop other types of critical thinking skills. I chose to use the PCTE partly out of convenience because it had been empirically validated and had been successfully used in the past. Future work on the benefits of classroom replications, however, may require designing more appropriate assessment tools.

A major limitation of this study was that it lacked a control condition. Consequently, it is also possible that the null effect may be due to a deficiency of the course or my instruction, rather than the replication project. Splitting the two sections into separate conditions would have further reduced the study's statistical power, which is one reason why I chose not to do so. However, for future studies, it is worthwhile to consider what an appropriate control condition would be. Because integrating a replication project into a research methods course is a significant undertaking, I believe it would be difficult to assess a replication project in isolation. Instead, I believe that the most informative comparison

would be between a more traditional research methods course and a modified course involving a replication project. Even if these two courses differed in multiple respects, comparing them would allow a researcher to tell whether the modified course overall led to better student outcomes.

I strongly agree with previous authors (Frank & Saxe, 2012; Grahe et al., 2012) who have argued that student-conducted replications would benefit psychological science. However, it remains unclear whether embracing this practice benefits students. This preliminary study reveals that this question is not straightforward to answer. First, advocates for student replications have not consistently pointed to the same student benefits. Second, some benefits, like critical thinking development, can be difficult to assess (see, e.g., Liu, Frankel, & Roohr, 2014). Third, there are multiple ways to incorporate replication into the classroom (Grahe, 2017), and different methods of involving students in replications may have different benefits. Regardless, as long as instructors are increasingly incorporating replications into research methods courses, I encourage them to build on this study by assessing the potential benefits of the practice, not only in terms of critical thinking skills, but in terms of learning motivation, development of research skills, understanding of statistics, and others. By sharing the results of these assessments, all instructors will learn whether and how using replication in the classroom can best benefit our students.

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