ARTICLE
A Capstone Course Where Students Present Contemporary Neuroscience Research to High School Students

Minjoon Kouh
Physics Department and Neuroscience Program, Drew University, Madison, NJ 07940.

This article describes a model of a neuroscience capstone course where students choose and study contemporary neuroscience research articles in depth and then present them to high school students in short videos. This course can provide a meaningful culminating experience where students are applying their neuroscience knowledge and communication skills acquired from their undergraduate education. As students take on the ownership of learning and presenting diverse neuroscience topics, this course can be run flexibly and remotely as needed. Developing a partnership with a local high school is an important aspect of this course.

Key words: Capstone; Partnership with High School; Presentation; Remote instruction

A capstone course, or a senior seminar, marks a culminating end-point of undergraduate curriculum in many colleges (Redman, 2013). As recommended by "the new blueprints" for undergraduate neuroscience education in the twenty-first century (Wiertelak et al., 2018) and as identified as a high-impact educational practice by Association of American Colleges and Universities (https://www.aacu.org/leap), such a course allows students to integrate and reflect on various skills and knowledge they have acquired in their collegiate studies. Furthermore, students may expand their knowledge about emerging trends and deepen their perspectives, whether the neuroscience curriculum has an emphasis on biology or psychology and whether or not students are pursuing further training in neuroscience or related fields.

Because a cohort of neuroscience students branches out into different subject areas, such as biology, psychology, biochemistry, etc. (Ramos et al., 2011; Pinard-Welyczko et al., 2017), a converging point for the cohort before their graduation is another reason for a capstone course. At the same time, the wonderfully interdisciplinary nature of our discipline makes it challenging to cater to the diverse interests and academic trajectories of our students. In this report, I describe a model of a capstone course where each student studies a contemporary neuroscience research article in depth and presents it to a non-expert audience, namely local high school students.

BACKGROUND

Within the neuroscience education literature, we can find a few models of high-impact capstone courses. In one model, students write and review mock grant proposals (Itagaki, 2013). In others, students deliver "brain briefings" or "neuroscience in the news" to their classmates (Kennedy and Hassebrock, 2012), or a particular neuroscience theme is framed around Tinbergen's Four Questions about mechanism, development, evolution, and function (Meitzen, 2015). In these capstone courses, including one reported here, students are engaging with contemporary neuroscience topics, applying their acquired knowledge and analytical skills, and delivering targeted presentations in various formats. Some of the distinguishing features of the capstone course proposed here are: (1) partnering with a local high school and (2) using short, online videos, which makes remote instruction and presentation possible. This latter feature was especially valuable during the COVID-19 pandemic in 2020.

As a background, my institution is a private liberal-arts college that graduates approximately 15 neuroscience majors each year. It is a stand-alone major, separate from biology and psychology. Requirements for the neuroscience major consist of the following: introductory neuroscience, general chemistry I and II, introductory biology, introductory statistics, intermediate-level neuroscience research method, cellular/molecular biology, three core courses that cover the areas of cell/molecular neurobiology, systems neuroscience, and cognitive neuroscience, 3 elective courses, and the capstone course. The capstone course is offered every year with half the degree credit of a typical course. A student working on an honors thesis project is exempt from the capstone course requirement, since an honors thesis also requires an in-depth study of a neuroscience topic and oral/written communication. The number of students enrolled in the capstone course is between 10 and 15. The capstone course meets once a week for 75 minutes in a seminar format.

CAPSTONE COURSE

I have managed and run the capstone course described for the past three years. The official description on the course catalog is: “An in-depth exploration of a specific topic in neuroscience, with an emphasis on current theories and research in the area (topic will vary with instructor). Each topic will be explored from a variety of different perspectives as students investigate the different ways of conceptualizing and approaching a common area of neuroscience research. Students will present and discuss the current literature in the

field and develop their own proposals for addressing an unresolved question in this particular area of neuroscience."

The learning goals are such that students will be able to do the following at a level appropriate for an advanced undergraduate:

- Demonstrate a working competency in the content, terminology, skills, practices, methods, questions and core principles of neuroscience;
- Communicate effectively in the discourse of neuroscience;
- Evaluate their own and others' work in neuroscience;
- Place neuroscience in relation to a broader context.

Here is an outline of the semester-long schedule:

- Weeks 1-2: Students are introduced to the learning goals and major assignments. Each student chooses a contemporary, high-impact primary research article to be studied in depth over the next few weeks. A PDF of the chosen article is submitted to the instructor, who signs off on the appropriateness of its topic, length, and scope. The instructor starts coordinating with the counterpart at a local high school (e.g., AP Biology teacher) for the final presentation event.
- Weeks 3-4: Students dive into their chosen articles and share what they are learning in short presentations. By the end of this period (a third of the way into the semester), students are expected to be familiar with the overall "story" of the research, such as its main results and significance. Each student makes a 5-minute presentation (~3 slides) in the class.
- Weeks 5-7: Students study important details of the chosen research and focus on one or two plots in each article (usually Figure 1 or 2 of the article under study). For example, they study what the axes of each plot represent, how key measurements are made, and how the main findings are quantitatively and graphically represented in the plots. Students may also complete an assignment of recreating one of the plots in the article with spreadsheet software.
- Weeks 8-10: Students prepare a presentation for high school students. The format could be a poster or a short video. Students produce multiple drafts on which the instructor and peers provide feedback. They develop strategies for effectively conveying technical and complex concepts to non-experts, by avoiding jargon, using analogies, removing unnecessary details, and focusing on the most relevant concepts.
- Week 11: The final draft of the presentation is due, and an internal presentation event is held (e.g., an in-class video screening or poster session).
- Weeks 12-13: Students make the final presentation to high school students in person (posters) or remotely (online videos). An additional Q&A session can be arranged. Students reflect on their learning experiences, focusing particularly on how they have learned a complex topic for themselves and made it accessible to a wider audience.

In order to impart a sense of ownership in the learning process, students picked the research articles that aligned with their own interest. Some students gravitated toward cellular/molecular research, and others, systems or cognitive research. In my capstone course, the articles had to be from the journal, Nature, published within the past 2 years. Imposing such constraints on a research article was necessary to prevent students from getting lost in an overwhelmingly large body of literature. There are other merits to limiting the source to a high-profile research journal like Nature or Science. The standard of research and writing is very high for these journals, and there is an emphasis on broader scientific significance. Consequently, many of the research articles on these journals often receive further media coverage, so there sometimes are secondary resources (e.g., a news article or a supplementary video) that can aid students' understanding of the primary sources.

Because most of these research articles were highly sophisticated and involved complex techniques that were beyond undergraduate neuroscience curriculum, just being able to describe the broad outline of the research and its key findings was sufficient as an initial learning goal at the beginning of the semester. Acquisition of further technical knowledge took place more slowly throughout the semester. As a way of managing students' expectations and providing encouragements, the instructor pointed out that these articles represent many years of focused experiments, analyses and writings that were made possible by combined and cumulative expertise of numerous researchers. For most undergraduate students, the longest duration of a project would have been at most a single semester, so they find such an extended research process interesting and inspiring. Short, one-on-one dialogues with individual students during in-class, working session or during office hours were used to provide supports and encouragements. Students were alerted that they would have to invest a significant amount of time in order to grasp the necessary background and details of the research throughout the course, and they appreciated the challenge and the opportunity to study advanced neuroscience research.

It took students several rounds of reading to reach a presentable level of understanding of the research articles, and they reached such a level at different times in the semester. The instructor helped students along with different checkpoint assignments. For example, students were asked to identify the overarching research question at the beginning of the semester and then present one of the main figures in the article mid-semester, etc. Because modern neuroscience research incorporates sophisticated experimental and computational techniques (e.g., optogenetics, two-photon and fluorescence microscopy, Machine Learning algorithms), students needed extra time to learn about such related topics.

Students were regularly reminded that they would be presenting to high school students. They were encouraged to devise an analogy to convey the main ideas in the research. For example, one student illustrated the idea about a behavioral change from an exploratory state to an exploitative state, by using an analogy of how people might consider different restaurants for a meal until deciding to go again to their regular, tried-and-true restaurants. Another

student illustrated the concept of an RNA profile of different cell types with an analogy of different ethnic cuisines that are characterized by their signature ingredients. The multiplexing nature of dopaminergic neurons was compared to the diverse roles that a high school student might play.

Being familiar with the level of knowledge of a high school student, as all students in the capstone course were in high school themselves only a few years ago, is advantageous, because the capstone students can assess whether their presentations are pitched at a reasonable level. Being able to break down a complex concept and explain it in simpler terms is a good measure of one's own understanding. Students were guided to focus only on directly-relevant concepts and not to "hide behind" technical terms during the presentation. Furthermore, it was recommended that the presentation include just one or two of the main plots from each research article, so that the audience could easily identify the takeaways within the presentation. Students also saw a few examples of how neuroscience concepts could be explained to different target audience, such as "Kids Judge! Neuroscience" events or the "Five Levels of Explanation" video series by the WIRED magazine (https://www.wired.com/video/series/5-levels).

Throughout the semester, students shared their progress through short, low-risk presentations, allowing the capstone course to function as an extended journal club, as well. Although it might be tempting for an instructor to deliver lectures on various concepts and topics, I believe it is important for the instructor to be a facilitator in self-learning, not a lecturer, in this model of the capstone course. It is neither realistic nor necessary for the instructor to be knowledgeable in all topics that are being explored. Instead of helping students learn about specific topics, the instructor could guide students to think about the broad significance of the research, to interpret plots, to identify the main results, to utilize library and other institutional resources, etc. The instructor could connect the neuroscience students to other experts outside of the neuroscience program (e.g., microscopy and optics researcher in the physics department). Going over the drafts of presentation materials (e.g., scripts, slides, etc.) and providing concrete suggestions for improvements turned out to be the most time-consuming parts for the instructor, since developing robust communication skills was an important learning objective of the capstone course.

Some of the main challenges for students were: (1) allocating and managing time realistically for different stages of the course (e.g., how many hours should be spent on studying the research methodology and on preparing for the presentation?), (2) breaking down the entire research article into smaller topics with a reasonable scope (e.g., how in depth should a particular topic be studied and covered?), (3) interpreting the graph (e.g., how does a particular graph represent the result of the research?), and (4) converting their understanding into a broadly-accessible presentation (e.g., how can a particular topic be explained to a high school student?).

During the COVID-19 pandemic in 2020, all instruction was moved online at my institution, so each student in the capstone course created a 3-minute video, in the spirit of "3 Minute Thesis" (https://threeminutethesis.uq.edu.au/). They were uploaded to YouTube as unlisted videos, and the links were shared with the high school students. There was a follow-up Q&A session via the online conferencing software, Zoom. Students interacted by asking and answering questions not only about the presented research, but also

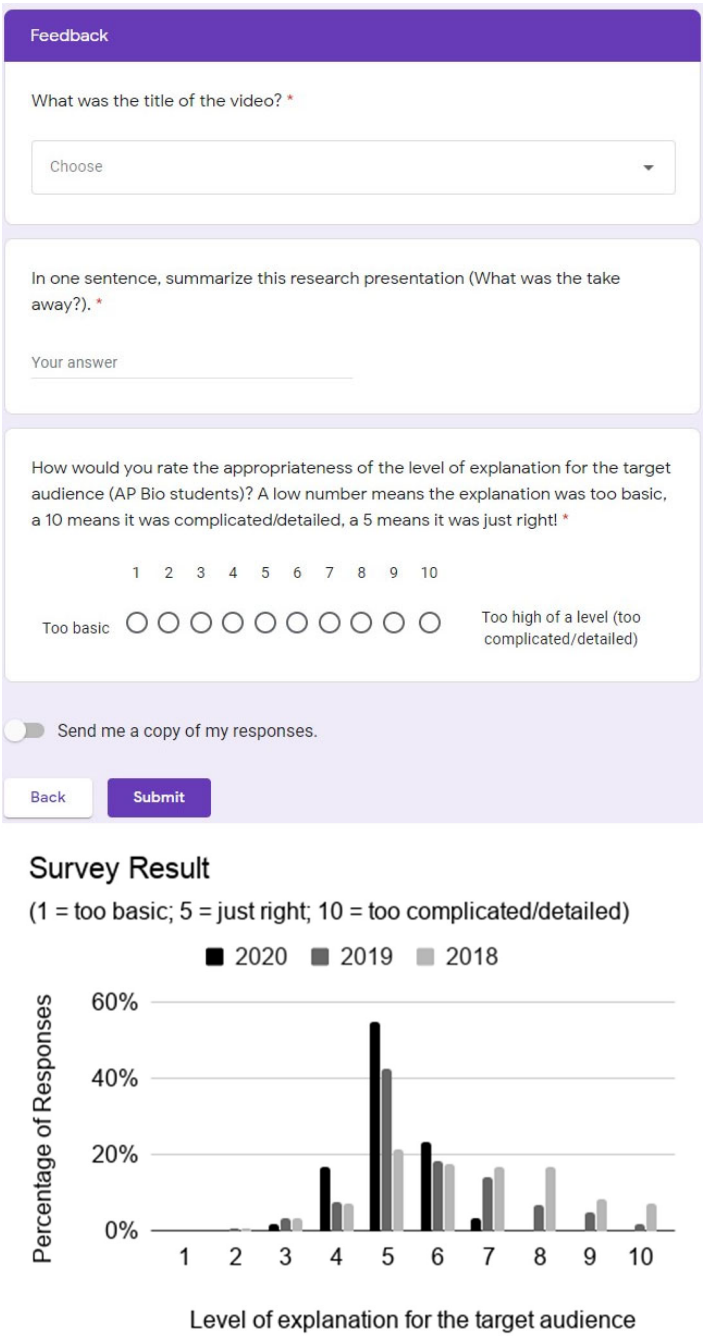

Figure 1. Survey form for the audience (top) and the results (bottom). The survey questions were: "In one sentence, summarize this research presentation (what was the take away?)." and, "How would you rate the appropriateness of the level of explanation for the target audience (AP Bio Students)?" The average ratings are 6.6, 5.8, and 5.1 in 2018, 2019, and 2020, respectively, showing the steady improvement over time, as the level of explanation was rated as more appropriate and not too complicated for the audience.

about studying neuroscience and life in college. In previous years, a poster session was held at the local high school. High school students were given a short survey to provide anonymous feedback. The survey asked for a one-sentence summary and a rating on the clarity of each presentation (see Figure 1). The survey results were then shared with the students in the capstone course. The videos and the survey from 2020 can be viewed at https://forms.gle/gBEKFNMpxtHyudpt6.

The final presentation materials, whether they were online videos or posters, contained clear acknowledgment and citation of the original research articles. Students were given a template sentence to credit the original authors and to specify that they were merely presenting the research. Students also emailed the original authors and shared the final presentation materials. An email template was also provided, so that students could compose a professional and concise message. Many authors graciously replied to students' emails with words of encouragement and additional information about the research.

Developing a good partnership with a local high school was one of the most critical and rewarding aspects of this capstone course. I was lucky to work with an AP biology teacher at a local high school who saw the value of having her students interact with the undergraduate neuroscience students and who rallied her students to participate in this activity voluntarily. We collaborated on the survey form as shown in Figure 1, and coordinated the schedule of the presentation. Because the presentation happened outside of her regular class time and location, she arranged a venue (high school library for the poster presentation in 2018 and 2019) and a special meeting time (lunch hour for in-person presentation and evening hour for a Zoom meeting in 2020). We agree that this partnership is mutually beneficial to both groups of students, and we plan to continue our collaboration.

The capstone students provided the following comments on the anonymous end-of-semester course evaluations:

> "[B]y the end of the course, you really realize how good of an experience it was. Working on the poster/video was time consuming, but you really felt happy with the final end product." (Spring, 2020)
>
> "Fantastic course!" (Spring, 2020)
>
> "Really great capstone project. Compared to other majors, the neuro capstone was incredibly fair and the amount/type of work we had to do was worthwhile. Being asked to turn very complex and advanced knowledge into a presentation that can be understood by people with varying levels of understanding on the subject was a lot harder than expected but also a very productive exercise. Whether you're going into clinical medicine, research, or other science fields, being able to explain complex concepts to others is always going to be a valuable skill." (Spring, 2019)
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> "[P]erfect way to end our neuroscience major. I loved presenting at [the local high school] and the opportunity to contact the authors of publications we looked at in a professional way. This was a great class!" (Spring, 2019)
>
> "It allowed me to think about simplifying complicated papers into understandable pieces for discussion…" (Spring, 2019)
>
> "[T]he experience of going to a high school to present research is a really innovative experience that will be memorable... [I]t gives us a chance to be a source of inspiration or motivation for those kids..." (Spring, 2018)

The average ratings for this capstone course were 3.87 (Spring, 2018), 4.45 (Spring, 2019), and 4.61 (Spring, 2020) out of 5.0. The college-wide average ratings were 4.38, 4.44 and 4.37, respectively. The positive trend in the rating is likely due to the fact that the instructor was able to lay down the directions and expectations more clearly for the students, by offering the course repeatedly. In 2020, students have expressed that they really enjoyed making the 3-minute video, instead of a more academic research poster, and this switch in the presentation format may have contributed to the increase in the rating. According to the short survey of the high school students, the level of explanation also improved over the same period, as shown in the bottom figure. The average scores were 6.6, 5.8, and 5.1, where the score of 1 signified the explanation was too easy and 10 indicated the presentation was too difficult. In 2020, the average rating was 5.1, indicating that the high school students thought the level of explanation in the video presentation was quite appropriate.

Students' final presentation constituted a large portion of their final grades. They were assessed using the oral communication rubric from the Association of American Colleges and Universities (AAC&U, 2009). The draft presentations were graded just on the basis of completion as low-stake assignments. At various points in the semester, students exchanged feedback on each other's drafts. For example, sometimes in small breakout groups of two or three students, students commented whether the draft presentation contained any jargons that might be replaced by simpler terms or any concepts that needed elaboration. At other times, the whole class listened to each other's presentation under construction and had a round of constructive feedback. During some of the earlier feedback sessions, the presenter did not have to answer any questions, but just noted questions and comments, so that they could address them in the next drafts. Another small grading element included listening to science podcasts regularly. Throughout the semester, students had to listen and submit short summaries from the daily, 10-minute science podcast, Short Wave, from National Public Radio. The main goal was to help students to develop a regular habit of learning something new and interesting (like low-impact, daily exercises to stay fit) and to expose them to many, good examples of science communication. Students submitted two-sentence summaries of the podcast episodes and submitted them on a simple electronic form (Google Form). As long as they provided two or three summaries

per week, students could achieve the full mark in this grading category. Another miscellaneous grading category in this capstone course was to submit an updated resume or CV and to seek the guidance of the career center, if they had never utilized the service.

SUMMARY

In this capstone course, students applied their neuroscience knowledge to digest contemporary research articles and then presented what they learned to a younger generation. Students find it a meaningful culminating experience of their undergraduate neuroscience education. As an instructor, it is rewarding to witness students' developments as independent scholars and teachers. It is also fulfilling to partner with other educators at a local high school. Another benefit for the instructor is to learn about diverse on-going neuroscience research topics as students are studying and presenting different articles. This capstone course ran successfully in an online format during the spring semester of 2020.

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Address correspondence to: Dr. Minjoon Kouh, 36 Madison Avenue, Drew University, Madison, NJ 07490. Email: mkouh@drew.edu