CASE STUDY
Two Scientists Share Nobel Prize for the First Time! A Case Study Developed for Exploring the History of Neuroanatomy

Darlene A. Mitrano
Department of Molecular Biology & Chemistry, Christopher Newport University, Newport News, VA 23606.

In this case, students read a 'press release' that describes the awarding of the 1906 Nobel Prize in Physiology or Medicine to Camillo Golgi and Santiago Ramon y Cajal. The case was developed to highlight the historical significance of these first descriptions of the nervous system for an upper level undergraduate neuroanatomy course. The dialogue was presented in a way to pique the students' interest by focusing on the disagreement between the two scientists on the structure and arrangement of neurons in the brain and peripheral nervous system. In the middle of the case, there were two concept check questions to ensure that the students understood the conflicting theories put forth by Golgi and Ramon y Cajal. At the end of the narrative, the class was broken into groups and assigned a series of questions to engage the students in reading primary literature (e.g., the acceptance speeches of both scientists), as well as secondary review articles on both Golgi's and Ramon y Cajal's contributions to the field of neuroscience. A series of primary and secondary articles was provided to the class, although this could be optional (depending on the course/level of students). Students presented their answers to the class in the form of short presentations. The case could also be used in an introductory neuroscience class to present the foundations of neuroanatomy, controversies in scientific discovery, biases that have existed or still exist, and how scientific information was disseminated prior to the 21st century.

Key words: *neuroanatomy, neuron doctrine, reticular theory, history of neuroanatomy, case-based learning, collaborative learning, primary and secondary literature*

CONTEXT

Recently, academics concerned with assessment, a hot topic of conversation in higher education, have been asking the question, "Are college graduates retaining what they have learned over the past four years and has their education prepared them to become productive members of society?" Part of what employers, graduate schools, etc., are looking for is individuals who can think critically and abstractly; in other words, to use skills acquired in college to critically analyze their world and think outside the box. Recent research on this topic by Arum & Roksa (2011) showed that reports of college graduates lacking these skills are increasing. Although the authors discuss many potential contributing factors , it is estimated that undergraduates spend over 80% of their time socializing, sleeping, volunteering, working, or participating in clubs, fraternities and sororities, while less than 20% of their time is spent in class or studying (Arum & Roksa, 2011). This lack of engagement surely has various causes, but as educators, we can do our best to encourage students to be more involved in their coursework by utilizing educational tools other than standard lecture.

One such pedagogical tool is the use of case studies either to introduce a new topic or to apply what is presented in lecture to a real-life scenario. Meil (2007) recognizes the advantages of using cases in undergraduate neuroscience classes. For example, case studies can put the student at the forefront of learning by having them gather and analyze novel information not provided in the case and encouraging them to come up with new ideas or hypotheses about a particular scientific concept (Meil, 2007). In relation to teaching undergraduate neuroanatomy, a short study completed by Greenwald & Quitadamo (2014), compared conventional lecture and lab to inquiry-based case techniques. Students in the inquiry-based class scored higher final exam and overall course grades and showed two and half times greater critical thinking gains on the California Critical Thinking Skills Test than did students in the conventionally taught class (Greenwald & Quitadamo, 2014). As E.O. Wilson (2002) stated, "So, how can we make science human and enjoyable without betraying its nature? The answer lies in humans' innate capacity to understand narrative."

Course Overview

The case presented here was written for an elective upper level neuroanatomy course that enrolls 15-20 junior or senior level neuroscience majors each year. When originally designing the course, the main challenges were (1) finding a textbook designed for undergraduates (not medical/graduate students), and (2) the lack of case studies available for neuroanatomy courses. One of the learning objectives developed for the course was to "Apply knowledge of techniques, structure, and function of the nervous system to lab activities and case studies." A recent search of the term *Neuroscience* on the National Center for Case Study Teaching in Science (NCCSTS) website found 12 cases, while the terms *Neuroanatomy* brought up one, and *History of Neuroanatomy* resulted in zero (NCCSTS, 2018). Over the past five years of teaching this class, cases from NCCSTS and the *Journal of Undergraduate Neuroscience Education* (JUNE) have been used.

However, the ones most useful for an upper level class were cases designed for medical school students that examine an injury or damage to the central or peripheral nervous system where the cause of the dysfunction must be identified (Martin, 2012). The medical school cases often contain technical jargon not appropriate for this type of class. Additionally, as neuroscience becomes a more common major, students enrolled in a neuroanatomy course are increasingly not destined for medical school nor a pre-health program (Ramos et al., 2011; Neuwirth et al., 2018). Therefore, there is a need for material such as this case, which is inclusive for all the students in the course.

Case Overview

An area that was missing from *almost all* neuroscience cases examined was one addressing historical aspects of neuroanatomy. "*Two Scientists Share Nobel Prize for the First Time! A battle to the end…who is actually right about the structure of the cells of the nervous system?*" was written to instruct about the foundations of modern neuroanatomy. This case uses a combination of working in groups, researching the topic using primary and secondary literature, having the students present their work to the class, and finally discussing the topic. Often, the founders of neuroanatomy are glossed over, and it is accepted that Santiago Ramon y Cajal correctly identified the morphology of the neuron and that spaces existed between them. Neuwirth et al. (2018) pointed out that most neuroanatomy curricula neglect to address any historical aspects of the field. Neglecting the historical aspects of neuroanatomy may present a disadvantage to students, as it has been shown that providing a historical context using case narratives promoted learning and remembering the information to build better bridges between the structure and function of the nervous system (Neuwirth et al., 2018). Therefore, this case was designed with some of those ideas in mind. The case aims for students to think critically and ponder questions such as why the neuron doctrine was finally recognized, what evidence or published work supports the ideas of the scientists, and why Golgi's reticulum view of the nervous system was accepted for so long over the work of Ramon y Cajal.

Classroom Management

The case was presented during the second week of the semester, after the gross anatomy of the brain was reviewed and before a unit on the evolution of the nervous system. The course met for 75 minutes, twice a week. The dialogue of the case was read aloud near the end of one class period and students were individually assigned the Concept Check questions in the middle of the case for homework. The rest of the case was read, and students were broken into five groups, which were each assigned a single question set (see implementation notes and full case study narrative, available upon request from cases.at.june@gmail.com). The first four question sets were to be answered in the form of a ~15 minute PowerPoint presentation during the next class, five days later (a grading rubric for presentations is provided in the implementation notes). A bank of review articles and copies of the Nobel Prize acceptance speeches was posted on a secured server for the students to use for this assignment (they are also listed at the end of the case narrative for the students). The fifth set of 'questions' aimed to enhance collaborative, creative work by assigning the students to create a conversation between Golgi and Ramon y Cajal as though they were alive today.

All five question sets were assigned to each of five different groups, but each set could stand alone, especially the last set, if the goal is to get the students to really think outside the norms of a science class. Students given this set of 'questions' seemed reluctant at first, but their product (in the form of a Twitter conversation) engaged everyone in the room. The presentations were graded according to a general rubric created for presentations with the expectation that everyone in the group would speak in front of the class and contribute to the work; therefore, all students in a group received the same grade. The presentations were posted to our secured class website so that all students could use them as basis to study for the next in-class exam. Based on student responses (see below), the case will be used again.

Learning Objectives

The case was designed with the following learning objectives in mind. Next to each learning objective is the Question Set in the Case Narrative to which each Objective corresponds.

Identify and explain the concepts of the reticular and neuron doctrines, the scientists who promoted them, and the brain structures these scientists used for evidence to support their claims. (Concept Check & Question Set #1)

Describe the Golgi method used by Golgi and Cajal, state how they recorded their results, and identify newer technologies and data that support Golgi and/or Cajal's theories on the structure of the nervous system. (Question Sets #2 & #3)

Describe alternate paths that can be taken by scientists during their careers (i.e., do scientists always remain in one discipline?). (Question Set #3)

Explain the history of a widely accepted neuroscientific concept and why some research findings are more highly valued by scientists/the public compared to others. (Question Set #4)

Identify changes that have occurred in the neuroscientific community since the time of Golgi and Cajal (e.g., the ratio of male to female scientists, technology, countries that are the leaders in science). (Question Set #4)

Apply primary and secondary literature to answer questions for an assignment and to appreciate the goal and practice of critiquing published scientific findings. (All Question Sets)

Enable students to look creatively at a seemingly dry

topic of neuroanatomy to increase student engagement in the topic. (Question Set #5)

CASE EVALUATION

Assessment Overview

Student learning was assessed in four formats: three which students had to complete individually and the fourth which was done as a group. First, the students were assigned two Concept Check questions that were embedded in the middle of the case as an independent homework assignment. This assignment was worth 10 points and was expected to be handed in during the next class (2 days later). The goal was for students to start thinking about the material on their own. They were required to use the references provided to them at the end of the narrative, which was also posted on the class website. A few students did not complete the assignment, but the average on the two questions was 7.84 out of 10 points.

Five days later, the students had to give their presentations to the class, based on the question set they were assigned. Students were given approximately 15 minutes and the other students were expected to pay attention and take notes, as the next in-class exam would contain questions covering the major points of the presentations. The presentation was worth 25 points, and all members of each group received the same grade. The average was 23.5 out of 25 across the five groups.

On the next in-class exam and on the final exam, students were given the same six questions that covered the major points of the case study. Out of the six questions, they were required to answer two. These questions can be found below in Table 1 (with the number of students that answered each one and the average score) and in the implementation notes. These questions will be revised for future use (see Summary and Future Directions below). Each question was worth 4 points. The last time the course was taught, material did not cover information about Camillo Golgi and thus is not comparable to this data.

Question	# of students answered: in-class exam / final exam	Average score (out of 4) +/- SD on in-class exam	Average score (out of 4) +/- SD on final exam
What brain regions were most highly studied by Golgi & Cajal using the black reaction? What is unique about the brain regions examined that allowed both Cajal & Golgi to draw conclusions about neurons from their observations?	8 / 11	3.87 +/- 0.35	3.27 +/- 0.75
How does the Golgi method work? Why did this method allow Cajal and Golgi (and other scientists) to examine the morphology of the neurons compared to earlier attempts?	2 / 0	4.00 +/- 0.00	------
What advancement in scientific technology in the 1950's offered support to Cajal's neuron doctrine? How and why?	13 / 14	3.77 +/- 0.60	4.00 +/- 0.00
What is a synapse? Do all neurons have the same types of synapses?	13 / 12	3.69 +/- 0.48	3.16 +/- 0.95
What element of trust can we have in diagrams drawn by Golgi and Cajal (i.e., do the drawings bias conclusions)? What do we do now to decrease bias in observing brain tissue?	2 / 2	3.50 +/- 0.71	2.67 +/- 0.00
Why do you think Golgi was so argumentative in his acceptance speech of the Nobel Prize? What else has he contributed to cell biology, in general?	6 / 5	4.00 +/- 0.00	3.47 +/- 0.73

Table 1. Questions given on the in-class exam and final exam. The number of students that answered each question is listed with the average score and standard deviation (n=22 students).

Survey Statement (1 = Strongly Disagree; 5 = Strongly Agree)	Average Rating (Mean ± SD; n=22)
1. I enjoyed learning about the foundations of neuroanatomy in this case study format.	4.19 ± 0.85
2. I would have preferred a lecture about Camillo Golgi and Santiago Ramon y Cajal rather than reading and working through the case study.	2.90 ± 0.48
3. I gained more knowledge about Golgi and Cajal from the 'news' story presented in the case rather from what I previously learned about them, either from a textbook or lecture.	4.19 ± 0.88
4. Looking through the acceptance speeches and review articles increased my knowledge about these two scientists.	4.24 ± 0.97
5. I enjoyed working in a group on the assigned questions.	3.62 ± 0.60
6. I previously knew how controversial the neuron doctrine was compared to the reticular theory and how much the scientists did not get along.	1.86 ± 0.36
7. The case made me think about scientific discovery in a different way than I usually do.	3.86 ± 0.69
8. It is important to learn about the history of a scientific concept.	4.48 ± 1.08
9. Creating a PowerPoint presentation in 5 days to answer the assigned questions was too much to ask of us.	2.10 ± 0.38
10. This case should be used again to teach the foundations of modern neuroanatomy.	4.38 ± 0.95

Table 2. Results of survey given to students after completion of the case. Using a Likert scale, students rated a variety of statements on their enjoyment of completing a case activity, the learning objectives, and how they felt working in groups and creating a presentation.

Student Feedback

After the first use of this case, students were asked to complete an anonymous survey on their opinions of the case study (see Table 2) prior to receiving their grades on the presentation, exam, and homework assignment. Overall, the case seemed to be well-received. Looking at specific items in the survey, it showed that most students did not know about the controversy and depth of disagreement between Golgi and Ramon y Cajal and enjoyed learning about it using case study format, rather than conventional lecture. Question 11 on the survey asked students to provide additional feedback on the assignment and the case; about half of them provided comments. Some students indicated they enjoyed learning about Golgi and Ramon y Cajal using a case study, others indicated that the rubric provided for grading purposes was a little vague. Example responses are included below Table 2.

Question 11 Responses:

"Enjoyed this assignment!"

"The instructions on the free response portion were unclear, but not impossible. Overall, I enjoyed the assignment."

"I feel parameters were too vague in expectations. The reason I feel like I would have preferred a lecture is to have explicit information."

"I learned more about Golgi and Cajal here as well as their respective theories than any other class."

"Only problem would be teamwork- having to match up times where everyone can meet."

"I loved the interactive forum..."

SUMMARY & FUTURE DIRECTIONS

After reviewing the student presentations, feedback, and scores on the in-class exam and final exam, most of the learning objectives originally designed for this case were met. Some of the original learning objectives and the grading rubric were broad in nature and hence have been modified for this manuscript (as noted above in the Context section and in the Classroom Implementation Notes, available upon request from the author). Overall, this case presented a unique learning opportunity for the students to delve deeper into the original terminology used to describe the nervous system and to look at the actual writings of the 'fathers' of neuroanatomy. The history of neuroscientific concepts is usually overlooked or skimmed over in introductory classes. Providing a 'press release' with a historical context not only allows the students to learn about these scientists, but hopefully improves retention of the topic (Wilson, 2002). Active-learning, which was designed into this case, has been shown to improve student performance on exams and to facilitate success in science overall (Freeman et al., 2014).

Responding to Student Feedback

In respect to the survey taken by the students, it seemed that they enjoyed a case/scenario format rather than a

standard lecture, and most agreed it should be used in the future. However, there were valid negative points brought up within the feedback. A new rubric will be used that breaks down the parts of the presentation with assigned point values (see Classroom Implementation Notes). Secondly, the Case Narrative was edited to make the 'press release' more realistic by giving names to the characters that were engaged in the dialogue (previously they were just labeled as Scientist #1 and Scientist #2). Additionally, the questions in each question set were modified to be clearer about what was expected in an answer.

Although a few students felt five days was not ample time to put together a presentation with a group, most felt this was not an issue. A few responses indicated that some students in the class were unsure that the presentations by the other groups correctly answered the questions in the assignment. In response to this matter, a future direction (discussed below) is to have peer evaluation of the presentations. This will hopefully lead to better recognition by the students themselves as to whether each question set was answered correctly.

Future Directions

One item to consider, as mentioned above, is peer evaluation of the presentations as part of the grade. This will encourage the students not only to pay attention to one another during the presentations, but also to consider whether or not the questions guiding the presentation were answered correctly. Student raters could then add in other information that was omitted. A rubric is currently in the works for peer evaluation.

Second, having the students find their own resources (primary or secondary literature) to answer questions would be valuable in enhancing their research skills. Since the majority of the neuroscience majors at the author's institution go on to graduate school, medical school, or an area related to research, being able to find evidence in the literature to support an idea is a highly valued skill.

Third, as displayed in Table 1, very few students chose to answer questions on the in-class exam or the final that addressed the actual neuroanatomical technique around which this case is centered, as well as questions on the cultural biases displayed. If deemed to be the most important information to gain, these should become mandatory questions instead of optional ones.

Overall, based on the quantitative and qualitative feedback, revisions to the rubric, and data on exam questions, this case is ready for further use. It encourages students to be part of collaborative learning, group work, research, and scientific communication.

REFERENCES

Arum R, Roksa J (2011). Academically adrift: Limited Learning on College Campuses. Chicago, IL: University of Chicago Press.

Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderworth MP (2014) Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences 111:8410-8415.

Greenwald RR, Quitadamo IJ (2014). A Mind of their own: Using inquiry-based teaching to build critical thinking skills and intellectual engagement in an undergraduate neuroanatomy course. J Undergrad Neurosci Educ, 12:A100- A106.

Martin JH (2012) Neuroanatomy Text & Atlas. 4th edition New York: McGraw-Hill Medical.

Meil WM (2007). The use of case studies in teaching undergraduate neuroscience. J Undergraduate Neurosci Educ 5:A53-A62.

National Center for Case Study Teaching Science (2018) Buffalo, NY: University at Buffalo. Available at: http://sciencecases.lib.buffalo.edu/cs/index.asp.

National Survey of Student Engagement (NSSE), Experiences that Matter: Enhancing Student Learning and Success (2007). Bloomington, IB: Center for Postsecondary Research, Indiana University.

Neuwirth LS, Dacius TF, Mukherji BR (2018). Teaching neuroanatomy through a historical context. J Undergraduate Neurosci Educ 16:E26-E31.

Ramos RL, Fokas GJ, Bhambri A, Smith PT, Hallas BH, Brumberg JC (2011). Undergraduate neuroscience education in the U.S.: an analysis using data from the National Center of Educational Statistics. J Undergrad Neurosci Educ, 9:A66-A70.

Wilson EO (2002) The power of story. American Educator 26:8-11.

Received February 4, 2019; revised February 4, 2019; accepted February 4, 2019.

Acknowledgements: NSF-RCN-UBE Grant #1624104: The Neuroscience Case Network (NeuroCaseNet); the support and collaboration of the NeuroCaseNet developers and fellows, namely Kristen Frenzel, Pat Marstellar and Leah A. Roesch; James W. Bogenpohl, Ph.D. for editing the manuscript; and lastly the Christopher Newport University Neuroanatomy students, past and present.

Address correspondence to: Dr. Darlene Mitrano, Christopher Newport University, Department of Molecular Biology & Chemistry, 1 Avenue of the Arts, Newport News, VA 23606. Email: Darlene.mitrano@cnu.edu