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ARTICLE

A Model For Teaching Advanced Neuroscience Methods: A Student-Run Seminar to Increase Practical Understanding and Confidence

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Neuroscience doctoral students must master specific laboratory techniques and approaches to complete their thesis work (hands-on learning). Due to the highly interdisciplinary nature of the field, learning about a diverse range of methodologies through literature surveys and coursework is also necessary for student success (hands-off learning). Traditional neuroscience coursework stresses what is known about the nervous system with relatively little emphasis on the details of the methods used to obtain this knowledge. Furthermore, hands-off learning is made difficult by a lack of detail in methods sections of primary articles, subfield-specific jargon and vague experimental rationales. We designed a student-taught course to enable first-year neuroscience doctoral students to overcome difficulties in hands-off learning by introducing a new approach to reading and presenting primary research articles that focuses on methodology. In our literature-based course students were encouraged to present a method with which they had no previous experience. To facilitate weekly discussions, "experts" were invited to class sessions. Experts were advanced graduate students who had hands-on experience with the method being covered and served as discussion co-leaders. Self-evaluation worksheets were administered on the first and last days of the 10-week course and used to assess students' confidence in discussing research and methods outside of their primary research expertise. These evaluations revealed that the course significantly increased the students' confidence in reading, presenting and discussing a wide range of advanced neuroscience methods.

Key words: interdisciplinary, life sciences, methodology, confidence, graduate teaching, hands-off learning, hands-on learning, pedagogy

Today, doctoral students in the life sciences are trained in a highly interdisciplinary environment that requires mastery of diverse methodologies (Holley, 2008). This represents a departure from the traditional model of doctoral education that encouraged specialization (McBride et al., 2011). However, core curricula for doctoral programs rarely include formal, laboratory-based instruction on advanced methods. There are several reasons for this, including potentially large investments of time and resources required to ensure that each student receives sufficient instruction and experience with a given method. At the University of California, Los Angeles, doctoral students in neuroscience identified this lack of instruction in methodology as a weakness of the core, required curriculum. To help address this weakness, we developed a new seminar course called Neuroscientific Methods (hereafter "*Methods*") to be integrated into the required first-year academic schedule for Neuroscience doctoral students.

Doctoral students are practically motivated to become experts in several complementary approaches to address their research questions. A diverse skill set leads to better outcomes on grant applications and in manuscript submissions. One common way to obtain proficiency with a research method is through the laboratory-training environment. Specifically, students often receive instruction from other laboratory members on methods central to the main focus of their mentor's research program. Students will also seek out training in additional techniques in other laboratories, especially those of collaborators on their campus.

It is less common for students to attempt to improve their understanding of techniques in the context of the classroom, without hands-on instruction. We believe this is a skill that, like any other, must be practiced to be improved. *Methods* offered an opportunity to introduce students to an approach to reading and presenting articles that focused on the methods sections, a part of primary research articles that non-experts often skim. The ability to evaluate and present unfamiliar topics is a necessary skill in academia where reviewing articles, grants and dossiers are required (Ullrich et al., 2014). We believe that the *Methods* course provides a supportive environment for first-year doctoral students to begin to hone this skillset with the help of their peers, as well as more advanced students.

At each meeting of *Methods*, we invited 1-3 "experts" to join the class to facilitate discussion. Experts were advanced graduate students with direct, often current, experience with the method being presented that week. Through participation in *Methods*, experts were able to practice discussing their own research and their informal teaching skills. In addition to the experts, the course was designed and facilitated by second-year neuroscience graduate students. For these aspects of the course, we were inspired by other studies demonstrating that graduate student-taught courses are successful models for graduate and upper-level undergraduate education (Needelman and Ruppert, 2006; Ullrich et al., 2012). In addition, the community-based teaching and support for this course gave the experts and facilitators a chance to engage in curriculum design and team-teaching, both important parts of academic life and professional development that are often overlooked in doctoral training (Austin, 2002; Ullrich et al., 2014). Indeed, perceived quality of professional development training has been shown to have an effect on self-efficacy measures in graduate teaching assistants (DeChenne et al., 2015). Coalescing around a community-identified need for further instruction in neuroscience methods to keep pace with the highly diverse and interdisciplinary nature of neuroscience research has helped foster an environment where UCLA neuroscience doctoral students feel that efforts to provide a holistic graduate experience are supported and valued.

In the present study, we report the rationale, goals, design, implementation and assessment of a seminar course focused on increasing students' confidence in their ability to comprehend new methodologies using a hands-off learning approach. The overarching goals of the course guided the design and implementation. Those goals were as follows:

1. Expose first-year graduate students to a wide range of neuroscience methods with a specific focus on widely used and newly developed methods featured in recent high-impact publications.
2. Promote discourse and collaboration between first-year and advanced neuroscience doctoral students, especially for learning about new methods that could be applicable to their work or for assistance in the process of choosing a dissertation laboratory.
3. Emphasize practical considerations of experimental design with a focus on the advantages and limitations of each method.
4. Build students' confidence in their ability to prepare and present material outside their areas of first-hand expertise.

MATERIALS AND METHODS

Participants

Methods was created for and has been implemented with first-year neuroscience doctoral students enrolled in the UCLA Neuroscience Interdepartmental Graduate Program (NSIDP). The course is now part of the required first-year curriculum for the program and is held in the winter quarter. In the context of the NSIDP, this is often the quarter when students are conducting their first laboratory rotation in search of a suitable mentor and research environment for their dissertation work. About 75% of the incoming students in the NSIDP start the program in the fall after their undergraduate graduation, and most of the remaining incoming students are within three years of completion of their undergraduate studies.

In addition to the students enrolled in the course, *Methods* drew on the larger neuroscience community for participation and support. Two second-year NSIDP students served as the course instructors (CRKC, TMH). Their roles included developing the mission and goals of the course, creating the syllabus and recruiting advanced graduate students and faculty to take part in weekly discussions. The instructors met each week before class to discuss the articles that would be covered and to compile lists of questions and comments that might be useful in guiding the group discussion. Throughout the course the instructors gave informal feedback to students about their presentations. The student creators of the course also acted as mentors for subsequent second-year student facilitators. Finally, *Methods* was overseen by a UCLA faculty member (AMA) who had designed a neuroscience methodology-focused seminar course during the previous year. *Methods* grew out of her course and she guided its year-to-year development and implementation.

Course Design

Methods was designed for weekly, 2-hour meetings over a 10-week quarter period and was listed as a seminar/literature review course. At each weekly session, two to three assigned readings were discussed: typically one review article focused on the method of interest and at least one experimental paper employing that technique. At the first meeting, the student course instructors gave an example presentation covering a review article on optogenetics and a primary research article that used an optogenetics study design. The instructors introduced an alternate approach to the standard journal-club style presentation that follows the structure of a primary research article (e.g., background, methods, results, discussion). Instead, student presenters were encouraged to 1) focus on the history, development, application, advantages and disadvantages of the assigned method; and 2) provide a critical interpretation of the results from the experimental paper (i.e., what might the study results mean in the context of known limitations of the method, was the method appropriate for the research question, how could the method have been used differently). Students were encouraged to use resources (e.g., JoVE, Wikipedia, textbooks) outside of the assigned reading to augment their understanding of the method and to prepare their presentations.

After the example presentation during week 1, students were asked to sign up to present on one of weeks 2-9. They were instructed to choose a week covering a method with which they had no past hands-on experience. To facilitate discussions, 1-3 "experts" were invited to class sessions. Experts were advanced UCLA graduate students who were actively engaged in using the method being covered that week. The experts served as co-leaders of the class discussions, provided critical commentary and bridged gaps in understanding. They were also valuable for their ability to correct misinformation or misconceptions regarding the use of a particular method. Experts' contact information was made available to student presenters so that they could also be consulted during the presentation preparation phase.

At the last meeting during week 10, students were instructed to prepare a 5-minute long “elevator-pitch” style presentation with no more than five accompanying slides. For the pitches, students focused on a method that they had hands-on experience using either in a previous research position or during their concurrent rotation. They were instructed to use their pitch to convince the audience that a particular method was the best one to address their research question and/or to test their hypotheses. The purpose of the elevator pitches was to encourage students to use what they had learned about presenting science from a methods-focused perspective. In *Methods*, we asked the students to tackle the difficult tasks of learning about a neuroscience method in a hands-off fashion and then presenting that method to their peers in a critical way. We wanted students to have the opportunity to apply what they learned about presentation and critical assessment skills to their own research. Our theory was that evaluating unfamiliar methods would provide new insight into the familiar methods our students use in their laboratories. The elevator pitches were an excellent capstone for students, who found the assignment fun and enjoyed hearing brief “pitches” by their peers.

Syllabus

The syllabus for the *Methods* course was separated into three modules: cellular, molecular and systems level neuroscience. Each module featured several corresponding neuroscience methods. The outline of the syllabus is included in the text that follows.

Week 1 - Introduction to the course and sample presentation on Optogenetics

Cellular Module:
- Week 2 – Innovative Approaches in Electrophysiology
- Week 3 – Two-Photon Microscopy

Molecular Module:
- Week 4 – Mapping Synaptic Contacts: Fun with Tracers
- Week 5 – Genetic Manipulation of Model Organisms
- Week 6 – Genomics and Bioinformatics

Systems Module:
- Week 7 – Behavioral Assessment in Model Organisms
- Week 8 – Structural MRI: DTI and Network Analysis
- Week 9 – Functional MRI: The BOLD Signal and the Resting Brain

Week 10 – Elevator Pitches

Course Assessment

An anonymous self-evaluation worksheet was prepared to assess students’ confidence with discussing research and methods outside of their primary research expertise. These worksheets were administered on the first and last days of the class and focused on assessing each student’s perceived confidence in reading, presenting and discussing advanced neuroscience methods.

There were nine items on the self-evaluation and students were asked to use a 10-point scale to rate each statement where 1=not at all/little to none/probably not and 10=very/definitely/very confident. The items were as follows:

1. I am familiar with a wide variety of methods currently being employed by neuroscientists.
2. I am confident in my ability to decide which methods should be used to address a wide variety of neuroscience research questions.
3. I understand the relative pros and cons to using competing neuroscience methods to address a research question.
4. I am comfortable approaching posters for studies that use methods outside of my particular research experience.
5. I find the language/terminology used in some neuroscience research papers intimidating.
6. I feel I can read and understand the methods section from journal articles outside of my expertise.
7. I feel comfortable presenting neuroscience journal articles to colleagues/peers.
8. I am confident in my ability to critically analyze the findings of any neuroscience paper.
9. I am confident in my ability to spot weaknesses in methods outside my own research background.

Finally, there was a prompt where students were asked at the first meeting to “include suggestions and comments about what you would like to get out of this course” and at the last meeting to “include suggestions and comments for improving the course; tell us about what you found useful and not so useful; which weeks/topics were your favorite/least favorite?”

Average ratings for each item on the first (time point 1; TP1) and last day of class (time point 2; TP2) were computed. Mean ratings for each student across all items at each time point were also calculated. Because the worksheets were completed anonymously, we could not examine changes in ratings for specific students, i.e., we could not carry out repeated measures analyses. Data were not normally distributed and thus, were analyzed using Wilcoxon rank sum tests to compare changes in ratings for each item and across items for TP1 *vs.* TP2. For item 5, lower scores indicated greater confidence. All statistical analyses were carried out using tools from the R Project for Statistical Computing (http://www.r-project.org).

RESULTS

The data described here were collected during the winter quarter, January - March 2013, at UCLA during the first implementation of *Methods*. We collected self-report worksheets from 11 students at TP1 and 12 students at TP2. Average ratings for specific items ranged from 5.7 – 7.0 at TP1 on the 10-point scale. At TP1, average ratings across all the items ranged from 3.7 – 9.7. Thus, across the class, self-reports of confidence in using, understanding and presenting unfamiliar methods varied widely. Interestingly, the highest student average at TP2 was 9.1, which was lower than the highest student average rating at TP1 indicating that there is variability in self-assessment across time. The range in student average scores at TP2 was 5.2 – 9.1. We compared students’ average ratings across the nine items at TP1 and TP2 and found that mean ratings increased over the course of *Methods* ($P<0.05$). Analysis of the self-evaluation individual item ratings at TP1 and TP2 revealed that the course significantly increased students' confidence in their familiarity with and ability to evaluate advanced neuroscience methods (items 1-3) with trends for positive outcomes in the other individual items; Figure 1). The average rating increased for each item from the first meeting to the last meeting of the course, except for item 5, which suggests less student intimidation by scientific terminology at TP2.

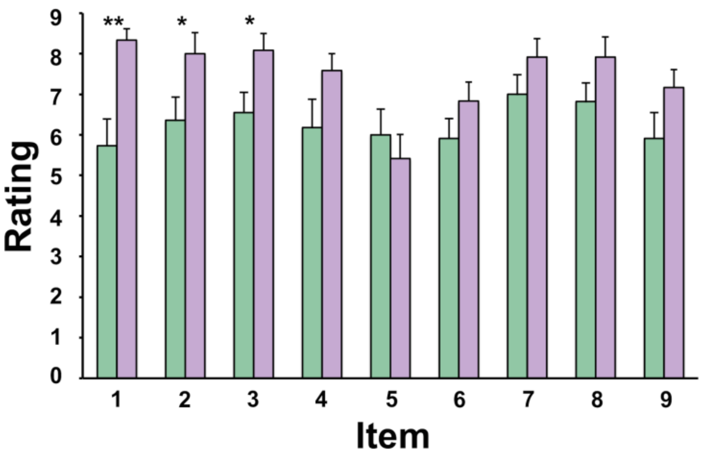

Figure 1. Average item ratings from student evaluations for each statement from the first (green, *N*=11) and last (purple, *N*=12) day of class. Mean ratings increased from the first to the last day for all statements except item 5 where a lower score reflected increased confidence (see item in *Materials and Methods*). Data are means ± standard errors of the means. *$P<0.05$ and **$P<0.01$ TP1 *vs.* TP2 for individual items.

In response to our prompt for what students would like to gain from the course, students wrote about wanting to start with the basics and build their neuroscience knowledge on a solid foundation. One student wrote, "I would like to get a basic understanding of a variety of methods. It often seems assumed that we have some background in a variety of techniques for which I have no prior knowledge, especially in genetics." Another student wrote that they hoped to gain a "more thorough understanding of the practical details/limitations of the methods we discuss."

At the final meeting, students were asked what aspects of the course they found useful or not useful. In general, the new course was well received and thought to be useful. Constructive criticism included some frustration with being asked to learn new methods from peers who were not experts themselves. For example, one student wrote, "It was hard to learn sometimes from people with little expertise in the research they were presenting. Perhaps assign two presentations to each person - one on a method in which they are expert and one where they are not an expert. Then a team of two can work together (one expert, one novice) on each methods presentation." Other students asked for more thorough coverage of certain topics they felt were underrepresented, like neurochemical techniques or nanoscience approaches to neuroscience topics.

DISCUSSION

We have developed and implemented a seminar-style course to teach neuroscience methods to first-year doctoral students in a non-laboratory environment. The *Methods* course is student-run by two facilitators and supported by the larger community of neuroscience doctoral students at UCLA and a faculty member. This approach with doctoral students learning and teaching together has been shown to be effective in other classroom models (Needelman and Ruppert, 2006; Ullrich et al., 2012). The *Methods* course aims to augment the traditional curriculum and emphasizes skills critical to the development of successful academics. The NSIDP grants doctorates in Neuroscience, a broad and interdisciplinary subject that requires concerted effort to familiarize oneself with the breadth of the field. *Methods* quickly gives first-year graduate students an opportunity to span that breadth through a presentation- and discussion-based literature review course.

Responses from the anonymous self-evaluation worksheets revealed that the course was successful in increasing student confidence when presenting and discussing neuroscience research and methods outside of their primary research expertise. Across students, the ratings for each item improved from the first meeting to the last meeting of the course. The increased confidence in exploring unfamiliar methods and topics is anticipated to encourage student participation in journal clubs, to motivate communication across disciplines at scientific conferences, to encourage rotations in a variety of laboratories, to identify courses in which to serve as a teaching assistant and to influence students' choices to employ a diverse set of methodologies in their own research.

One limitation of the course assessment was that the self-evaluations were collected anonymously with no opportunity to match individual student's ratings at the first meeting to their ratings at the final meeting (e.g., to run paired analyses). Another limitation was that subsequent *Methods* course graduate student facilitators have used their own approaches to assessing the value and effectiveness of the course (Ching et al., 2013; Einstein et al., 2014; DiTullio et al., 2015). That said, the focus of this report was to introduce the novel course design and to include the initial data indicating its success, not to perform a meta-analysis. Moving forward, we are partnering with the NSIDP leadership to create a standardized *Methods* evaluation and assessment tool that will enable data analysis across yearly implementations of the course.

One of the benefits of enabling each pair of facilitators the opportunity to improve and expand the course is the increased focus on presentation efficacy and skills. Now, as part of *Methods,* each student receives aggregated feedback from their peers on how clearly and effectively they presented their assigned material. As one of the founding goals of the course was to build students' confidence in their ability to prepare and present material outside their areas of first-hand expertise, we believe the addition of formal presentation feedback has strengthened the course overall. In addition, subsequent iterations of the course have, based on class size, allowed students to make two shorter presentations during the quarter so that presentation feedback can be directly applied to the second assignment. Finally, the elevator-pitch session at the end of the course has been modified to a 3-minute presentation with no accompanying slides. This approach encourages students to focus more on the content and style of their presentation instead of prepared slides, while still allowing them to apply what they learned about presenting neuroscience methods to their own research experience.

The most common criticism of *Methods* was that a particular technique might have been effectively explained and taught by a student that had prior experience using that technique. We do not disagree with this feedback; it is true that individuals who have first-hand experience are likely to present on a particular method more easily and effectively. However, a key goal of this doctoral-level course is to place students outside of their comfort zone and to illustrate how much can be gained by an in-depth and critical examination of an unfamiliar technique. Each week, presenters demonstrated an understanding of the basics and, sometimes, the subtleties of the method they were assigned. Experts assisted and their participation proved to be an effective way to focus the discussion when presenters struggled. We believe the challenges that students face in the *Methods* course are similar to challenges they will face in their professional careers. The opportunity to practice these skills is an important part of the doctoral training experience that, if provided in the curriculum, often requires non-traditional approaches (Needelman and Ruppert, 2006).

We believe *Methods* can be adapted to an upper-division undergraduate seminar course and would be a valuable addition to undergraduate science curricula. Our suggestions for this design are based, in part, on the feedback we received from our first-year doctoral students. There is a well-described lack of instruction on the scientific process in undergraduate education (Handelsman et al., 2004; Coil et al., 2010). *Methods* would serve as many undergraduates' first exposure to examining techniques as a primary aim, while gaining exposure to primary research articles. This exposure would begin to address the need for a more comprehensive undergraduate science education that includes critical evaluation of experimental design and interpretation of data (Kozeracki et al., 2006). By engaging in this type of critical thinking, undergraduates will be mentally stepping into the scientific process from the classroom. With graduate student co-facilitators and graduate student expert partners, *Methods* can be brought to a level appropriate for upper-division undergraduates. Students could pair or form groups to prepare joint presentations; preparation of presentations could be guided by graduate student experts. Thus, the burden of teaching the methods would not fall solely to the undergraduates. In addition to being a crucial part of an undergraduate version of the *Methods* course, the communication and discourse between doctoral students and undergraduates provides a low-barrier way for younger students to learn more about post-graduate science education and life as a doctoral student.

We have been gratified to see *Methods* continue to thrive after its initiation in 2013. Beyond this specific course, *Methods* serves as an example of how existing courses can be developed by students into student-led activities. We believe that the process of creating curricula is a social endeavor, with influences from the faculty, the students and the material itself (Tierney, 1989; Lindblom-Ylänne et al., 2006). In that spirit, each pair of subsequent student co-facilitators has added their own unique modifications, improvements and perspectives to *Methods* such that it continues to grow organically. However, the founding mission and goals of the course remain the same: to expose students to a diverse set of neuroscience research methods, to promote discourse between students at different stages of their degree and professional development, to encourage the practical analysis of current research and ultimately, to build student confidence in understanding neuroscience research outside their primary areas of expertise.

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