ARTICLE
From Botox to Behavior: Neuroscience for Non-Scientists at Emory

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For the past six years, we have been teaching a neuroscience for non-science majors course titled "From Botox to Behavior: Neuroscience for non-scientists." The primary objectives for this course are to create science literate students using neuroscience concepts as the foundation. The evidence from our course assessments suggest that the students are learning fundamental concepts and developing skills of source evalution, using evidence in an argument and appreciating the role of neuroscience in society. While the course has been very successful as measured by student performance on assessments of content learning and student satisfaction, we have noticed a pervasive weakness in quantitative literacy. Our future directions include assessing what kinds of interventions and approaches work best to increase quanitative literacy among non-science majors.

Key words: Active learning; non-majors; Problem Based Learning (PBL); liberal arts; synaptic communication.

INTRODUCTION: Why and What we teach

We teach at a highly-selective liberal arts college within a research university. All undergraduate students must complete two science courses with at least one including a laboratory course in order to graduate. While many undergraduates at Emory pursue a natural science major and/or a "pre-health" track that includes many rigorous science courses with laboratories, students from non-science majors often feel overwhelmed in these courses. Thus in this context, science courses with laboratories that are not filled with natural science majors or students pursuing a pre-health track, are in very high demand.

Whether it is best to segregate out the non-science majors into their own classes or redesign the introductory major courses to be more inclusive and broad is an important debate (Klymkowsky, 2005; Wright, 2005), but at Emory the tradition has been to design separate science courses exclusively for non-science majors. For this reason we created "From Botox to Behavior" with a heavy emphasis on the "Core Concepts" for public neuroscience knowledge developed by the Society for Neuroscience Education Committee (http://www.brainfacts.org/about neuroscience/core-concepts/). In order to discourage science majors from enrolling in this course, it does not count toward any science major, so each semester it primarily fills with non-science majors looking to fill the graduation requirements. Within this context, we set out to create a course that would help students achieve both content and process goals (Figure 1), and we organized the course in a bottom-up structure. The first module focuses on synaptic communication, the second on sensory systems, the third on motor systems and finally the fourth module highlights complex behaviors.

METHODS: How we teach

We have arranged this 4 credit course to meet six hours/week (similar to a 3 credit + 1 lab credit course), but in a studio-style that meshes the 'lecture' and 'lab' time into two three-hour class meetings each week. The course is team-taught so that two faculty members share the instruction each term. In the six years of running the course, we've generally had both professors present at all of the course meetings to help facilitate class discussion and interaction with the material. We've kept the class relatively small at 24 students who work in small groups during class activities and lab exercises.

In each of the course modules, we emphasize active-learning pedagogies to achieve outcomes in both content knowledge and process skills. Examples of activities and lessons are shown in Figure 2.

Overarching course goals

Content goals:
- Understand how two neurons communicate, and predict how modifications will affect this communication.
- Discuss how circuits of neurons can govern simple and complex behaviors.

Process goals:
- Critically evaluate sources, data and arguments.
- Use evidence to support an argument or make a strong conclusion.
- Appreciate the influence of the brain on behavior.
- Identify impacts of neuroscience research on society.

Figure 1. Course Goals were heavily influenced by the SfN Core Concepts.

Active-learning addresses CONTENT & PROCESS

Problem-Based Learning cases
- Synaptic communication 3-case series (for example, see Roesch and Frenzel, 2016)

Inquiry-based labs
- Sensory & Motor systems labs

Discussion, debate, small-group activities
- NOVA and Frontline videos and discussions

Fieldtrips and guests
- Yerkes National Primate Research Center
- fMRI imaging facility tour
- Shepherd Center therapists discuss spinal cord injuries

Figure 2. Active-learning Pedagogies are used throughout the course.

Learning Issue Example topics	Select Evaluation Criteria		Average Grade
• Effectiveness of heroin assisted treatment centers • Sarin gas mechanism • Botox injections for migraine • ACh receptor antagonists • Incidence of stroke in Indonesia • How saxitoxin works	**Critical review of resources**	Thorough analysis of all resources including author's perspective	First Paper 87% Last Paper 94% Across all Papers 91% Typically 4-7% gain
	Summary writing	Concise synthesis of information; substantial depth of coverage of topic	

Figure 3. Example Learning Issue topics from the first module, example evaluation criteria and average grades over two cohorts.

RESULTS: What are they learning

Over the semester, we use four main assessment tools. Learning Issues papers are short investigative research papers focused on a topic which the student identifies during the activity/module/lesson. In addition to the content, the students must critically evaluate each reference they use before incorporating the source into the document. Learning Issues are evaluated on the basis of accurate and substantive information as well as on the strength of the evaluation of the sources used. Over the semester, each student writes six of these Learning Issues papers. Figure 3 highlights some example Learning Issue topics covered in the first module, two evaluation criteria used when grading the papers, and average grades for two cohorts of the class. Note the large increase in grades over the course of the semester- students get much better at this assignment with practice.

As a second assessment, students write longer papers critically evaluating a portrayal of a neuroscientific topic in the media. Examples of topics the students have chosen recently as well as example evaluation criteria are presenting in Figure 4. In general, students use the skills in finding high-quality references which they've developed in the Learning Issues work to tackle often-times messy, exaggerated or false neuroscientific content in media. Topics range from mental health disorders shown by characters in tv and film, to claims of products like Neuro drinks and Lumosity. This assessment evaluates process goals of critically evaluating sources, using evidence to support an argument and appreciating the role of neuroscience research in society. Students generally do well on these papers, and the first Critique Paper comes after the students have completed four shorter Learning Issues papers and thus the grades show modest improvement and stay strong.

Example Topics	Select Evaluation Criteria		Average Grade
Movies & TV Finding Nemo (amnesia) House (poisoning) *Video Games* Labyrinthine Dreams (depression) *Products* Neuro water	**Description of content**	Precisely describe the neuroscientific content within the item.	First Paper 89% Last Paper 94% Across all Papers 91% Typically 2-5% gain
	Critical Analysis	Well-supported, fact-based analysis of the portrayal.	
	Citations	Student provided documentation to support all facts.	

Figure 4. Example topics for Critique Papers, example evaluation criteria and average grades over two cohorts.

Example Presentation formats	Select Evaluation Criteria		Average Grade
Skit, play or film Multimedia presentations Song or music video Adapted games Original games Puppet show	**Creativity & interest**	Engaged the class with an interesting approach and/or activity.	First Presentation 90% Last Presentation 94% Across all 92% Typically 2-4% gain
	Depth of coverage	Covered at least 4 topics from the unit and they were presented clearly, accurately, and in depth.	
	Created context	Related the topic(s) to content from other classes and/or society.	

Figure 5. Example formats, example grading criteria and performance for two cohorts of students on group presentations.

To conclude each of the four modules, the students give 15-min. group presentations followed by brief multiple-choice quizzes, which are taken individually. These assessments emphasize content learning but the nature of the oral presentations allow for students to be very creative and require that they connect the content of the module to other aspects of their lives (e.g., topics from other courses, extracurriculuar activities, current events). The students choose which topics are most relevant to cover in the presentation, and this student-centered approach allows for assessment of how well the students are evaluating and connecting the individual topics in each unit. Figure 5

gives examples of formats students have chosen for the presentations, example criteria for evaluation, and average grades for two recent cohorts. Like the performance on Critique Papers, students start with quite high grades and stay relatively high throughout the semester.

Lastly, this course is also a laboratory course and as such students are required to write up several of the inquiry-based lab activities as lab reports. We integrate seven lab activities into the course, and the student performance on the labs is assessed with lab reports. This assessment evaluates students' ability to create hypotheses, to create data charts and tables, and to draw conclusions from their data analysis. Figure 6 lists the lab exercises in the course, shows two example criteria by which we evaluate the reports, and average grades for two recent cohorts.

Although our students learn and apply many fundamental neuroscience concepts in the context of the lab activities, they struggle to use data to support their arguments, frequently ineffectively present data they collect in lab activities, and often inappropriately interpret results in the context of the overall hypotheses. As shown in Figure 6, there is little difference in the report grades at midterm and final, suggesting little improvement in the process despite practice and feedback. Among the six iterations of our course, we've tried to help students better understand the labs and more effectively communicate their work. After our first round of disappointing lab reports, we tried to add more time for pre- and post-lab discussion. While these talks added more context to the research question, provided example data and figures, and gave students more time to wrestle with the findings and ask questions, the overall performance on lab reports remained relatively flat. We then added more choice as to which lab reports are written formally and handed in (4 of 7 instead of 7 of 7), but even the reduced workload didn't help the performance. Finally, we have honed in on some fundamental weaknesses and discomfort with quantitative reasoning that could be underlying the perennial weak student performance on the lab reports. See further details in the discussion section as to how we hope to improve performance on lab reports.

Laboratory Activities	Select Evaluation Criteria		Average Grades
Comparative neuroanatomy Two-point discrimination Thermo-receptors & Menthol Hearing in the Dark Taste Reflex Reaction time	**Data Interpretation**	Clearly interpret what the data mean with respect to your original hypothesis.	First set 87% Last Set 88% Across all labs 88% Typically 1% gain
	Putting results in context	Summary ties results into bigger picture and published information about the topic.	

Figure 6. Names of the seven lab activities with two example grading criteria and performance for two cohorts of students on the lab reports.

DISCUSSION: What have we learned

There are major strengths to this course design. Student satisfaction is high and it is a popular course. The course regularly fills up quickly and there are many requests to overload each semester. Overload requests usually include a comment about how excited the student is to take our course specifically and a statement about the great reputation of the course. At the end of each semester, the students have ranked each major assignment, on average, a 3.9/5 for "usefulness" and 3.5/5 for "engaging or interesting" on a Likert scale. Other feedback from course evaluations include an overall ranking of 7.8/9 on a Likert scale incorporating ideas broadly about how well the class promotes learning. Both instructors enjoy teaching the non-majors and watching the improvement and growth in the students over the semester. The vast majority of students learn fundamental neuroscience concepts during the course as shown by strong overall performances on short papers, longer media critique papers, class presentations and quizzes. Students improve greatly on their process skills including finding and evaluating sources and connecting neuroscience to their daily lives. Even the long class periods of three hours is a success in that students have plenty of time to question and explore as we discuss and work through case studies in class.

The weaknesses to this course design are that it is a heavy workload for both instructors and students. Two faculty members are in class together for six hours/week and there is a substantial amount of grading over the semester. This workload biases the class to a small size and therefore limits the volume of students taking the class each term.

Although we continue to be impressed with the content and process skills our students develop over each semester, we've also noticed a pervasive discomfort with quantitative reasoning. After six years of teaching this class, we have remarked on the depth and consistency of this limitation, which is especially present in the lab report assessments. In the most recent edition of the class, we've tried to add some specific scaffolding exercises (e.g., exercises with quantitative figures to discuss, formative assessments of data charts and figures before lab reports are due, more explicit discussions of means and variability) to each assignment in order to specifically address quantitative reasoning. Because quantitative reasoning is so fundamental and our students' weakness seems so pervasive, a highly detailed analysis, perhaps using both quantitative and qualitative measures, is needed in order to assess the effects of interventions intending to specifically address quantitative reasoning outcomes.

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