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Teaching Science Writing in an Introductory Lab Course

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One challenge that many neuroscience instructors face is how to teach students to communicate within the field. The goal of this project was to improve students' scientific writing in an introductory psychology laboratory course that serves as a feeder course into the neuroscience curriculum. This course included a scaffolded approach - breaking assignments into different sections that build upon each other to allow for more direction and feedback on each section. Students were also provided with examples of scientific writing, given direction on finding and reading journal articles, and were taught how to effectively peer review a paper. Research papers were assessed before (Year 1) and after (Year 2) this scaffolded approach was instituted. The assessment included measures of "Genre Knowledge" for each section of a research paper (abstract, introduction, method, results, discussion) as well as measures of "Writing Elements" (grammar, formatting, clarity, transitions, building to the hypothesis, using evidence). The results indicated that there was an improvement for Genre Knowledge scores when comparing Year 1 to Year 2. However, there was no systematic improvement in Writing Elements. This suggests that this teaching technique was most effective in improving students' ability to write within the scientific genre. The logistics of implementing such an approach are discussed.

Key words: neuroscience, science writing, genre knowledge, writing elements

A crucial skill that future neuroscientists must develop is the ability to effectively communicate their research. Recently, there has been a growing focus on the importance of teaching science process skills, including scientific literacy and writing, at the undergraduate level (Coil et al., 2010; American Psychological Association, 2013; Brownell et al., 2013), and students who can demonstrate their ability to write effectively are often desirable candidates for neuroscience graduate programs. Fischer and Zigmond (2004) recommend that students provide samples of their science writing in their neuroscience graduate school applications to illustrate to the admissions committee their potential as a neuroscientist. Further, writing ability was listed as one of the top skills sought after by graduate schools (Appleby et al., 1999), and poor writing was cited as one of the top five "kisses of death" in graduate school applications (Appleby and Appleby, 2006). Thus, graduate programs are acutely aware that successful neuroscientists need to be able to be effective science writers.

Despite the strong need for neuroscientists to be effective writers, many students have not effectively learned how to write in their field by the end of their undergraduate careers (Jerde and Taper, 2004). This lack of preparedness or skill in scientific writing does not appear to be due to a lack of concern for science writing and other science process skills among undergraduate faculty. In fact, in a recent survey of life science faculty, oral and written communication was listed among the most important categories for undergraduate education (Coil et al., 2010). However, as detailed by Coil and colleagues, the majority of faculty respondents felt that they did not spend nearly enough time teaching these skills, primarily because of the significant time commitment involved and the need to focus on more traditional content learning. However, by not devoting significant time and resources to the development of science process skills, such as scientific writing, students may be left unprepared for the writing demands and other requirements of graduate education and professional careers in neuroscience (Adams, 2011).

The critical need for early training in science writing is especially salient when one considers the interdisciplinary nature of neuroscience. Neuroscientists often need to communicate to an audience that comes from a number of different backgrounds. Moreover, neuroscientists often need to flexibly write within the sciences, following each journal's structural requirements. Therefore, we feel that it is essential to introduce structured scientific writing early in the undergraduate curriculum in order to start building the foundation of these skills. To address this interdisciplinary field, our goal was to draw from a number of different scientific disciplines in an introductory psychology course, which acts as a feeder course to both the psychology and neuroscience curricula.

In the past, the teaching of science literacy and communication has been approached using a wide range of pedagogical strategies. For instance, the incorporation of primary scientific literature is often used as a means to improve critical thinking skills while exposing students to the process of science and the discipline-specific characteristics of science writing (i.e., the genres of science writing). Explicit instruction on how to read and interpret scientific articles, even at the introductory level, has been found to significantly improve scientific literacy, including understanding of how science is conducted and how scientific articles are structured, as well as how to interpret and draw conclusions from data (e.g., Krontiris-

Litowitz, 2013). However, in order to effectively comprehend and analyze scientific literature, students must first be familiarized with the genre of science writing (Gillen, 2006).

For our purposes, we draw on Bawarshi's (2003) understanding of genre as a site where writing takes place. "To write is to position oneself within genres," he writes, "to assume and enact certain situated commitments, identities, relations, and practices" (p. 14). Essay assignments, literature reviews, and the scientific lab report are often the initial sites of entry into science discourse practices for many undergraduates. Beyond necessary skill training for neuroscience students, genre-specific writing can have significant benefits for both non-science and science majors alike. For instance, science writing encourages students to develop and support an argument and communicate their findings in a clear and concise manner while following specified formatting guidelines. Students who are encouraged to write in a variety of genres also become more apt to understand audience and its relation to specific field knowledge. Finally, science writing has been hypothesized to help initiate and reinforce new learning. According to Keys (1999), "Writing in scientific genres promotes the production of new knowledge by creating a unique reflective environment for learners engaged in scientific investigations" (p. 119). In short, scientific genre knowledge helps create content knowledge. Further, knowing the predominant genres in a field is, in fact, knowing part of the content of that field. This may be especially salient as it may be the only time to reach those students who do not go on to a career in the sciences. As many faculty may be postponing teaching scientific writing until students reach upper-level neuroscience courses, many beginning college students and non-science majors may not receive any instruction in science writing and science literacy, leaving them without the skills necessary to critically evaluate scientific claims (Firooznia and Andreadis, 2006; Coil et al., 2010). Through this training, students of all majors may be better positioned to critically interpret and analyze neuroscience research as presented in the popular press and support funding of neuroscience research.

One hurdle that many instructors have to overcome in teaching science writing is that students are often at a loss on how to approach these writing assignments due to their lack of understanding of the discipline-specific conventions of science writing (Krest and Carle, 1999). By instituting structured and scaffolded approaches to the teaching of science writing, previous studies have shown significant improvements in the quality of writing, as well as in critical thinking skills, academic performance, and self-confidence in the ability to understand primary scientific literature and effectively communicate scientific results (DebBurman, 2002; Dirks and Cunningham, 2006; Quitadamo and Kurtz, 2007; Coil et al., 2010; Libarkin and Ording, 2012; Brownell et al., 2013). Perhaps even more striking, Birol and colleagues (2013) found that repeated science writing assignments produced the most profound improvement in writing in the lowest-performing students. This may suggest that inclusion of writing may be especially useful as a targeted intervention aimed at improving learning and educational performance in struggling students.

Although the value of writing exercises has been well explored, few studies have quantitatively assessed how teaching formal discipline-specific writing, such as laboratory reports in the style of primary research articles, impact genre knowledge (or knowledge of the conventions and practices of the discipline) and writing skills. Moreover, relatively few studies have examined the impact of a genre-specific writing curriculum within a 100-level introductory science course. We feel that this introduction to formal scientific writing early in the undergraduate career, rather than a generalized focus on college-level writing, is critical for both neuroscience and non-science majors. As described by Jerde and Taper (2004), prior experience with scientific writing, but not general instruction in college-level writing, was associated with significantly better performance on an upper-level science writing assignment. Therefore, the best prescriptive for improved writing in neuroscience may simply be more experience with science writing.

In order to meet these writing goals, we chose to restructure an introductory laboratory course. The Introduction to Psychological Science course was chosen, as it is a 100-level laboratory science course that is both a general education course as well as a feeder course into the neuroscience and psychology curricula. This course is an important part of the curricular skill development because the focus is on the development of science process skills as opposed to discipline-specific techniques that may predominate in upper-level laboratory courses. This course uses the publication guidelines of the American Psychological Association (APA), which we feel gives students very structured guidelines for the specific genres they will be asked to write in Psychology and Neuroscience, but may also provide students with opportunities to learn a genre they are not familiar with when they come to college. Since APA style is very detailed, we feel that it also can be used to start to train students to follow instructions to the minute detail – a skill that is extremely valuable to future scientists. Furthermore, their writing abilities will fluctuate as they begin to write in this new genre, but their genre knowledge will help solidify their course experience and influence future writing in the discipline.

Specifically, this introductory laboratory course was restructured to more gradually and explicitly teach the discipline-specific conventions that characterize formal science writing. It also introduced students to the necessary science literacy skills needed to effectively analyze existing scientific literature in neuroscience and psychology. To help improve genre knowledge, we instituted a pedagogical design that first introduced students to the genre of science writing through analysis of scientific literature and its structural components and functions (Coil et al., 2010; Bean, 2011; Colabroy, 2011; Senkevitch et al., 2011). In addition, we utilized exercises that allowed students to practice science writing in a low-stakes, informal setting, as repeated practice with science writing has been cited by students as a critical factor that

improved their overall writing abilities (Brownell et al., 2013). Finally, we used a structured approach that emphasized mastery of each section of a scientific report (written in the style of an APA journal article). By using this approach, combined with an emphasis on instructor assistance and modeling, we sought to examine whether genre knowledge would significantly improve.

Moreover, we determined whether a focus on genre knowledge would have the added benefit of improving general writing skills. This question of focus on genre knowledge and improvement of writing is one that has not been answered. In fact, the debate over how discipline-specific writing genres are "threshold concepts," or concepts that students must grasp prior to advancing their knowledge in a given field (Land and Meyer, 2010), is yet to be studied. Unlike the grammatical conventions of Standard Written English that is focused on throughout a student's entire course of study, genre allows entry into specific disciplines. However, it is unknown how a specific focus on genre may impact general writing skills. In the current study, we have constructed a repeatable, and we believe, productive, model of pairing the teaching of writing as a content (genre) with the teaching of an undergraduate neuroscience curriculum. What we observed was that genre knowledge advanced as students better understood the specific stances and moves of discipline-specific writing.

METHODS

Project Population. The study took place over two semester-long iterations of Introduction to Psychological Science at Wofford College, an undergraduate liberal arts institution. This course, which included both a lecture and a laboratory component, could be used for students to fulfill a general education requirement in the sciences, but was also a prerequisite for both neuroscience and psychology courses. Each section had approximately 22 students, with the majority of students being first-years or sophomores. In Year 1 there were a total of 40 students across two sections (22 female). In Year 2 there were a total of 47 students across two sections (30 female). One instructor (KRMS) taught in both years, while the instructor for the second section differed between Year 1 and Year 2. For the purpose of the assessment, a random blinded sample of 72 lab reports was taken, with 36 papers sampled from each year, and equal numbers collected from each section of the course.

Year 1. In the first year, students were expected to write three full lab reports, which included a title page, abstract, introduction, method, results, discussion and references. One laboratory period was dedicated to teaching science writing at the beginning of the semester. During this session, students were given preliminary instruction on APA style in an active lecture format. Students also completed an activity related to reading scientific papers and read a sample paper. A subsequent lab period focused on statistics. Following these two introductory labs, three different lab modules were conducted over the course of the semester. Three lab periods were used for each experiment: data collection, data analysis, and peer review. For each lab report, students were required to meet with the teaching assistant (TA) and undergo a peer review process in which students exchanged papers and commented on each other's work using a rubric provided by the instructor. No detailed formal instruction on how to conduct a peer review was given during Year 1.

Year 2. In order to examine the influence of a scaffolded approach to the teaching of science writing, certain systematic changes were made to the laboratory course. We adjusted the introductory lessons to more explicitly introduce the overall components of a scientific paper and science writing, and writing assignments were adjusted to use a structured approach that focused on writing and mastery of each section. Through this deliberate manipulation, we could compare how student writing changed in comparison to the previous year's writing which did not include these elements.

Introduction to the genre. As described in Table 1, students were introduced to the scientific method and how it is communicated during the first lab class meeting. The instructor discussed the scientific method and introduced students to peer-reviewed literature and APA style. Handouts on APA style were distributed and the instructor went over each section of a scientific article with students, highlighting its structure and purpose. Students were then assigned to read a peer-reviewed scientific article that would be easily accessible to undergraduate students as an example of APA style and scientific writing (Carney et al., 2010) and were given guided reading questions to answer in preparation for the next lab period. Articles were chosen that showed common methods within both neuroscience and psychology. Finally, with the assistance of a reference librarian, students were introduced to how to search for peer-reviewed journal articles using common library databases in psychology. In order to give students practice using these databases, small groups were given a range of topics to search for, including "Does birth month predict the occurrence of schizophrenia?", "Does meditation benefit your brain?", etc., and were asked to present their findings to the class.

For the second lab, students discussed the assigned article (Carney et al., 2010) in small groups and answered questions about where they would find specific information within a scientific article using Gillen's (2003) web-based tutorial 'Reading Primary Literature in Biology' (www.biology.kenyon.edu/Bio-InfoLit/index.html). To begin to introduce the mechanics of scientific writing and analysis, students worked with an example dataset on rates of alcohol drinking among college students. Small groups were assigned a research question (for instance, sex differences in weekly or peak alcohol consumption, age differences in alcohol consumption, etc.), and were instructed on how to analyze the dataset and make a graph using SPSS and Excel software. Each student group submitted a graph, figure caption and results sentence (in APA format) to the instructor and received feedback on writing style and APA formatting.

Week	Learning Outcome(s) *Students will be able to:*	Activities, Handouts and Assignments
1	▪ Describe the structure of an APA-style paper. ▪ Find peer-reviewed journal articles using common databases in psychology.	▪ **ACTIVITY 1:** Guided introduction to science writing and APA style. ▪ **ACTIVITY 2:** Introduction to literature searches by reference librarian. ▪ **HANDOUTS:** APA style guide. ▪ **ASSIGNMENT:** Research paper (Carney et al., 2010) and guided reading questions.
2	▪ Read primary literature and summarize key findings. ▪ Generate figures and captions. ▪ Write a results sentence.	▪ **ACTIVITY 1:** Guided discussion of research paper and structure. ▪ **ACTIVITY 2:** Group analysis of data set, creation of figures and results write-up. ▪ **HANDOUTS:** Practice data set and research question.
3	▪ Read primary literature and summarize key findings. ▪ Describe the purpose of each section of a scientific article. ▪ Write a simplified methods and results section in APA format.	▪ **ACTIVITY 1:** Reading and discussion of findings / purpose of each section of a research article (Beall and Tracey, 2013). ▪ **ACTIVITY 2:** Group write-up of methods and results section using example research protocol and results (experiment writing prompt). ▪ **HANDOUTS:** 'Says / Does' worksheet (Bean, 2011); simple APA methods and results example**; experiment writing prompt**.
4-6	▪ Write a methods and results section, generate figures. ▪ Create a peer review rubric. ▪ Effectively peer review a laboratory report.	▪ **ACTIVITY 1 (Week 6):** Jigsaw groups discuss criteria for scientific writing and draft peer review rubric. ▪ **ACTIVITY 2 (Week 6):** Jigsaw groups critique 'interestingly problematic' lab report using rubric. Guided discussion of problems and recommendations for revision. ▪ **ACTIVITY 3 (Week 6):** Peer review groups assigned (with representative from each jigsaw group). Peer review of student papers using grading rubric. ▪ **HANDOUTS**: Guided instructions for method and results sections; 'interestingly problematic' lab report for peer review; grading rubric. ▪ **ASSIGNMENT:** Lab report 1 – Title page, methods, results (including figures).
7-9	▪ Read a research paper and use findings to motivate experimental hypothesis. ▪ Write a concise and informative introduction that motivates the hypotheses. ▪ Write a methods and results section, generate figures. ▪ Effectively peer review a laboratory report.	▪ **ACTIVITY 1 (Week 8):** Guided small group and classroom discussion of assigned research articles; focus on how results inform experimental hypotheses. ▪ **ACTIVITY 2 (Week 8):** Guided instruction on writing an introduction; evaluation of example introduction section and outline. ▪ **ACTIVITY 3 (Week 9):** Peer review of 'interestingly problematic' lab report using grading rubric. Guided discussion of problems and recommendations for revision. ▪ **ACTIVITY 4 (Week 9):** Peer review of student papers using grading rubric. ▪ **ACTIVITY 5 (Week 9):** Individual meeting with instructor to receive feedback on introduction. ▪ **HANDOUTS:** Peer-reviewed research papers (2) and guided reading questions; example introduction section**; guided outline for introduction; guided instructions for method and results sections; grading rubric. ▪ **ASSIGNMENT:** Lab report 2 – Title page, introduction, methods, results (including figures), references.
10-12	▪ Find relevant peer-reviewed journal articles using common databases in psychology. ▪ Write a complete lab report in the format of a scientific journal article. ▪ Effectively peer review a laboratory report.	▪ **ACTIVITY 1 (Week 10):** Research groups identify research question and perform literature search for 2-3 peer-reviewed publications. ▪ **ACTIVITY 2 (Week 11):** Guided instruction on writing an introduction and discussion section. ▪ **ACTIVITY 3 (Week 11):** Review of articles and introduction outline with instructor and/or TA. ▪ **ACTIVITY 4 (Week 12):** Peer review of student papers using grading rubric. ▪ **HANDOUTS:** General guidelines and suggested outline for introduction and discussion**; instructions for abstract; grading rubric. ▪ **ASSIGNMENT:** Lab report 3 – Title page, abstract, introduction, methods, results, discussion, references.

Table 1. Description of assignments and activities incorporated in Year 2. ** Handout included in Supplemental Material.

Finally, in order to continue to help students understand the formatting and style of science writing, students read and discussed a primary research article and wrote a subsection of a research article using provided data. Using the 'Says/Does' structured worksheet described by Bean (2011), students read a primary research article that was chosen for its interest and accessibility to introductory students (Beall and Tracey, 2013). In small groups, they read each paragraph and section and discussed not only the content of the paragraph (i.e., 'Says'), but also what function each paragraph and section served within the scientific report (i.e., 'Does'). In addition, students were given the opportunity to practice writing a method and results section in a low-stakes, group format. First students were given a simplified example of a method and results section (see Supplementary Material), as well as detailed instructions and comments on formatting and writing style. Students were then given a hypothetical experiment that asked whether blood pressure decreased after taking an exam (see Supplementary Material). Key participant and procedural details, as well as hypothetical data and analyses were provided. In pairs, students created a mini-APA style report including title page, method, results, and graph, and submitted the report to the instructor for feedback on style.

Lab report 1 (weeks 4-6): Method and results. The first experiment and written lab report was performed over weeks 4-6 (see Table 1). In Year 2, the same experimental procedures were used as Year 1, but rather than requiring students to write a full lab report in the style of a journal article, students were assigned to write a title page, method section, results section, and graphs. The rationale for breaking this assignment down and beginning with the method and results was that these sections are the most discipline-specific and are often very difficult for novices to write due to lack of experience writing in this genre. Often students would revert to narrative or overly descriptive writing styles, and so emphasis was placed on using simple and direct language in these sections. To assist students, outlines were provided that included the necessary material and procedural details that would need to be included, as well as an outline that listed all the statistical comparisons to be done.

In Year 2 we continued the use of peer review on a lab report draft; however, a few key changes were instituted to improve the quality of the peer review process. In our experience, students are often ill equipped to provide constructive comments on their peer's writing, so more explicit instruction and opportunities to practice peer review were incorporated into the Year 2 curriculum. As described in Table 1, we used a jigsaw classroom approach: students were first divided into small groups and assigned a section of the lab report (i.e., title page and formatting, method, results, graphs) and created a draft rubric of what was required for each section. Students were told that they would then be considered the 'expert' for the assigned section in their peer review groups. These guidelines were then discussed as a class, and students read an 'interestingly problematic' paper (a blinded student paper from a previous year that did some things well, but needed significant improvement) in order to apply these guidelines to the review of a paper draft. As a class, each section of the problematic paper was discussed and solutions were suggested for revision. Finally, peer review groups were created, which included one student from each jigsaw group, and a copy of the grading rubric was distributed. Students then exchanged papers and provided feedback in the style that had been previously demonstrated. Prior to turning in the final draft of the paper, students were also required to meet with the lab TA outside of class for review.

Lab report 2 (weeks 7-9): Introduction, method and results. For this report, students were asked to write a full introduction section, along with the method and results. In order to assist students with constructing an introduction, an example (see Supplementary Material) was distributed and discussed in class. As this was also the first lab report that required the inclusion of primary literature, a significant amount of time was dedicated to literature review. All students were assigned two research articles that would be the basis for the current experiment, and guided reading questions were assigned as homework. In addition, an explicit outline was given to students to help them structure the introduction section. Briefly, students were asked to introduce the topic in paragraph one and its significance, review relevant literature in paragraph two, and highlight what remained unknown in paragraph three, thereby motivating the research purpose and directional hypotheses presented in paragraph four. The purpose of this outline was to create a structured guide on how to write the introduction, helping point students to the relevant details of the primary literature that would need to be included, and helping them learn how to structure their argument and motivate their hypotheses. This genre feature is analogous to some previous knowledge students may possess, but identifies the key structures of the genre that often trouble students.

Similar to the previous peer review session (see above), an interestingly problematic paper was distributed to students that included an introduction, method and results from a previous year on the same topic. Using a grading rubric, students read and commented on this paper and discussed suggestions for revision as a class. Emphasis was also placed on whether the introduction clearly led to the hypotheses. In addition to the group peer review of student papers and TA review, which matched previously described methods, students were also required to meet with the instructor for a brief review of their introduction section. The instructor review was added as many students needed more explicit advice on how to write and structure this section.

Lab report 3 (weeks 10-12): Abstract, introduction, method, results, and discussion. For the final lab report, students collected data on a number of different variables, and were given the choice on which research question to

pursue (i.e., students had the opportunity to select a range of comparisons to analyze within a large dataset examining personality variables and health-related behaviors). As each student's topic was unique, each student was required to find their own supporting primary research articles in order to incorporate into their introduction and discussion sections. The TA gave a short refresher on online literature searches, and students were required to select two-three relevant sources for their papers and to receive approval on these choices from the instructor or TA. In addition, a general outline was given to students on how to structure their introduction, and more explicit outlines and guidelines were distributed and discussed on how to write a discussion section (see Supplementary Material). Similar to previous lab reports, peer review was conducted prior to the report being turned in, and students were encouraged to discuss drafts with the instructor.

Assessment. Using assessment strategies common in the field of composition studies (Yancey, 1999; Huot, 2002; Walvoord, 2010), the assessment was designed as follows. Across the two years, the third lab report of the semester was used for the purpose of the assessment, which was on the same topic and was the only assignment across the two years to include a full, journal article-style lab report. The primary focus of the assessment was the shift in the teaching focus of the course to include an emphasis on the genre conventions ("Genre Knowledge") outlined in APA style. However, the conventions of writing ("Writing Elements") were also assessed as a secondary question in order to determine if these also improved when genre knowledge was specifically taught. Reviewers included two psychology professors, who were also instructors for the courses and involved in the restructuring of the course, as well as the director of the writing center at Wofford College. Each reviewer had an approximately equal number (21 or 22) of papers, randomly selected from the entire pool of papers. Reviewers were blind to student identity, instructor, and year. Reviewers rated lab reports on a rubric that included two sections: Genre Knowledge and Writing Elements (see Table 2). Each category was rated on a one to four scale. All reviewers read and assessed eight articles together in order to standardize assessment techniques and assure that the majority of assessment ratings were within one point difference.

Data Analysis. Because the data were ordinal, median scores were used for all analyses. To make comparisons on each rating scale between Year 1 and Year 2, non-parametric Mann-Whitney U tests were conducted. These tests were Bonferroni-corrected to account for multiple comparisons, where appropriate. Effects sizes were calculated for each comparison using Pearson's correlation coefficient r. To control for any potential biases between reviewers, eight papers (four from each year) were randomly selected from each reviewer to be used in the analyses. Median scores between the three reviewers were used for the eight articles that were read by all reviewers. Thus, 32 papers were included in the analyses: eight from each of the three reviewers and the eight commonly read papers.

GENRE KNOWLEDGE
Abstract: Should include a sentence about each primary section of paper. No more than 250 words
Introduction: What is the general topic? What do we know from previous research? What is new about the current paper? What are you going to try to demonstrate? What are your hypotheses? Formal scientific language.
Methods: Participants: Describes sample Apparatus and/or materials: Describes computers, tests, materials used Procedure: What did the participants do? What did the researchers do with the subjects?
Results: What statistical tests were conducted and what were the findings? (no interpretation)
Discussion: Restates purpose and hypotheses. What is the interpretation of the findings? How can study be improved (what are the flaws)? What are the future directions?
WRITING ELEMENTS
Introduction leads to hypothesis
Transitions clear between paragraphs
Uses evidence and shows understanding of literature / background reading
Writing is clear and direct
Writing is free of grammatical errors
APA citations and format followed throughout

Table 2. Grading rubric. Each element was scored on a 4 point scale: 4 = excellent, 3 = good, 2 = fair, 1 = weak.

RESULTS

Reviewer. In order to determine any potential differences between individual reviewers in the assessment of Genre Knowledge and Writing Elements, median scores were compared between the three reviewers and the commonly read papers using a Kruskal-Wallis Test. This test revealed no significant differences between reviewers for either Genre Knowledge ($H(3) = 4.80$, $p = .19$) or Writing Elements ($H(3) = 5.06$, $p = .17$).

Genre Knowledge. Median values for Genre Knowledge across sub-categories were compared between Year 1 and Year 2 using a Mann-Whitney *U* test. Overall, there was a significant effect of year on Genre Knowledge ($U = 211.0$, $z = 3.35$, $p < .001$, $r = .59$). Students in Year 2 ($Mdn = 3.0$, $IQR = 3.0\text{-}4.0$) showed significant increases in genre scores as compared to students in Year 1 ($Mdn = 2.0$, $IQR = 2.0\text{-}3.0$).

Bonferroni-corrected Mann-Whitney *U* tests were then used to compare Year 1 and Year 2 for each element of Genre Knowledge (resulting in a critical value of $p < .01$). Scores were significantly higher in Year 2 than in Year 1 for the introduction, method, results, and discussion. See Table 3 for a breakdown of median scores and statistical comparisons.

Writing Elements. Median values for Writing Elements across sub-categories were also compared between Year 1 and Year 2 using a Mann-Whitney *U* test. Contrary to the Genre Knowledge comparison, there was no significant effect of year on Writing Elements ($U = 161.5$, $z = 1.34$, $p = .21$, $r = .36$), nor was there any significant effect of year on any comparison of individual writing elements.

GENRE Section	YEAR 1 *Mdn* (*IQR*)	YEAR 2 *Mdn* (*IQR*)	COMPARISON (Mann-Whitney U)
Abstract	2.5 (2.0-3.0)	3.0 (2.25-4.0)	$U = 178.0$, $z = 2.01$, $p = .06$, $r = .37$
Introduction	2.0 (1.25-2.0)	3.0 (2.25-4.0)	$U = 226.5$, $z = 3.97$, $p < .001$*, $r = .70$
Method	2.5 (2.0-3.0)	3.5 (3.0-4.0)	$U = 224.0$, $z = 3.94$, $p < .001$*, $r = .70$
Results	2.0 (2.0-3.0)	4.0 (3.25-4.0)	$U = 235.0$, $z = 4.25$, $p < .001$*, $r = .75$
Discussion	2.0 (1.0-3.0)	3.0 (2.63-4.0)	$U = 192.5$, $z = 2.53$, $p = .01$*, $r = .32$

Table 3. IQR reflects the interquartile range. *Signifies a statistically significant result using a Bonferroni-corrected Mann-Whitney U test to account for multiple comparisons. Significance was set at $p < .01$.

Student Evaluations. Students were asked to reflect on their experiences after going through the new laboratory-writing course. Common themes in these evaluations were as follows:

1) *Students felt that they learned the genre knowledge of science writing and building an argument based on prior literature.*

"I feel that I learned the structure of the lab and how to use articles to further expand my argument."

"I feel like I have learned how to properly write a lab report, understand lab reports, and how to explain why previous studies are relevant to the current research."

"I learned to write in a scientific manner, to use previous literature to support a conclusion, attention to detail (APA format)."

2) *Students felt the most challenged by writing the introduction and discussion.*

"The most challenging aspect was writing a good introduction and discussion because they are precise, but somewhat unknown."

3) *Students found feedback, be it from the instructor, the teaching assistants, or the peer review, to be helpful.*

"The process of peer revision and TA revision is also hugely beneficial."

4) *Students found the examples (either instructor-provided, or journal articles) to be helpful.*

"I would say what helped the most would be the outlines and in class examples of how to write each part."

5) *Students felt that they grasped each section more thoroughly by tackling them one at a time.*

"I feel that by progressively learning each section I learned more than all at once."

"The most helpful was breaking down each section and giving us examples of how to do it."

DISCUSSION

The focus on science writing in this laboratory course led to higher ratings in Genre Knowledge, but not in Writing Elements. This may be because improving writing within the genre was a main goal of the course, and many of the course discussions were focused specifically on science writing. We propose that the key to improvements in Genre Knowledge observed in this study was due to: 1) the structured and scaffolded approach, which allowed students to focus on one section of the paper at a time with significant support from the instructor, 2) the focus on repeated exercises to give students practice in writing within the genre, and 3) consistent feedback on student writing.

Many students lack experience in science writing when they enter college. Therefore, there may have been the biggest gains in Genre Knowledge as it was an area that started at lower proficiency. The largest effect sizes within Genre Knowledge were for the Introduction, Method, and Results sections. As described in Table 1, students had more practice with these sections as they wrote them for multiple assignments. These sections were also the only ones in which students all had received feedback from the instructor in Year 2. In contrast, the abstract and discussion sections had the lowest effect sizes. However, what's striking is that in Year 1, the assessed assignment (lab report 3) was the third time that students had written an abstract and discussion. In Year 2, this was their first time writing these sections, yet significant improvements were still seen above Year 1. We hypothesize that in Year 2 the more explicit focus on scientific literacy, the structure of the scientific paper, and how to communicate scientific evidence to readers led to improvements in writing even without the additional practice. Therefore, benefits in genre-specific knowledge may occur even without repeated practice.

Understanding genre knowledge may have a number of different benefits. For the students who go on to a career in science, these skills will be invaluable in their field. However, for students who pursue other careers, there are many benefits as well. Through writing, students learn to have a deeper understanding of scientific knowledge (Keys, 1999). Students also learn how to create an argument, how to write using direct language, how to pay attention to detail, how to follow a specified format, and how to attach writing purpose to audience. This kind of writing fosters the development of critical thinking skills, the cornerstone of the liberal arts education (Wade, 1995). Further, these students learn to be better consumers of the scientific literature as they now have experience reading peer-reviewed sources as well as the understanding of what it takes to conduct and analyze such experiments (Firooznia and Andreadis, 2006).

Though learning to write within the genre is important, we also sought to improve students' general writing abilities. This assessment included clarity of writing, grammar, APA formatting, transitions, and using evidence to support an argument from the primary scientific literature (see Table 2). Perhaps because genre was the focus of the course, scores on Writing Elements did not significantly

improve. General writing skills are an important part of many of the courses that will be taken in college. Although we did not find a significant improvement in writing skills, in general, teachers of writing understand that students learning new or difficult content (and genres) often experience slippage in grammar and mechanics. Given this, it may be that a structured approach to teaching genre may not effectively soften that slippage. However, this groundwork at the introductory level does allow students entry into the field, and may have lasting effects on their ability to navigate future writing situations – inside and out of science courses.

As described in the student evaluations of the laboratory-writing course, receiving feedback during the writing process was one of the key factors that helped improve student writing. Although peer and TA review had been incorporated into the prior iterations of the course, we expanded our implementation of the peer review process, with students being given more explicit instruction on how to conduct peer reviews as well as access to the grading rubrics during the peer review periods. Students were also given more opportunities for instructor feedback during the drafting process (either in individual appointments or in class) in order to revise and incorporate this feedback prior to turning in the final paper. Although time consuming, we feel that incorporation of extensive instructor and peer feedback during the writing process helps improve student writing. Other studies have found this to be true as well (Stellmack et al., 2012; Brownell et al., 2013; Walker and Sampson, 2013). For example, in an upper-level writing-intensive undergraduate biology course students strongly agreed that receiving feedback from the course TAs and participation in the peer review process improved the quality of their writing (Brownell et al., 2013). Students also often rely on instructor feedback in order to make changes. This feedback, when given in process, is most useful. If students are expected to take feedback on final drafts and apply it to the next writing situation, there is little or no improvement (Haswell, 1983). Therefore, we see any means of intervention during the drafting stage — whether it be by the instructor, by a TA, or even by peers — allows for improved writing.

Providing the foundational knowledge and skills needed for neuroscience education is critical in building a neuroscience curriculum. We feel that writing in discipline-specific genres is one of these skills (and content) that should be addressed early on. Even at an introductory level we found that more explicit instruction in discipline-specific writing improved student genre knowledge. Limitations were that teaching writing in this way was a very time intensive process. In future iterations of this course, we hope to improve upon student writing by including more practice in writing the discussion section, as students found this to be one of the most difficult sections to write. Teaching this kind of writing is essential for neuroscience students because it includes not only teaching how to write, but also how to interpret the literature, break it down to its primary findings, and use this to build an argument and support a discussion. It requires extensive drafting and feedback to help students refine their writing. These skills are difficult to develop in one semester. We feel that the strongest way to assist students in developing these skills would include continuing to build upon the intensive writing instruction in future neuroscience courses. As students begin to develop the skill of scientific writing, this could be used as a springboard to focus on knowledge development in more advanced courses. Through continued exposure to primary literature, and improvement of science writing, students can continue to develop critical thinking and higher-level cognitive reasoning skills, as well as improve their understanding of science and their ability to communicate effectively.

REFERENCES

Adams J (2011) “Writing in neuroscience”: a course designed for neuroscience undergraduate students. J Undergrad Neurosci Educ 10:A50-A57.

American Psychological Association (2013) APA guidelines for the undergraduate psychology major: version 2.0. Retrieved from http://www.apa.org/precollege/undergrad/index/aspx.

Appleby DC, Appleby KM (2006) Kisses of death in the graduate school application process. Teach Psychol 33:19-24.

Appleby D, Keenan J, Mauer B (1999) Applicant characteristics valued by graduate programs in psychology. Eye on Psi Chi, 3:39.

Bawarshi AS (2003) Genre and the invention of the writer: reconsidering the place of invention in composition. Logan, UT: Utah State Univ Press.

Beall AT, Tracy JL (2013) Women are more likely to wear red or pink at peak fertility. Psychol Sci 24:1837-1841.

Bean JC (2011) Helping students read difficult texts. In: Engaging ideas: the professor’s guide to integrating writing, critical thinking, and active learning in the classroom (2nd ed), pp161-182. San Francisco: Jossey-Bass.

Birol G, Han A, Welsh A, Fox J (2013) Impact of a first-year seminar in science on student writing and argumentation. J Coll Sci Teach 43:82.

Brownell SE, Price JV, Steinman L (2013) A writing-intensive course improves biology undergraduates’ perception and confidence of their abilities to read scientific literature and communicate science. Advan in Physiol Edu 37:70-79.

Carney DR, Cuddy AJC, Yap AJ (2010) Power posing: brief nonverbal displays affect neuroendocrine levels and risk tolerance. Psychol Sci 21:1363-1368.

Coil D, Wenderoth MP, Cunningham M, Dirks C (2010) Teaching the process of science: faculty perceptions and an effective methodology. CBE Life Sci Educ 9:524-535.

Colabroy KL (2011) A writing-intensive, methods-based laboratory course for undergraduates. Biochem Molec Biol Educ 39:196-203.

DebBurman SK (2002) Learning how scientists work: experiential research projects to promote cell biology learning and scientific process skills. Cell Bio Educ 1:154-172.

Dirks C, Cunningham M (2006) Enhancing diversity in science: is teaching science process skills the answer? CBE Life Sci Educ 5:218-226.

Firooznia F, Andreadis DK (2006) Information literacy in introductory biology. J Coll Sci Teach 35:23-27.

Fisher BA, Zigmond MJ (2004) Helping students get into graduate school. J Undergrad Neurosci Educ 3:A4-A8.

Gillen CM (2003) Reading primary literature in biology. Retrieved from www.biology.kenyon.edu/Bio_InfoLit/index.html.

Gillen CM (2006) Criticism and interpretation: teaching the persuasive aspects of research articles. CBE Life Sci Educ

5:34-38.
Haswell RH (1983) Minimal marking. Coll Engl 45:600–604.
Huot B (2002) (Re)Articulating writing assessment for teaching and learning. Logan, UT: Utah State Univ Press.
Jerde CL, Taper ML (2004) Preparing undergraduates for professional writing: evidence supporting the benefits of scientific writing within the biology curriculum. J Coll Sci Teach 33:33-36.
Keys CW (1999) Revitalizing instruction in scientific genres: connecting knowledge production with writing to learn in science. Sci Ed 83:115-130.
Krest M, Carle DO (1999) Teaching scientific writing: a model for integrating research, writing, and critical thinking. Am Biol Teach 61:223-227.
Krontiris-Litowitz J (2013) Using primary literature to teach science literacy to introductory biology students. J Microbiol Biol Educ 14:66-77.
Libarkin J, Ording G (2012) The utility of writing assignments in undergraduate bioscience. CBE Life Sci Educ 11:39-46.
Land R, Meyer JHF (2010) Threshold concepts and troublesome knowledge (5): dynamics of assessment. In: Threshold concepts and transformational learning (Meyer JHF, Land R, Baillie C, eds), pp61-80. Rotterdam, The Netherlands: Sense Publishers.
Quitadamo IJ, Kurtz MJ (2007) Learning to improve: using writing to increase critical thinking performance in general education biology. CBE Life Sci Educ 6:140-154.
Senkevitch E, Smith AC, Marbach-Ad G, Song W (2011) Improving scientific research and writing skills through peer review and empirical group learning. J Microbiol Biol Educ 12:157-165.
Stellmack MA, Keenan NK, Sandidge RR, Sippl AL, Konheim-Kalkstein YL (2012) Review, revise, and resubmit: the effects of self-critique, peer review, and instructor feedback on student writing. Teach Psychol 39:235-244.
Wade C (1995) Using writing to develop and assess critical thinking. Teach Psychol 22:24-28.
Walker JP, Sampson V (2013) Argument-driven inquiry: using the laboratory to improve undergraduates' science writing skills through meaningful science writing, peer-review, and revision. J Chem Educ 90:1269-1274.
Walvoord B (2010) Assessment clear and simple. 2nd edition. San Francisco, CA: Jossey-Bass.
Yancey KB (1999) Looking back as we look forward: historicizing writing assessment. College Comp Communication 50: 483-503.

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