INTRODUCTION TO THE EDUCATIONAL CHALLENGE

As reflected in the recent call for reform of undergraduate science education in the American Association for the Advancement of Science (AAAS)'s Vision and Change (1), effective scientific communication is an essential skill for undergraduates majoring in STEM. Science faculty from a wide range of institutions ranked communicating results in oral and written formats as one of the most important science process skills for students to acquire in an undergraduate education (2). Curricular changes that incorporated communication instruction into STEM classrooms have demonstrated improvement in students' argumentative reasoning skills, problem solving, and knowledge application (3), in their scientific literacy (4), and in the organization, clarity, and delivery of their oral presentations (5, 6). Despite the AAAS's call for communication instruction to be systematically included in undergraduate biology education, as well as the abundant evidence in the pedagogical literature on the positive outcomes of such instruction, biology educators are not typically trained to teach communication skills. Consequently, our students rarely receive much instruction in these valuable skills or many opportunities to practice them. Yet in their coursework and research labs—not to mention in graduate studies and scientific careers—they are expected to write and present about science, despite their lack of formal education in communication, particularly oral communication.

Many US universities now have writing or communication centers. Traditionally, these centers have offered support to undergraduates in the form of peer tutors: students make appointments to work with a peer tutor, often on a written assignment, with no disciplinary specialization or focus (7). Now, however, these centers frequently have more direct contact with courses and instructors, through Writing in the Disciplines (WID) or Communication in the Disciplines (CID) programs, and provide support designed around the communication conventions and expectations of specific fields. Even when a WID or CID program does not exist at an institution, communication center staff may be willing to partner with an instructor in order to offer instruction and support to students (8, 9). In this piece, we report on one such partnership between the instructor of a synthetic biology laboratory course (Beth) and the director of a multimodal communication center (Jennifer).

CREATION OF THE PARTNERSHIP

Undergraduate laboratory courses offer an opportunity for large numbers of students to learn multiple process skills, including communication of science. A journal club is one pedagogical approach that can develop and improve students’ skills, by giving them experience in analyzing and
presenting scientific literature (10–12). In Beth's upper-level synthetic biology laboratory, students give a journal club–style presentation about a research paper on a relevant topic. Presentations are given by teams of two to three students, with two to three teams presenting in a given class period. (In Beth's experience, having students present as teams rather than as individuals is essential to promote student confidence and to ease the pressure of feeling solely responsible for the journal club assignment.) Initially, students were assigned a specific research article during the first week of class, but more recently students have had the option of choosing an article from a list or selecting their own from the primary literature.

Although in past semesters Beth had given a generic lecture on “how to give a presentation” to help the students prepare for the journal club presentation, students frequently struggled with preparing well-designed slides and delivering clear and accurate presentations. While Beth has many years of personal experience in preparing and delivering scientific presentations, she does not have any formal training in teaching communication. Beth’s motivation to improve the educational experience for her students combined with the establishment of the Center for Written, Oral, and Visual Communication (CWOVC, https://cwovc.rice.edu/home) at Rice University inspired her to contact Jennifer Wilson, the director of the CWOVC, to see whether a CWOVC staff member could design and lead a workshop related to the journal club presentations (see 13).

Fortunately, the Rice CWOVC was prepared to accommodate Beth’s request. The center does offer traditional one-on-one tutorial appointments on students’ writing. However, as a multimodal center, it also provides support for public speaking, slide design, research poster design, and visual representation of research. While there was not at the time a specific WID/CID program at Rice, the CWOVC is not limited to supporting students in a specific department or school of study, and several staff members, including Jennifer, have experience working in WID programs at other institutions. Nor is the CWOVC’s mission restricted to students; staff in the CWOVC hold syllabus and assignment consultations with faculty across the campus and routinely give course-based communication workshops at the request of instructors. As a result of this open mission and past experience, Jennifer was very amenable to Beth’s request.

**DESIGNING THE WORKSHOP TOGETHER**

Since this lab did not begin until the second half of the semester, we initially offered the new, required workshop the week before the course started, at the same time as class would normally be held. We met in person two weeks before the workshop date to brainstorm ideas and approaches. When Jennifer learned that she would have 90 minutes to teach multiple skills—slide design, table and figure design, content selection, and public speaking—she recognized that she would have to focus on fairly specific aspects of these skills. As a result, Jennifer asked Beth to identify the main problems she had found with previous presentations for this assignment, and Jennifer designed the workshop around the following four issues, grouped into three categories:

1. **Content**
   a. Not including enough background information
   b. Including too many details about the results

2. **Visual design**
   c. Slides too hard to read

3. **Public speaking**
   d. Presentation not rehearsed

Using this structure, Jennifer was able to include communication content she felt was important, while relating this content directly to the assignment. For example, under “Slides too hard to read,” Beth had noted that students often used inappropriate colors (in a variety of ways) and font sizes and often crammed too much material onto each slide. These are, of course, very common mistakes in the use of PowerPoint or other presentation software, and many university workshops on oral presentations address this material, including the lecture Beth had given in previous years. In this new workshop, however, Jennifer engaged in specific “consciousness-raising” of these features (e.g., 14, 15) by relating her discussion of them directly to students’ mistakes in this very course in the past (see Fig. 1). This approach differed greatly from the lectures Beth had given in the past, which focused on general best practices for preparing and delivering oral presentations. Students seemed to be much more interested in hearing about specific mistakes made by their peers than in being shown only the “correct” way to present scientific information.

Another important aspect of this workshop was using authentic materials combined with active learning to underscore the topics of discussion. For example, students were shown a publicly available image of a group of Rice students presenting in a course taught in the business school and asked what feedback they would give to those students. In addition, Beth provided several slides created by previous biosciences students (with identifying information removed) for a variety of courses, and the final workshop activity asked students working in small groups to apply the concepts just presented to identify what the slides’ creators had done well and what could be improved. We intentionally selected slides from students who had graduated (i.e., > 4 years old) so as to minimize the chance that students would recognize work from one of their peers. We verbally gave the prompt for this activity during the workshop presentation. Although each group critiqued only a single slide, each slide was shown to the entire class so that all students could see a variety of strengths and weaknesses in slide design for this specific assignment. Incorporation of this interactive component of the workshop combined with peer discussion engaged student interest and promoted critical analysis of what makes an effective slide. This use of models to teach
specific conventions of a disciplinary genre has been used successfully in a variety of contexts (e.g., 16, 17), and the active learning and discussion components used with these materials promoted deeper student learning than when the material was delivered via lecture (18).

At a more micro level, examples throughout the workshop were taken from biological and biomolecular materials, supplied to Jennifer by Beth. For example, when discussing how to condense complete sentences into short phrases, the example sentence used was, “DNA polymerase catalyzes elongation of DNA chains in the 5’ to 3’ direction.” When describing parallelism, rather than just showing the students examples of parallel versus non-parallel text, students were given non-parallel examples from a typical scientific-methods slide and asked to create parallel text (see Fig. 2). Likewise, students were shown how to use color and animation to draw attention to a specific reaction in the Krebs cycle and how to simplify a figure from Cell. This attention to authenticity further emphasized the relevance of the workshop content to the course and assignment (19). As the scientific examples presented on the instructional slides were not necessarily related to synthetic biology, which was the topic of this particular course, the skills learned by students should readily transfer to other contexts, including different courses and journal clubs connected to a research lab.

**Check for Grammatical Parallelism**

- Use same grammatical form in lists
- **Not parallel:**
  - Cells were lysed in buffer
  - 5 minute centrifuging of lysate
  - Removed supernatant

**FIGURE 2.** Workshop slide. Students are asked to create parallel text for a typical scientific-methods slide. We use this same slide in workshops for both the journal club presentation in the upper-level synthetic biology lab and the research presentation in the freshmen introductory-level lab. After students have tried to revise the “not parallel” list themselves, we use animation to make the parallel list pop up. In the introductory lab, we also show a list from an actual student slide that is not parallel.

**FIGURE 1.** Discussion of presentation issues directly addressed students’ mistakes in this course in the past. (A–C) Examples of slides used during the workshop. Additional workshop slides can be provided upon request.

**BENEFITS OF THE PARTNERSHIP**

This partnership has benefited multiple stakeholders: students, the instructor, and the CWOVC. While we do not currently have IRB approval to share student results and thus have not yet formally assessed this workshop, based on Beth’s observations of both grades and student performance as well as impressions from informal student feedback, we believe that the workshop we designed around the components of an effective presentation has helped students prepare and share professional presentations about a scientific journal article. Beth has been evaluating the journal club presentations with a similar rubric since before our collaboration (Table 1 shows the major categories considered in the evaluations). Based on her evaluations with this rubric, the overall quality of the slides and the presentations improved by approximately one letter grade in each semester that we have offered this workshop compared with student presentations before we designed this workshop. Furthermore, based on the content and wording in their presentations and their handling of questions, students show enhanced understanding of the scientific concepts in the articles. This is evidenced by their explanations of essential background information, overview of critical methods, and discussion of key findings (see Table 2). Anecdotally, students seem more confident not only in giving their own presentations but also in asking questions about the journal articles presented by other students in the class; their questions really dig into...
the science, more so than previously. Moreover, students apply what they learned in the workshop to design the slides for their presentations: background slides use eye-catching visuals and well-organized text to introduce the topic of the paper; complex figures from the article are broken up and presented on multiple slides with supporting descriptive text (previously, students would show a multi-panel figure on a single slide); and only selected results are presented (in the past, students would present every figure and table in a given paper). In the final course presentations, students were able to apply slide-design and data-presentation concepts discussed in our workshop to communicate scientific information about topics not directly addressed during the workshop, which implies that students may be able to transfer knowledge gained from the workshop about journal club presentations to different types of STEM presentations.

As a result of this collaboration, Beth feels more confident giving students in other courses instruction and feedback about oral presentations. She is also more likely to incorporate additional communication assignments into both her introductory and advanced courses. In addition, she has applied presentation strategies covered in this workshop to coach the Rice iGEM team as they prepare to present at the iGEM Competition’s annual Giant Jamboree.

A benefit to the CWOVC from this project has been additional exposure in the School of Natural Sciences. Following this initial collaboration in the upper-level synthetic biology lab, Beth worked with Jennifer to design a research presentation workshop for freshmen taking an introductory open-ended, project-based lab course, which adapted the original material by removing content-oriented suggestions (such as those in Fig. 1) and adding slides on creating tables and figures to display research results. For example, students were asked to apply visual design principles (presented in the workshop) by critiquing a standard table from a graduate student’s thesis defense slide; following their critique of the original, students were shown one set of possible revisions to that table. Several days before their presentations, we required student teams to meet with a nonscience consultant at the CWOVC for suggestions on slide design and feedback on presentation style. In addition, Beth’s enthusiasm about the collaboration has sparked an increase in CWOVC presence in the BioSciences department; CWOVC staff members now give workshops on a variety of oral and written skills in several upper-division courses and to summer NSF REU interns.

FUTURE DIRECTIONS

In future offerings of this course, we plan to assess the effectiveness of the workshop and its impact on student

| TABLE 1. | Categories in the rubric used to evaluate journal club presentations. |
| --- | --- |
| Clarity and Content | Goals/objectives (identified clearly) |
| | Background (appropriate level) |
| | Methods/experimental approach (appropriate detail) |
| | Results/data (clearly presented) |
| | Conclusions/big-picture significance |
| Graphic Design | Layout, composition, font size, grammar, etc. |
| Delivery | Professional: practiced, not dependent on notes |
| | Voice quality, speaking volume, pronunciation |
| | Mannerisms: eye contact, gestures, stance, fillers |
| | Stayed within 20-minute time frame |
| Handling of Questions | The complete rubric can be provided upon request. |

| TABLE 2. | Observations of student improvement after implementation of the journal club presentation workshop. |
| --- | --- | --- |
| Feature of Student Work | In Previous Years | After Workshop Was Implemented |
| Content selection | Students focus on background material that is common knowledge to a basic researcher and/or students do not connect the background information to the context of the research | Students explain background and methods more coherently |
| | Students include every piece of data regardless of its relevance to conclusions of the research | Students focus only on most important results |
| Visual presentation quality | Text on slides is written in full sentences making it difficult to read during presentation | Text on slides is easy to read |
| | Text on slides is out of order and/or not linked to images | Text on slides is better organized |
| | Complex figures are used that contain non-relevant data | Complex figures are simplified and easy to read |
| Engagement with performance evaluations | Students provide numerical ratings of peer performance with minimal critical feedback | Students are more willing to ask questions after peers’ presentations |
learning. We now have an umbrella IRB protocol for teaching-related research led by the Center for Teaching Excellence (http://cte.rice.edu/umbrella-irb-for-teachingrelated-research/), and we will join this protocol so we can publish data from this course. Beth is interested in administering pre- and post-surveys to the students about the workshop as well as the journal club presentation to determine its impact on their ability to read and evaluate primary literature and to examine its influence on affective outcomes, such as increased confidence and enthusiasm. Students will be asked to reflect upon their experiences, which will provide insights into student perceptions. We will continue to revise the workshop and the assignment to meet the needs of the “next class” of students. Looking beyond the specific requirements and grade for this particular assignment, students should be able to apply the skills they acquired through the workshop and journal club presentation not only to future course work but also to meetings and collaborations in their chosen careers.

We encourage biology instructors at other institutions to look for ways to build similar partnerships on their own campuses. Writing centers, communication centers, and Communication in the Disciplines programs are all good places to find a person knowledgeable about teaching communication skills to university students. In our experience, these individuals welcome the opportunity to share their knowledge with students. When setting up such a relationship, we have two pieces of advice for the biology instructor:

1. Be as specific as possible about your students’ needs and your desired outcomes for both the specific assignment and the workshop;
2. Share as much material as you can from the course. This can include student work/samples, as well as your assignments, rubrics, and course readings. You can even offer to add the communication partner to your course management site, if one exists, to allow her/him an in-depth look at your content and course design.

In this piece, we described a collaboration between a biosciences instructor and a communication expert that focused on incorporating a workshop into a biology lab course in order to improve student presentations of primary literature. This collaboration allowed the workshop to retain its disciplinary focus while incorporating pedagogical techniques and technical information from the communication perspective. Moreover, we have found that the design and focus of the workshop can be easily adapted to meet the specific needs of one's students and can be tailored for instruction at different levels (e.g., introductory, advanced, nonmajors). The most important lesson Beth learned while working with Jennifer to build this workshop was that she did not have to develop materials or implement curricular changes all on her own.

As educators and scientists, we should seek out and build partnerships with communication professionals at our own or neighboring institutions. Establishing these relationships will improve our efforts to teach effective science communication skills to our students.

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REFERENCES

1. American Association for the Advancement of Science. 2011. Vision and change in undergraduate biology education: a call to action: a summary of recommendations made at a national conference organized by the American Association for the Advancement of Science, July 15–17, 2009. Washington, DC.
2. 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.
3. Reynolds JA, Thaiss C, Katzkin W, Thompson RJ. 2012. Writing-to-learn in undergraduate science education: a community-based, conceptually driven approach. CBE Life Sci Educ 11:17–25.
4. Balgopal M, Wallace A. 2013. Writing-to-learn, writing-to-communicate, and scientific literacy. Am Biol Teach 75:170–175.
5. Bayer T, Curto K, Kriley, C. 2005. Acquiring expertise in discipline-specific discourse: an interdisciplinary exercise in learning to speak biology. Across Discipl 2, http://wac.colostate.edu/atl/articles/bayer_curto_kriley2005.cfm.
6. Kolber B. Extended problem-based learning improves scientific communication in senior biology students. J Coll Sci Teach 41:32–39.
7. Bouquet EH. 1999. “Our little secret”: a history of writing centers. Coll Comp Commun 50:463–482.
8. Bernstein D, Greenhoot AF. 2014. Team-designed improvement of writing and critical thinking in large undergraduate courses. Teach Learn Inq J 2:39–61.
9. Morris WL. 2006. Math in the writing center. Clearing House 80:70–73.
10. Glazer FS. 2000. Journal clubs—a successful vehicle to science literacy. J Coll Sci Teach 29(5):320–324.
11. Kozeracki CA, Carey MF, Colicelli J, Levis-Fitzgerald M. 2006. An intensive primary-literature-based teaching program directly benefits undergraduate science majors and facilitates their transition to doctoral programs. CBE Life Sci Educ 5:340–347.
12. Kitazono AA. 2010. A journal-club-based class that promotes active and cooperative learning of biology. J Coll Sci Teach 40:20–27.
13. Robertson K. 2012. A journal club workshop that teaches undergraduates a systematic method for reading, interpreting, and presenting primary literature. J Coll Sci Teach 41:25–31.
14. Ellis R. 1994. The study of second language acquisition. Oxford University Press, Oxford.
15. Freedman A. 1993. Show and tell? The role of explicit teaching in the learning of new genres. Res Teach Eng 27(3):222–251.
16. Charney DH, Carlson, RA. 1995. Learning to write in a genre: what student writers take from model texts. Res Teach Eng 29(1):88–125.
17. Hyland K. 2004. Genre and second language writing. University of Michigan Press, Ann Arbor, MI.
18. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderoth MP. 2014. Active learning increases student performance in science, engineering, and mathematics. PNAS 11:8410–8415.
19. Ambrose SA, Bridges MW, DiPietro M, Lovett MC, Norman MK. 2010. How learning works: seven research-based principles for smart teaching. Jossey-Bass, San Francisco, CA.