An Upper-Level Biology Course Designed to Develop Science Communication in STEM Majors by Examining the Biotechnology Industry

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Abstract

Many undergraduate students pursuing life science majors are not aware of job options outside of medicine and academic research, because many departments stress these as the only primary career pathways. In addition, biology students often do not have many opportunities to develop their science communication and presentation skills due to the rigorous course requirements inherent in these fields that would make them more competitive for careers in biotechnology. We developed a course using diverse pedagogies designed to introduce students to new careers in biotechnology, to help them understand the role of ethics in the drug development pipeline, and to incorporate more communication assignments, such as student presentations and journal-club-style paper discussions to more effectively prepare them for many STEM-based career possibilities. By the end of the course, students had broader knowledge of previously unknown science careers, had improved their scientific communication skills, and reported a greater understanding of course material as a result of the science communication assignments.

Key Words: *science communication; presentation skills; biotechnology.*

○ Background

Traditional career paths in the life sciences usually fall into the category of medicine or academia. Undergraduate biology curricula rarely introduce students to other fields and career pathways. Biotechnology is a fast-growing industry that employs almost 70,000 people in the Boston area, and includes careers ranging from project manager to research scientist, with represented degrees ranging from bachelor's to doctorate (Massachusetts Biotechnology Council, 2018). Despite many universities' proximity to Boston, course offerings in most schools in the area do not reflect this, and many undergraduate students remain unexposed to the biotechnology and pharmaceutical industry. As a result, many students are unaware of, and may not be considering, the full range of careers at their disposal when planning their futures and have not fully developed the skills necessary to be competitive for these positions.

In order to be successful in a career in biotechnology, students not only need exposure to and education about the field, but they also need to have the scientific skill set required by employers. The National Academy of Sciences has maintained that possessing effective scientific communication skills is a requirement for all scientists and has recently published a research agenda about communicating science effectively (National Academies of Sciences, Engineering, and Medicine, 2017). The ability to read, write, and effectively communicate science is often listed as a job requirement for many positions in biotechnology (Mische, 2012) research and medicine, yet traditional exam-based courses often do not employ assessments based on these skills or provide students with the opportunity to practice and improve their ability over time. There is a need in STEM classrooms to incorporate more inclusive pedagogical practices to meet our diverse student populations (Moriarty, 2007).

The importance of teaching life science students the process of science has been emphasized for many years (Brownell et al., 2013). The process of science includes being able to evaluate and understand primary literature and to present findings, data, and arguments orally and in written formats (Eisen, 1998). Several studies have demonstrated that both students and educators recognize the need for skills training in these areas in an undergraduate curriculum (Kovarik, 2016).

It has recently come to light that interactive discussions enhance learning in science courses (National Research Council, 2003; Wood, 2003). Presentations, while often part of STEM courses, are a one-time occurrence at many schools. Delivering multiple presentations in a given course is beneficial in many ways: students often better prepare for presentations because they must respond to questions from the audience, they learn to distill the most important information from a given source, and they better retain the information they presented. Research has shown that lecture-based instruction is less successful than evidence-based courses, which allow for interactive and immersive learning that is beneficial across STEM disciplines (Gasiewski et al., 2011; Malcom & Feder, 2016).

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With these educational goals in mind, we developed a course titled "The Pipeline of Drug Development: From Basic Research to Your Medicine Cabinet" (referred to as PDD hereafter) focusing on the drug development pipeline for undergraduate science students. This course was designed to incorporate a wide range of skills, including science communication and literacy, around the overarching topic of drug discovery and development.

○ Description of Course

Brandeis University is a liberal arts research university. Almost half of the students who come to this university intend to pursue a degree in a STEM field. Among our life science majors, we have a great majority who want to pursue medicine or research. One common misconception among incoming STEM students is that in order to be successful scientists, they need to become doctors or be involved in basic research in an academic setting. Many other career options exist that are often not advertised to college students as a possible career path. With the challenge of preparing students for the professional world, this class was designed with several goals in mind, using an advanced science topic and exploring career options in the field as tools. Importantly, these concepts were taught by focusing on writing and presentation assignments, a method that engages students in ways that traditional lecture-based courses do not. Class debates and journal-club-style paper discussions were incorporated to expose students to scientific literature often throughout the class, enhancing their understanding of the lecture content. This class explored the biological and ethical aspects of the drug development pipeline from a scientist's perspective. Students were taught how drugs are created and discovered, and what their mechanisms of action are. In addition, this class focused on exposing the students to different career options involved in the drug development pipeline and the ethical dilemmas those in each role encounter, creating an authentic experience of what it means to be a scientist for undergraduates who are pursuing this career.

Course Design

PDD was designed for upper-level undergraduate students majoring in biology, health science and science policy (HSSP), or biochemistry. The class was advertised as a biology elective that fulfilled the Brandeis oral communication requirement. Oral communication courses at this university require that students deliver at least three different presentations during the semester and receive constructive feedback regularly to improve their skills in this area. Students who wanted to pursue medical or graduate school were encouraged to enroll. While in class, students were asked to participate in lectures and group discussions. There was a total of 26 classes: 13 classes of interactive PowerPoint lectures (including three guest lecturers), five classes of group activities (including group presentations), five of class discussions including debates and journal-club-style discussions, one of review session, and two for exams. This summed to 50% of lecture, 39% of active learning, and 11% of review/exams. With the exception of guest lectures, lectures were given by the course instructor and focused on the biology of drug development while group discussions focused on interpreting scientific articles, with the goal of engaging students in understanding and critiquing past and current scientific research. Students had the opportunity to practice and improve their oral communication and writing skills by presenting scientific papers, writing technical science pieces, engaging in peer review, and interacting with different audiences composed of both science majors and non–science majors. The conceptual course objectives are summarized in Table 1. Copies of the course syllabus and assignments are available upon request.

Table 1. Course objectives.

1. Explain how drugs are designed to target cellular processes.
2. Compare and contrast targeted and off-target effects of different chemotherapeutic and antiretroviral drugs.
3. Analyze and critique scientific research articles.
4. Distinguish between ethical and unethical scientific behaviors and thoughtfully discuss potentially controversial gray areas.
5. Engage in scientific discussions of the drug development pipeline across different fields.
6. Utilize verbal and written skills to effectively convey scientific ideas to a target audience.

Nineteen students, nine juniors and 10 seniors, enrolled and completed the course in its first offering in fall 2018. Their majors were biology, HSSP, and biochemistry, and their career aspirations were mostly in the health sciences. They were demographically diverse with respect to gender, race, and ethnicity. Eighteen of the 19 students participated in course research surveys (eight of these students were juniors and 10 were seniors).

Science Communication Focus

The ability to properly and effectively communicate scientific discoveries, problems, and solutions is a skill at which all scientists should be proficient. Many schools in the Boston area are known to subject students to a rigorous science curriculum that prepares them to enter and succeed in highly competitive graduate or medical programs. However, there is a lack of opportunities in courses currently offered that allow students to develop other relevant and necessary skills in science. Our foundational courses have a large number of students enrolled and a large amount of material that needs to be covered, leaving scarce time and resources for the inclusion of science communication activities. PDD aimed to help fill this void. It is unreasonable to think that one class could solve a problem of this magnitude, but this class style, combined with assessment choices, can be a model for other classes to use and to adapt to current students' needs. This course could present a framework for incorporating essential instructional elements, including adapting to individual students' needs, problem-based learning, and practical instructions applicable to post-graduate life (Elrod, 2010; Palmer et al., 2013; Laforce et al., 2016). At Brandeis, the racial, socioeconomic, and gender diversity of the STEM student body has dramatically changed over the past 15 years, and this trend is likely to keep happening in other schools in the area. With this constant change in mind, this course could serve as a model for inclusive STEM teaching.

Assessment Design

Students were assessed by filling out a short-answer questionnaire during class. The questions assessed students' interest, engagement, and perception of content knowledge acquisition. There were three different assessments, with some overlapping and different questions for each. The first was given during the first day of class, the second during midterms, and the last was given during the last day of class. All questionnaires were anonymous and there was no time limit for completing them. The questionnaires were designed, and the answers compiled in spreadsheets and analyzed, by the authors (see Supplemental Material with the online version of this article).

○ Results & Discussion

STEM students experience high levels of anxiety and stress throughout their academic journey (Malcom & Feder, 2016). This is especially true in underrepresented student populations. The students enrolled in PDD followed the same trend. When designing this course, we aimed to reduce the stress level and promote a healthy environment for learning by incorporating assignments beyond traditional examination techniques. Any assignment, including a presentation, has the potential to cause students stress; therefore, each assignment was carefully crafted to reduce potential anxiety. For example, oral presentations can be intimidating for many students, and long presentations that are heavily graded can cause high levels of stress. In this class, students were given the opportunity to deliver a five-minute PowerPoint presentation as an extra-credit assignment (called "Drugs in the News"). For this presentation, they chose a topic related to the class and presented in an informal way, without the fear of getting a bad grade. Students said (in person to the instructor) that by having class discussions and small presentations, they became more confident and less stressed by the time they had to present later on in the semester. Additionally, students who claimed that their presentation skills had improved also attributed the improvement to a gain of confidence after having multiple opportunities to speak in public. The instructor also noticed that students who were nervous to speak in front of the class in the beginning of the semester gained confidence throughout the assignments and eventually even led group discussions.

Having multiple ways to assess knowledge and promote learning allowed for the closest to an unbiased way to evaluate the progress of students using techniques that do not exclude those who are not good test takers. At most schools, the majority of science classes assess knowledge by written exams. When exams are the main or only way of assessing knowledge, students have the pressure to excel in test taking, consequently increasing their levels of anxiety. Out of 18 students, 14 claimed to experience a higher level of stress and anxiety when taking a science exam, compared to a non-science exam. This reflects a possible need for the education system to adapt to students' reality and foster a learning environment where students have the opportunity to learn in multiple ways, thereby reducing the anxiety caused by courses that use just a few exams to determine a grade.

We designed PDD to fill an oral communication void in our curriculum at our university, to make students aware of careers in biotechnology and to expose students to scientific ethics. Given that the class was enrolled at maximum capacity and students had many other upper-level electives from which to select, we were interested in why the students enrolled in this course. When students were asked why they chose the course, answers included the phrases "interesting topic," "real world relevance," "class environment," "more discussions," and "many opportunities to receive help," and one-third of the class mentioned "many opportunities to present." This suggests that our students acknowledged and understood the lack of practice in oral communication they had received from other classes and desired further opportunities. This also presented a unique opportunity to use oral communication as a tool to help students learn and be assessed in a more inclusive way that focuses on a diverse set of skills.

The students in this class had different levels of experience with scientific research, with eight seniors and six juniors describing themselves as experienced and one senior and three juniors disclosing no research experience at all. Despite a majority of students classifying themselves as "experienced," students could name only five potential career paths on average. Of note is that a self-evaluation of "experienced" in scientific research did not necessarily translate to being more knowledgeable about potential career paths. Career goals were mixed between the two groups, with several in each demographic unsure of their career plans. These data at the beginning of the course highlight that many students have a limited awareness of diverse career paths by their junior and senior years – even those students with a high level of self-reported experience in the field of scientific research. These initial data suggest that additional avenues, such as courses, would allow students to become more familiar with diverse career paths during their college experience.

Midway through the semester, students were asked again how many careers in the research field they could name. About half of the students mentioned 6–10 different careers, and the others named more than 10. This is in striking contrast to the initial average of five named careers. This demonstrates that even halfway through the course, students already had an increased knowledge of career options. In addition, 17 out of 18 described this course as having a format that was very different when compared to their other science classes. Specifically, the students highlighted the existence of more opportunities to present and develop science communication skills, while learning about different careers distinguished this course from others in the department. The most surprising data collected was on how this class influenced or changed career goals. Among the 15 usable answers, eight students said that their goals were influenced/changed, four said that the class did not change their goals but added options in their field, two said "not yet," and one said that it did not change their goals but helped reinforce them. Three answers were unclear. These data support the notion that courses could be an effective way to expose students to careers in their field and could provide some guidance as students begin to think about their plans after graduation.

Science Communication

During the semester, students had multiple assignments to develop their science communication skills. Those included short PowerPoint presentations, one-page summaries of scientific articles, debates, and informal as well as journal-club-style discussions. Incorporating multiple presentations throughout this drug discovery course served to give students experience in effective science communication, but also shifted the learning burden to the students themselves, many of whom reported feeling the need to better prepare, which then led to better learning. The course design also made use of several journal-club-style paper discussions facilitated by groups of two or three students who were assigned a section of a scientific article chosen by the instructor and were responsible for explaining it to the rest of the class. After each section, the other students interacted by asking questions, and together at the end of each article we came up with potential future experiments.

Since one of the major goals of this course is to improve students' science communication skills, at the end of the course, we asked 18 students if those skills were improved. We formally asked only about their comfort in speaking in public at the end of the course; however, during office hours the instructor had multiple conversations with students who expressed their lack of practice and possible fear of speaking in front of the class. The instructor recalls one student who said he was afraid of forgetting the words, since English is not his first language. They came up with an arrangement where in case he forgot the words, he would "animate" a few words to show up in the PowerPoint slide, which would then remind him of what he planned on saying. This arrangement was successful, and by the end of the course this student no longer felt "unprepared." Seventeen out of 18 students claimed to have significantly improved their science communication skills, and the remaining one claimed to have improved them somewhat.

Further, we asked the students how confident they were in having science dialogues with people in science, people not in science, children, relatives, and others. In each category, students were given examples of potential audiences. Examples included principal investigators and graduate students for the "science" category, lawyers and politicians in the "not in science" category, siblings for the "children" category, parents for the "relatives" category, and a friend for the "others" category. A vast majority felt confident in their ability to talk to most people, with some exceptions, including children and lawyers. These data show that this course was effective in improving the students' perceived science communication skills. When we asked students about their hesitation in speaking with children and lawyers, they had similar answers, saying that "it is difficult to talk to children because they do not want to talk about science" or "lawyers use words that I do not understand, and it is intimidating." This is very interesting for a few reasons. It shows us that there is still a need to further develop science communication skills that will be approachable for all ages. As adults, we cannot ignore science communication with children, and from early ages they should be learning about science concepts in a language they can understand. It is also worth nothing that the emphasis on lawyers having a complicated vocabulary could point to a larger problem of appropriate and effective communication to a targeted audience by a field perceived as complicated. Lastly, every student reported feeling comfortable talking about science to peers and mentors in science, indicating that each student at least perceived they had achieved a level of scientific literacy that would allow them to effectively discuss and communicate science with these groups.

Skills Acquired

At the end of the course, students were given a final questionnaire to evaluate the course. Without looking at the syllabus with the course objectives, students were asked what skills they had acquired and which skills the course was most successful in promoting. Out of 18 students, 14 mentioned a gained understanding in the course content, nine described a gained ability to criticize scientific articles, and 17 mentioned a gain in confidence to engage in scientific discussions while using different communication skills. Three students also mentioned that the class size was ideal because it allowed every student to participate in multiple interactive activities. In addition, students were given a list of soft skills that were potentially acquired or developed during the semester (Table 2). The most-cited skills were teamwork, accept and deliver feedback, adaptability, problem-solving skills, decision making, creativity, time management, and self-motivation, respectively – all essential skills for for any type of career in science. This course format and the assignments chosen allowed students to develop these skills throughout the semester. Based on their feedback, the course was successful in helping them develop soft skills that would prove useful in future endeavors.

Table 2. Soft skills used in PDD and numbers of students (out of 19) reporting that they acquired these skills.

Soft Skills	Number of Students
Time management	6
Teamwork	18
Accept and deliver feedback	16
Self-motivation	5
Adaptability	13
Problem-solving skills	10
Creativity	9
Decision making	10

Feedback & Room for Improvement

Overall, the feedback from this course was very positive, with student satisfaction at 4.8 out of 5.0. Positive comments included the phrases "teaching the subject offered," "breaking down complex topics," "exposure to the research field," "exposure to different career options," "helped us become comfortable discussing science topics," "interactive presentations," "real life examples," "including students' participation in learning," and "dynamic pedagogy." Given this feedback, we conclude that this class had a successful outcome, and that this kind of class structure is important to creating a career-oriented STEM class that develops science communication skills.

Students' suggestions for improving the course included keeping it small, increasing the number of case studies used, and having even more discussions, especially during class periods in which a large amount of material was presented. This feedback was important in highlighting the acceptance of a different course structure when more opportunity to improve communication skills is present. Although the size of the class was ideal for this course pilot, should enrollment be larger, the class design could be modified to incorporate sections and facilitated group discussions.

Conclusions

The course described here, "The Pipeline of Drug Development: From Basic Research to Your Medicine Cabinet," emphasized the biology behind how drugs are designed to target cellular processes, while teaching and developing scientific critical and verbal skills among an upper-level STEM cohort. Using a student-centered approach, with assignments in a variety of learning styles and teaching methods, the professor and the students created a learning environment that fostered social justice in the way that each student felt equally valued and included in their education. Our student-centered approach shifted the responsibility of learning from the instructor to the student, since the students had to contribute to their learning by interpreting scientific articles, presenting new materials to the class, and actively engaging in scientific conversation during debates and class discussions. Data from our last questionnaire confirm the efficacy of our approach, with students saying, for example: "This class has improved my confidence in speaking in public significantly, I had never had to discuss scientific papers before"; "This class allowed us to bounce ideas off each other which made it easier to learn"; and "This class was unique and made me feel comfortable learning and discussing the materials with my peers" (see questionnaire in Supplemental Material).

Assessment results demonstrate that students achieved the course's learning goals in addition to self-reporting improvements in a variety of soft skills (Tables 1 and 2). Specifically, students reported a better understanding of the drug development pipeline, improved ability to analyze and critique scientific articles, and enhanced science communication and discussion skills. Students also stated they had gained skills related to time management, teamwork, accepting and delivering feedback, problem solving, and other categories (Table 2). In feedback received in informal settings such as office hours, students expressed feeling welcomed, challenged, and supported during the semester, while learning essential biological aspects of the drug development and biotechnology industry.

Taken together, these data demonstrate that the structure of this course can serve as a model for inclusive pedagogy in STEM. The success of this course strongly suggests that upper-level science topics are well suited to formats that differ from the traditional lecture style. The incorporation of regular oral communication assignments and class discussions as well as problem-based learning not only improved student learning but also provided an opportunity to develop soft skills that are essential in STEM fields but are not necessarily the focus of traditional lecture courses. We propose that upper-level science courses should be designed similarly to incorporate many of these components, in order to better address individual student needs, improve overall learning, and provide tools that could be beneficial upon graduation.

References

Brownell, S.E., Price, J.V. & Steinman, L. (2013). Science communication to the general public: why we need to teach undergraduate and graduate students this skill as part of their formal scientific training. *Journal of Undergraduate Neuroscience Education*, *12*(1), E6–E10.

Eisen, A. (1998) Small-group presentations: teaching "science thinking" and context in a large biology class. *BioScience*, *48*, 53–58.

Elrod, S. (2010). Project Kaleidoscope 2.0: leadership for twenty-first-century STEM education. *Liberal Education*, *96*(4). https://www.aacu.org/publications-research/periodicals/project-kaleidoscope-20-leadership-twenty-first-century-stem.

Gasiewski, J.A., Eagan, M.K., Garcia, G.A., Hurtado, S. & Chang, M.J. (2011). From gatekeeping to engagement: a multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in Higher Education*, *53*, 229–261.

Kovarik, M.L. (2016). Use of primary literature in the undergraduate analytical class. *Analytical and Bioanalytical Chemistry*, *408*, 3045–3049.

Laforce, M., Noble, E., King, H., Century, J., Blackwell, C., Holt, S., et al. (2016). The eight essential elements of inclusive STEM high schools. *International Journal of STEM Education*, *3*(1).

Malcom, S.M. & Feder, M.A.(Eds.) (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways*. Washington, DC: National Academies Press.

Massachusetts Biotechnology Council (2018). MassBio's 2018 industry snapshot shows 48% of all US-based biotech IPOs in 2017 were from Massachusetts companies. Press release, August 29. http://www.massbio.org/news/recent-news/massbio-s-2018-industry-snapshot-shows-48-of-all-us-based-biotech-ipos-in-2017-were-from-massachusetts-companies-145370.

Mische, S. (2012). Job opportunities in pharma and biotech: what makes a future employee stand out? *Journal of Biomolecular Techniques*, *23*(Supplement), S12–S13.

Moriarty, M.A. (2007). Inclusive pedagogy: teaching methodologies to reach diverse learners in science instruction. *Equity & Excellence in Education*, *40*, 252–265.

National Academies of Sciences, Engineering, and Medicine (2017). *Communicating Science Effectively: A Research Agenda*. Washington, DC: National Academies Press.

National Research Council (2003). *Bio 2010: Transforming Undergraduate Education for Future Research Biologists*. Washington, DC: National Academies Press.

Palmer, R.T., Maramba, D.C. & Gasman, M. (2013). *Fostering Success of Ethnic and Racial Minorities in Stem: The Role of Minority Serving Institutions*. New York, NY: Routledge.

Wood, W.B. (2003). Inquiry-Based undergraduate teaching in the life sciences at large research universities: a perspective on the Boyer Commission report. *Cell Biology Education*, *2*, 112–116.

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