Integrating open science in the teaching of cognitive research methods: Comparing virtual vs face-to-face delivery

Ralph S. Redden[1,2] & Colin R. McCormick[2]

[1] University of Alberta; [2] Dalhousie University

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Corresponding Author:

Ralph S. Redden

rredden@dal.ca

Abstract

Openness, transparency, and reproducibility are widely accepted as fundamental aspects of scientific practice. However, a growing body of evidence suggests these features are not readily adopted in the daily practice of most scientists. The Centre for Open Science has championed efforts for systemic change in the scientific process, endorsing practices such as preregistration and open sharing of data and experimental materials. In an effort to inculcate these practices early in training, we integrated several key components of open science practice into an undergraduate research methods course in the cognitive sciences. In the first iteration of the course done in the traditional face-to-face format, students were divided into research teams: each with the goal of carrying out a replication experiment related to the topics in the course. Teams completed a preregistration exercise, and importantly, were encouraged to consider a priori the criteria for a successful replication. They were also required to collect and analyze data, prepare manuscripts, and disseminate their findings in poster symposia and oral presentations. In two subsequent iterations of the course, the COVID-19 pandemic forced the course into an online, asynchronous format. Whereas the course deliverables were modified substantially to suit the new format of the course, the learning objectives remained the same. Students independently conceptualized a replication experiment of their own choice based on their interests in the course material. Considerable flexibility was built into the capstone projects in order to empower students to focus on work they found engaging. Students were encouraged to focus on the theoretical motivations for replicating their study of choice, based on consensus (or lack theoreof) of a literature review, as well as on the methodological and analytical aspects of their replication, guided by preregistration templates. Critical appraisal of the goals and implementation of the course across formats are discussed.

Openness, transparency, and reproducibility are widely accepted as fundamental aspects of scientific practice. However, a growing body of evidence suggests that these features are not readily adopted in the daily practice of most scientists (Munafò et al., 2017). In fact, research on the reproducibility crisis in STEM fields estimate that less than half of published findings in the literature are reproducible (Ioannidis, 2005; Nosek et al., 2015; for a concise review, see Galetzka, 2019). Moreover, institutional pressures and systemic biases have been posited as key factors in the resistance to shift from the status quo of scientific practice (Guest, 2016), such as the job market and job insecurity, or a lack of diversity in scientific culture. The Centre for Open Science has been championing efforts for systemic change in the scientific process, with newly adopted practices such as preregistration and open sharing of data and experimental materials. Furthermore, the Diversity, Justice, and Sustainability Model proposed by Grahe, Cuccolo, Leighton, and Cramblet Alvarez (2020) reinforces not just the practical side of Open Science, but the philosophical and social implications for a barrier-free scientific community.

Concerning these efforts to change the culture of scientific practice, improved training of early-career researchers is thought to be integral to the success of a paradigm shift (Munafo et al., 2017). When surveyed on strategies to increase the reproducibility of scientific output, more than 90% of over 1500 surveyed researchers endorsed educational and training interventions as the best options (Baker, 2016). In accordance with this perspective, efforts to integrate open science practices at the grassroots level have shown promise (Button, Chambers, Lawrence & Munafo, 2019). By leveraging multi-site collaborations, Button and colleagues (2019) developed a consortium-based model that trains undergraduate researchers with modern scientific skills, while generating meaningful, reproducible scientific findings. However, undergraduate theses and dissertations tend to be conducted in the final year of study. It is our position that the training in open science theory and practice ought to be integrated earlier still in training, so these skills are already instantiated *prior to* commencing one's first venture into independent research. As such, in an effort to inculcate consideration of open science thinking early in training, we integrated several key components of open science practice into an undergraduate research methods course in the cognitive sciences.

Like many other educators, we were faced with an abrupt transition to online learning as a result of the COVID-19 pandemic. The traditional, face-to-face version of the class was held in Winter 2019, and online, asynchronous versions were subsequently offered in the first full academic year of the pandemic (Fall 2020 & Winter 2021). Here we outline the strategies employed to accomplish the learning objectives in the two formats, subsequently compare and contrast the approaches to the same course, and summarize our recommendations for future versions of courses such as this.

Course Themes + Content

The course was listed in the academic calendar as 'Research Methods in Attention', as such many of the lectures explored different foundational concepts and mechanisms within the field of attention, including the networks of attention, search, and inhibition of return (e.g., Fan et al. 2002; Treisman, 1986; Klein, 2000). Students were asked to prepare for each lecture by reading assigned research papers on these topics. Other class sessions pertained to more generalizable concepts within research methods, including how to design a research poster, and how to implement open science practices into research (more on this below). The lecture content remained the same between the in-person and online iterations of the course.

Students were evaluated on these topics by way of essay questions on a quiz. Quizzes were formatted in such a way that students knew in advance all of the candidate essay questions that might be on the quiz, and a subset were selected by random draw on the day of the quiz. By providing a candidate quiz question promptly following a particular lecture, we provided immediate reinforcement for the main thesis of the topic, and structured guidance for how the students ought to proceed with their review of the content.

In addition to the operational open science behaviours put into practice in our curriculum, discussions on the philosophical values of openness were interleaved throughout the subject matter. For instance, Fecher and Friesike (2014) describe open science as a means to impact equity in five domains: scientific technology, metrics of scientific impact, access to knowledge, access to knowledge creation, and collaborative potential. Woelfle, Olliaro and Todd (2011) describe open practice as a scientific accelerator, whereby large-scale discovery can be "crowdsourced" by leveraging the contributions of many by making materials and protocols openly accessible. Moreover, the Open Science MOOC (massive open online course; https://opensciencemooc.eu/) describes the core values of open science to be diversity, inclusivity, fairness, equity, social behaviour, accountability, ethics and responsibility. We integrated critical appraisal of constructs such as these in relation to the scientific content being covered. In particular, an explicit recognition of privilege was a running theme in all content. We discussed systemic pressures leading to the underrepresentation of females, and visible and invisible minorities in the published STEM literature, and ways in which open science practices could be leveraged to empower less visible groups (e.g., Grahe et al., 2020; Pownall et al., 2021).

Traditional Face-to-Face Format

Replication Experiment

Students were divided into four research teams, each with the goal of carrying out a replication experiment related to the study of attention. More specifically, each project was a replication of one of various experiments produced by the lab in which the authors have completed their graduate training. The choice to replicate our own lab's work served two aims: First, it made operational sense as all original experimental code and materials were available on-site. Second, this decision modeled to the students that, foremost, scientists ought to be open to critical and empirical appraisal of one's own work. We sought to cover a variety of topics commonly associated with many facets of attention. These topics were complementary to the wider curriculum in the course, and as such, students could integrate concepts from lectures and class discussions in their project development.

One team explored temporal cueing effects, and how attention can be allocated both intentionally and reflexively to moments in time (McCormick, Redden, Lawrence & Klein, 2018). Another group looked at the effects of various foreperiods between an alerting signal and a target in a task-switching paradigm, as done by Posner, Klein, Summers and Buggie (1973; see also, McCormick, Redden, Hurst & Klein, 2019). A third team re-examined the question previously asked by Redden, d'Entremont & Klein (2017) as to whether volitional spatial orienting can elicit prior entry (for review, see Spence & Parise, 2010). Finally, a fourth team assessed whether strategy differences related to target difficulty would modulate the size of the attentional blink, as previously examined by McLaughlin, Shore and Klein (2001), and Shore, McLaughlin and Klein (2001). These projects were associated with a number of different learning objectives and evaluated materials, which are explained below.

Science Communication & Dissemination

In order to expose the students to as much of the research process as possible, many components of the course were completed collaboratively. Collaboration was emphasized both for practical reasons (i.e., to leverage individual contributions toward a greater end within the constraints of a single academic term) and to emulate the process in a prototypical lab setting, whereby various personnel contribute to research efforts. Teams were required to complete a preregistration template, and importantly, to define a priori the criteria for a successful replication. Teams collected data, and participated in analysis workshops to produce the quantitative component of their research reports. Each team produced a Method and Results section, as these components of a manuscript tend to be more rote in nature, and each individual was required to produce an original Introduction and Discussion, as these components can better reflect critical thinking and independent appraisal.

Students also provided anonymous peer review at two points during the term. Early in the term they provided critical feedback to a collaborating teammate on their Introduction, so that each member of the team would be exposed to another sample of writing directly relevant to their own project. Near the end of the term, each student provided critical feedback on a full report from a different team project, so that each student would be exposed in-depth to a project other than their own. Students were evaluated on the quality of feedback they provided to their peers, rather than on the critique they received.

Each team hosted a symposium of talks to present papers that motivated their replication study. Furthermore, a capstone oral and poster symposium provided teams with the opportunity to present their findings. Additionally, while not an explicit component of the course, students were also extended the invitation to present their team projects at the Dalhousie Psychology and

Neuroscience Annual In-House Conference, and the Science Atlantic Undergraduate Psychology Conference.

Online/Asynchronous Format

Replication Experiment

Because the class was both virtual and asynchronous, many students were not on or near campus at all during the term (one student reported residing over 5000 km away). As such, it was not feasible to require students to work collaboratively (due to implicit constraints arising from time zone differences), nor could we oblige them to be on campus to collect data. Given this, students independently completed a replication exercise. Our primary tool for these projects was the PsyToolKit (Stoet, G., 2010; Stoet, G., 2017) online library of experiments. Students were instructed to find a research article that employed one of the tasks emulated in the PsyToolKit library. Importantly, students were explicitly instructed to find an article that addressed a topic that interested them personally. For instance, students with interests in pursuing clinical studies often chose articles addressing cognitive functioning in a particular subgroup (e.g., Gernsbacher et al., 2018); others with interest in sport performance selected articles assessing the cognitive functioning of high performance athletes (e.g., Huertas, Zahonero, Sannabria, & Lupianez, 2011).

Science Communication & Dissemination

Students submitted written reports for their planned experiment. They were instructed to describe the rationale for their study, and justify the motivation for the replication with converging evidence from the literature. Students were prompted to consider reasons for why there might be doubt in the original findings, or otherwise, why might the field be interested in building more confidence in the hypothesis. Moreover, they were also required to complete a preregistration template, and importantly, to define a priori the criteria for a successful replication. Students also created a poster that would be suitable for an academic conference, based on the article that motivated their replication study.

In addition to producing written term reports, students also completed a knowledge translation activity. Students produced a press release report in reference to an article of their choice related to the course content. Students were tasked with translating a primary source peer-reviewed article into a format that would be suitable for a general public audience, such as a daily newspaper or science blog.

Contrasting In-Person vs. Online/Asynchronous Formats

Students demonstrated an excellent understanding of the topical subject matter across both delivery formats. Student comments suggest that the quiz structure (long form questions disseminated in conjunction with lectures) was well received, and that the format enabled them to focus on the key concepts without the stress associated with the unpredictability of more traditional testing formats; reinforcing comments associated with stress mitigation were more prevalent in the virtual cohorts, possibly due to the pandemic eliciting higher general levels of stress than what may have been typical pre-pandemic.

In both course formats, there was a requirement to preregister experiments. Students did so using the preregistration template provided by the Open Science Framework. In both formats, students provided excellent descriptions of their method, sampling plans, and reported precise dependent and independent variables. However, systematic critique across both versions of the course was that students had difficulty in declaring objective criteria (e.g., reaction time cutoffs, minimum accuracy thresholds, etc.) for their analysis plans; a pattern mirroring that reported by Blincoe and Buchert (2019). Since nearly no students in any iteration of the class had any prior experience working with real behavioural data, it was extremely challenging for them to conceptualize the sequence of the various analytic decisions they would eventually be required to make at the data analysis stage. In future iterations of this course, or others modeled from it, we would recommend demonstrating a hypothetical analysis pipeline in advance of the preregistration task. This would be particularly straightforward to execute if others followed our strategy of replicating experiments from within one's own laboratory, or building from those with fully open materials.

Further to this point, it was not feasible given the logistics and resources available for students in the online versions of the class to collect performance data in their planned experiments. We embraced this as an opportunity to instead challenge the students to conceptualize ambitious studies (e.g., visuospatial orienting behaviour in Parkinson's patients; Attention Network Task differences in varsity athletes), as the experimental design was explicitly a conceptual/hypothetical exercise. However, this meant that students in the in-person version benefitted from working with real, raw human performance data whereas those in the online version did not. On reflection, it is our opinion that this is a significant omission. Future online/hybrid iterations of the class ought to consider leveraging the myriad of options for online data collection, and prioritize exposing students to the rigors of processing and analyzing raw human performance data.

Another noticeable issue that could potentially be addressed by advancing online technology was the difference in collaborative experiences between versions of the course. While we made concerted efforts to replace the collaborative components with meaningful independent exercises in the online versions of the course, it is our subjective assessment that the collaborative components built into the in-person version were valuable to the students beyond the specific curriculum. As mentioned above, many students attended a regional undergraduate conference—a completely elective, extracurricular experience held outside the regular term. Several of the students reported that it was an experience they felt they wouldn't have had otherwise without their research teams, and the confidence instilled by engaging in the conference collectively with their classmates. Upon reflection, this type of experience was glaringly missed from the online versions. Collaborative tools currently available across a variety of platforms (e.g., Teams, Slack, Brightspace, eClass) can provide a great deal of flexibility in this regard, and can potentially serve to fill in the chasm we observed on this front between the in-person and virtual experience.

Feedback from the students in both formats of the course suggest that the on-going narrative of the philosophical value of open science, and the associated benefits for under-represented and marginalized persons, played an integral role in facilitating their engagement with the course material. Students in both modalities reported feeling validated and respected as a consequence of being in a class environment where these discussions were prioritized. It would be inappropriate to infer a causal relationship between the level of engagement with the philosophical values of open science, and the engagement with the practical and methodological concepts underlying the philosophy (i.e., did students buy into the philosophy because of their methodological understanding, or did students invest greater engagement with the practical components due to alignment with the philosophical components). Rather we believe these conceptual distinctions to be symbiotic. Interleaving them in a curriculum with a focus on both the practical approaches and the philosophical motivations underlying the open science movement can result in increased learning and engagement.

Summary

Across both formats, students demonstrated strong understanding of subject matter. This reinforces that conceptual understanding can be robust across virtual and in-person delivery. However, limitations imposed by the virtual/asynchronous delivery in retrospect created tangible differences in the subjective experience of the student. Whereas advances in multimedia technology have since become available that can possibly mitigate some of these limitations, it is heretofore untested in this particular circumstance whether these online tools can support the level of interpersonal, collaborative engagement that was lacking relative to the in-person format.

Integrating open science theory and practice early in training has shown promise for the success of early-career research (Button et al., 2019). We reinforce this by demonstrating that when open science theory and practice are defined as explicit components in an undergraduate course curriculum, students can demonstrate proficiency in both conceptual and practical aspects of this modern approach to science. Importantly, these skills were highly developed regardless of the format of the course, as students showed mastery in both the in-person and virtual delivery modalities. Moreover, across both formats students report valuing these discussions, and appreciate the importance and need for systemic change in science.

These outcomes suggest promise for the prospects of future undergraduate research as students can learn the theoretical and practical concepts associated with open and transparent science prior to, rather than concurrently with, engaging in their own research efforts.

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