Strong communication skills are essential for future science professionals, but practical training has not been featured strongly in undergraduate curricula. To better train diverse life science majors in communication theory and skills, we created a foundational 200-level course and an advanced 400-level science communication course. Here, we outline the strategy, including lesson plans, assignments, and grading rubrics, for these courses. The science communication assignments presented are diverse in terms of audience, including communication to fellow scientists, to clinicians, and to the public, as well as in terms of format, including written, oral, and visual modes. We also provide suggestions for placing assignments designed to build upon each other into preexisting courses in a scaffolded manner to promote mastery of science communication skills.

INTRODUCTION

The COVID-19 pandemic demonstrates the importance of scientists having the necessary skills to communicate clearly and directly with scientists outside their discipline, with experts in nonscientific disciplines, such as economics and policy, and with the general public. Because scientists traditionally have not been provided communication training and their discipline requires a focus on data and fine distinctions, effective communication beyond their discipline tends to be a rare attribute. Consequently, there have been calls for science communication to be included in STEM education (1–4). Although excellent training activities in various aspects of science communication have been published (5), a holistic approach to developing an essential communication skill set has not been integrated into most STEM curricula. To begin to address this, we pioneered two new courses with the goal of formulating a curriculum that would instill in our life science majors the necessary theory and best practices for communicating effectively with diverse audiences. We initiated this by implementing a foundational experience at the 200 level and a mastery experience at the 400 level.

Faculty in our college at a large R1 university identified, through programmatic assessment, the need for an earlier introduction to scientific literature in the undergraduate curriculum. This, coupled with opportunities to practice different forms of science communication, would better prepare students for not only advanced coursework but also diverse career paths. Because existing courses with a focus on science communication were upper-division courses, a new 200-level introduction to life science communication course was designed, piloted, and refined by the authors and their faculty colleagues.

Simultaneously, there was concern that the current 400-level senior capstone course, with its focus on scientific writing, was aimed at students bound for graduate programs and thus not serving the needs of the majority of our STEM graduates. Specifically, skills in communicating about science with nonscientists are essential for career success in clinical professions, the biotech industry, sales and marketing, science journalism, etc. Thus, we sought to redesign, pilot, and refine a curriculum that would provide students opportunities to develop and hone skills in communicating about science in various formats to diverse audiences.

This paper delineates the lesson plans, assignment guidelines, and grading rubrics for the two semester-long courses and provides an analysis of student achievement of the learning objectives. Although the courses were preemptively designed to build upon each other, the first several groups of students taking the 400-level course did so without having previously experienced the 200-level course. This necessitated creating assignments and lessons that were self-contained. As a result, the assignments and rubrics can easily be adapted individually and placed into preexisting courses to effectively scaffold communication education throughout the undergraduate science curriculum.
Use of human subjects

This work was certified as exempt by the Washington State University Institutional Review Board (IRB #18121-001), and students underwent an informed consent process for their assignments and grades to be used for the study.

Intended audience

This curriculum is designed for life science majors.

Learning time

This paper describes the curriculum for two 3-credit courses, one at the 200 level and one at the 400 level. The 200-level course was held 3 days a week, for a 1-hour lecture on Mondays and 2-hour labs on Wednesdays and Fridays. The 400-level course was held 3 days a week, for 1 hour each on Monday, Wednesday, and Friday. However, the lessons and assignments described could easily be implemented into other preexisting courses.

Prerequisite student knowledge

The 200-level course and assignments are designed for students who have taken a 100-level general biology course. The 400-level course and assignments are designed for a senior capstone course but would be appropriate for juniors or seniors who have taken higher-level life science courses in their specific discipline.

Learning objectives

200-level science communication course and assignments:

1. Demonstrate appropriate use of a toolbox of strategies for interpreting and communicating science in a variety of formats
2. Develop skills for critically analyzing science communication for content, credibility, and quality of presentation
3. Develop an awareness of the ethical and legal aspects of science communication
4. Demonstrate the ability to use evidence to make a claim

400-level science communication course and assignments:

1. Communicate both the significant findings of cutting-edge research and their societal implications
2. Analyze and synthesize scientific data from various sources
3. Interpret a scientific paper in order to articulate its main points and identify the strengths and weaknesses of the work
4. Discern the main ideas from a source and clearly articulate them in writing
5. Analyze controversial topics in science, taking into account the ethical concerns of different groups
6. Communicate scientific findings via different modes, e.g., an oral presentation, a poster presentation, and in writing
7. Survey the scientific literature on a topic and prepare a summary suitable for lay, physician, and scientific audiences

PROCEDURE FOR 200-LEVEL SCIENCE COMMUNICATION COURSE

Materials

Students need access to one of the books listed in the “Book Review” assignment guidelines (see Appendix 2); these books are available at most university and public libraries.

Student instructions

During the semester, students learn how scientists communicate with other scientists and how scientists communicate with the public. Students complete the assignments listed in Table 1. Appendix 2 includes more detailed assignment guidelines and a grading rubric for each assignment.

Faculty instructions

Faculty should first create a schedule of assignments and due dates; a sample syllabus and schedule are shown in Appendix 1. Although this sample schedule includes all nine assignments listed in Table 1, individual assignments could easily be interspersed into preexisting courses. Some assignments, for example, “Critiquing Science on Display” and the “Science Talk Analysis,” require students to attend science talks or poster presentations and competitions on campus. However, substituting videos of science talks or research poster presentations would also be successful.

Secondly, faculty should provide interactive lessons to teach students specific aspects of science communication, such as tips for targeting your audience, important differences between oral and written communication, and the ethics of avoiding misrepresentation of data when creating visualizations or figures. Accessibility concerns, such as the importance of considering color combinations when creating PowerPoint presentations, should also be discussed. See Appendix 3 for sample lesson plans, links to videos, and resources.

Suggestions for determining student learning

The rubrics for grading each assignment are included along with the assignment guidelines in Appendix 2. The rubrics assess student learning in diverse ways, analyzing
TABLE 1.
List of assignments for 200-level science communication course.

| Category Regarding Audience of Communication | Name of Assignment               | Description of Assignment                                                                 |
|----------------------------------------------|----------------------------------|------------------------------------------------------------------------------------------|
| Simplify, critique, and produce communication by scientists to scientists | CREATE Portfolio (6)            | Implement the CREATE method in order to simplify and understand a scientific journal article |
|                                              | Critiquing Science on Display    | Attend a research poster competition and critique scientific posters                      |
|                                              | Science Talk Analysis            | Attend a science talk and review the presentation                                         |
|                                              | Mini Review Article              | Compare and contrast the data regarding three scientific papers on similar topics, synthesizing information and making a claim about the field |
|                                              | Book Review                      | Choose a popular press book about a scientific topic (from list provided by the instructor) and give a 5-minute presentation to the class |
|                                              | Message Box (7)                  | Use the method developed by COMPASS, an organization that helps scientists share their knowledge for public discourse |
|                                              | Visualizing Science              | Develop an infographic to communicate a scientific concept                                |
|                                              | Three-Minute Thesis              | Create an “elevator pitch” to explain the research in a scientific paper concisely        |
|                                              | Flame Challenge (8)              | Answer a scientific question in video, graphic, or written form in a way a middle schooler can understand! |

*CREATE is an acronym for consider, read, elucidate hypothesis, analyze and interpret data, and think of the next experiment.

how clearly students communicate scientific content as well as how well they targeted the information to their unique audience for that assignment. There was no exam in this course.

Sample data

Appendix 4 includes examples of student work from the course.

Safety issues

Not applicable.

PROCEDURE FOR 400-LEVEL SCIENCE COMMUNICATION COURSE

Materials

None.

Student instructions

During the semester, students practice different forms of communicating scientific information to diverse audiences. They synthesize information from previous life science courses to investigate a new topic within the field. They engage in rigorous discussion with their instructors and classmates about communication, ethics, science policy, business, and more. Students complete the assignments listed in Table 2. Appendix 6 includes more detailed assignment guidelines and a grading rubric for each assignment.

Faculty instructions

Faculty should first create a schedule of assignments and due dates; a sample syllabus and schedule are shown in Appendix 5. While this schedule includes all the assignments listed in Table 2, individual assignments could easily be interspersed into preexisting courses. The News Article assignment requires students to write about recent research; this could be based on a student research poster presentation, talks given to the class by graduate students, or videos of research talks.

In addition to teaching principles of science communication, each instructor frames their course around a “hot” topic. For instance, the microbiome, vaccinations, cancer immunotherapies, and reproductive genetics have been successful, as they encompass important recent research and ethical considerations. The instructor generates a list of suitable, relevant journal articles, and students choose from this list a paper that will be the basis of their Oral Presentation and News & Views article. At the end of the
semester, small student groups develop their Selling Your Science biotech pitch assignment to solve a problem associated with the topic of their section.

Finally, this course includes several guest speakers who visit the course in person or via Zoom or Skype to discuss their career path and how they use science communication in their work. Diverse careers in science and medicine are represented. The instructor is responsible for organizing and scheduling these guest speakers; in our experience, alumni have provided particularly successful sessions.

See Appendix 7 for lesson plans and teaching materials regarding science communication principles, course content for class discussions on the example section topic of targeted cancer therapies, and a list of careers represented by guest speakers.

**Suggestions for determining student learning**

Rubrics for grading each assignment along with assignment guidelines are provided in Appendix 6. The rubrics are specific for each assignment but maintain common themes of assessing how well students integrate scientific information to make a point as well as how well they deliver this point to the intended audience. There was no exam in this course.

**Sample data**

Appendix 8 includes examples of student work from the course.

### Safety issues

Not applicable.

### DISCUSSION: 200-LEVEL SCIENCE COMMUNICATION COURSE

#### Field testing

This course has been under development for three semesters, with an increasing enrollment each semester. Assignments for successive years are modified based on feedback from students and instructors. The most recent semester had ~25 students.

#### Evidence of student learning

Figure 1 indicates which assignments were used to assess student achievement for each learning objective. The mean and standard deviation of student rubric scores for each assignment provide a measurement of achievement for each learning objective and demonstrate that, overall, students have achieved the learning objectives, at least at the elementary level assessed by the rubrics. Because this was a 200-level introductory course, rubrics were not designed to discriminate students who mastered a skill at a very high level compared with those who were just beginning to showcase the skill.

Based on the scores, students struggled most with the objective to “demonstrate the ability to use evidence...”

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### TABLE 2

List of assignments for 400-level science communication course.

| Audience of Assignment | Name of Assignment | Description |
|------------------------|-------------------|-------------|
| Physician or Clinician  | Oral Presentation  | Present the content in a scientific paper in a way that is relevant to a medical audience; receive constructive criticism from fellow students |
| Scientific             | Synopses           | Write a short paragraph to highlight the important hypotheses and conclusions of the scientific papers presented orally by fellow students |
| Scientific             | News & Views       | Write a Nature News & Views (9)-style article based on the paper presented in the oral presentation, explaining the discoveries to a general scientific audience |
| Lay/Public             | News Article       | Present new research done by researchers on campus in a way that appeals to a non-scientific audience |
| Lay/Public             | Selling Your Science | Develop a hypothetical scientific product/medical treatment to solve a problem, brand a theoretical biotech company, and pitch the product to “investors” |

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SCAFFOLDED SCIENCE COMMUNICATION CURRICULUM
to make a claim.” While most students learned to explain one concept to various audiences (the focus of most assignments), they struggled to link multiple concepts to make a new claim or argument (the focus of the Mini Review). While the concept of review articles was taught in class, students analyzed several published review articles, and students provided peer review to each other at multiple stages of the outlining and writing process, this was clearly not sufficient. Instructor feedback on a draft is a potential inclusion to help students better achieve this learning objective.

Although it was optional for their majors, students were highly engaged in this course. When asked their opinion, students noted the course was helpful in developing their science communication skills but also in preparing them for other courses (emphasis added):

“I think this class is extremely valuable and really helped provide me with the knowledge I needed to complete assignments/writing in other classes.”

“I enjoyed being able to produce a variety of assignments in creative ways. I was able to think of ways in which I could utilize this information on a daily basis in my future occupation.”

“This class was very helpful for those going into the medical field, research, and journalism. This class taught me to not only explain the topic to those who do not understand, but it also helped me create ways to further teach myself and be able to fully understand what I am reading.”

“There isn’t much I would change about this course. I learned a significant amount of material that is useful to my career and it covered a very big topic that has fluctuated and [with which I have] struggled for years, which is the ability to communicate science across a variety of audiences in very dynamic ways. This course should be mandatory for incoming majors [in our department].”

**Possible modifications**

When prompted for improvements to the class, a few students mentioned they would have preferred more activities and guest speakers and less in-class work time. The authors believe this is valuable feedback that should be acted upon. Students who unexpectedly struggle with the assignments need close attention to help identify whether it is lack of interest, skills, time, effort, or something else that prevents their success. Conversations with these students generally revealed a reason for their struggle and a way for the instructor and student to work together to ensure their learning in the course.

This course and its assignments could be modified and applied to new situations and courses. The assignments were created for a 200-level science communication course for life science majors. The college is considering making this a required course for microbiology, genetics, biochemistry, and neuroscience majors, while leaving it as an optional course for other life science majors. Another option is requiring this course for students who struggle with lab reports or other forms of science communication in 100- and 200-level courses, thus helping these students grow in these skills before reaching their upper division courses. The diversity of assignments in the course made it attractive for students interested in pursuing careers as diverse as research, medicine, science journalism, and forensics, so the course would be successful if required for all students.

However, the course in its entirety or individual assignments may be adapted easily. For instance, a hard science course may include the presentation of a Three-Minute Thesis covering a recent discovery in the field to engage students in new research and encourage them to consider the relevance of the work for nonscientists. A laboratory course could have an assignment where students use the
Message Box format to explain the implications of their experimental data for diverse public audiences. In fact, reinforcement of science communication principles outside of courses designed to hone science communication skills could provide even stronger training in this important professional skill.

**DISCUSSION: 400-LEVEL SCIENCE COMMUNICATION COURSE**

Field testing

This new version of the senior capstone has been taught for three semesters, with ~50 students per semester. Seven different instructors in the department have successfully taught the course, with students divided into 15 to 18 students per section.

Evidence of student learning

One component of this course is submission of a draft of two assignments, the News Article and the News & Views, for instructor feedback. These two assignments together provide a representative example of student mastery of many of the learning objectives in this course. Additionally, the rough draft highlights student achievement of the learning objectives based on discussions and teaching in the course, while the final draft highlights student achievement of the learning objectives after instructor feedback specific to that assignment. A sample of rough draft and final draft scores for both assignments were pulled from two semesters. The data are presented in Figure 2.

A couple of things are important to note. First, these rubrics are more rigorous than those for the 200-level course, as this was a 400-level science capstone course. The 200-level course is intended to introduce concepts, while the 400-level course is intended to help students master these concepts. Secondly, this highlights the importance of feedback for student mastery of science communication. We recommend that any science communication courses or assignments include feedback from peers, teaching assistants, and/or instructors, as feedback is crucial for producing quality communication.

Because this was a senior capstone course meant to represent a synthesis and culmination of student learning and achievement, all learning objectives were relevant to all assignments. Figure 3 lists the student scores from one semester for each assignment. Of note, students seemed to have mastered the News Article and Selling Your Science assignments more easily than the Oral Presentation and News & Views assignments. Based on the target audiences for these assignments, it appears students are actually better able to communicate with nonscientists (the general public, businesspeople) than those with a scientific background (scientists, clinicians). This was interesting, as any focus on communication in other courses in the curriculum was mainly regarding communicating with other scientists rather than with nonscientists. This suggests that students may still identify more with lay audiences than with scientific audiences and that in science communication-focused and other courses, students still need extensive training in the technical aspects of communicating science.

Students were engaged in this course, even in the midst of other difficult required courses during their senior year. When asked about the course, students provided feedback such as (emphasis added):

“This course was challenging and involved but it also helped me grow professionally and taught me so much about how to communicate science.”

“I feel that the 20-minute presentation assignment, although very time consuming, was a good assignment. It helped students practice presenting information in a scientific manner which many needed practice doing.”

“I like how this class gave us a chance to read papers and see the kind of work that we might be doing when we graduate. It also gave us a lot of opportunities to practice presenting and speaking our own opinions.”

“I thoroughly enjoyed the challenge of reading difficult science papers and being able to dissect them and delve deeper into subjects I normally overlook. I feel like I have a better understanding of what is happening in the scientific community.”

“I loved the group project, and presentations! They were great practice for the future, and I enjoyed that providing constructive feedback to our peers was one of our focuses.”

Possible modifications

When prompted to suggest improvements, a few students indicated that weighing all five assignments equally seemed inappropriate given the time required for the Oral Presentation and News & Views compared with the News Article. The instructors discussed this but decided to keep the grading the same for future semesters, because it supports the message that communicating science to the public is just as valuable as communicating to scientists and clinicians.

While this course was designed as a 400-level senior capstone course, certain assignments could be easily co-opted for other courses. For instance, students could give an Oral Presentation geared toward a medical audience to consider the clinical applications of what they are learning in a basic science course. Students in a lab course could convert a lab report into a News Article intended for a lay audience to help them appreciate the relevance of the work to nonscientists. Students in a lecture course could work in groups to create a product to solve a
scientific or medical problem, using the Selling Your Science assignment guidelines. Indeed, these assignments could be implemented in many ways to provide practice in communicating with different audiences. As evidenced by the work of our students before and after feedback, any implementation of these assignments gives students opportunities to respond to peer or instructor feedback to improve their skills. Additionally, the production of written or other forms of communication about science supports students’ learning of the science itself (11); thus, inclusion of these assignments in basic science courses would support science communication as well as science content learning objectives.

CONCLUSION AND FUTURE DIRECTIONS

This paper outlines the curriculum for 200- and 400-level courses focused on science communication, highlighting how the assignments and rubrics allowed us
to assess student achievement of learning objectives. Currently, no students have taken both the 200-level and 400-level course. As students who took the new 200-level course progress through their degree programs and take the revised 400-level course, it will be interesting to determine how the introduction of science communication skills at the 200-level impacts the mastery of these skills at the 400-level. Further, by modifying assignments and using them in laboratory and basic science courses as well as science and society courses, training in science communication can be scaffolded and reinforced throughout the life science curriculum. Further work is being done by author Nicole Kelp to analyze student science communication skills across departmental curricula.

SUPPLEMENTAL MATERIALS

Appendix 1: Sample syllabus and schedule for 200-level science communication course
Appendix 2: Assignment guidelines and rubrics for 200-level science communication course
Appendix 3: Lesson plans and teaching materials for 200-level science communication course
Appendix 4: Example student work from 200-level science communication course
Appendix 5: Sample syllabus and schedule for 400-level science communication course
Appendix 6: Assignment guidelines and rubrics for 400-level science communication course
Appendix 7: Lesson plans and teaching materials for 400-level science communication course
Appendix 8: Example student work from 400-level science communication course

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