ARTICLE
Using Case Studies as a Semester-Long Tool to Teach Neuroanatomy and Structure-Function Relationships to Undergraduates

Susan Kennedy
Psychology Department and Neuroscience Program, Denison University, Granville, OH 43023.

In addition to being inherently interesting to students, case studies can serve as useful tools to teach neuroanatomy and demonstrate important relationships between brain structure and function. In most undergraduate courses, however, neuroanatomy is presented to students as a "unit" or chapter, much like other topics (e.g., receptors, pharmacology) covered in the course, over a period of a week or two. In this article, a relatively simple model of teaching neuroanatomy is described in which students are actively engaged in the presentation and discussion of case studies throughout the semester, following a general introduction to the structure of the nervous system. In this way, the teaching of neuroanatomy is "distributed" throughout the semester and put into a more user-friendly context for students as additional topics are introduced. Generally, students report enjoying learning brain structure using this method, and commented positively on the class activities associated with learning brain anatomy. Advantages and disadvantages of such a model are presented, as are suggestions for implementing similar models of undergraduate neuroanatomy education.

Key words: Case studies; neuroanatomy; active learning exercises; neuroscience pedagogy

One of the most persistent challenges for teachers of neuroscience is teaching neuroanatomy to students. Mastering the anatomy of the nervous system is known to be quite challenging to many students, due to the sheer complexity of the organization of brain systems (Sheldon, 2000). Most textbooks used in Neuroscience related courses present neuroanatomy as a chapter or "unit," similar in length to other topics covered in the course. Therefore, students are required to learn significant amounts of new and relatively difficult information in a limited time before progressing onto subsequent topics that themselves rely on students having acquired a sense of mastery over neuroanatomy.

This paper will address a relatively simple model of teaching structure-function relationships in a more "distributed" manner. The model is based on peer collaboration and active student engagement (presentation and discussion) with case studies throughout the duration of the semester, in an attempt to provide more regular integration of basic and applied neuroanatomy once the basic structural organization of the nervous system has been presented earlier in the semester. Student feedback on this model, as well as advantages and disadvantages of such a teaching model, will then be presented.

To date, the model described in this paper has been piloted in two different sections of a 300-level Biological Psychology course). Biological Psychology is a required course for students pursuing Denison's neuroscience concentration; students enrolling in the course are generally Psychology or Biology majors, with a smaller number of Biochemistry or Chemistry majors enrolled.

CASE STUDIES AS TEACHING TOOLS

The use of case studies as tools to better understand brain-behavior relationships is certainly not new. For example, students of neuroscience have long been introduced to the famous case of Phineas Gage to demonstrate important inhibitory functions of the brain that may be lost following damage to frontal lobes. Similarly, the historic work of Flourens and Broca, and more recently of Rorden and Karnath (2004) illustrate the usefulness of experimental ablation and clinical observation to highlight some important functions of the cerebral cortex (loss of contralateral movement, speech alterations for instance). In the preface to "Phantoms in the brain," Ramachandran (1998) recognizes the important insights gleaned through careful observations of patients sustaining injury to the nervous system, and how these cases have provided valuable information about the mysteries of the brain.

Case studies continue to be a useful pedagogical tool in undergraduate neuroscience courses (e.g., Meil, 2007; Kennedy and Hassebrock, 2012). In fact, Meil (2007) reports a recent increase in the use of case studies in a number of textbooks currently used in undergraduate neuroscience and biological psychology courses. These texts often highlight case studies to introduce a chapter or concept, or integrate case studies throughout various chapters of the text, thereby providing students with numerous opportunities to examine the structural and behavioral consequences of various neurological disorders (Meil, 2007).

There are a number of ways that case studies can be integrated into student assignments (e.g., Sheldon, 2000; Meil, 2007). Meil (2007), for example, describes an exercise in which students engage in literature review of a particular case, presentation of the case to the class, and design of a potential experiment that addresses a question not yet answered by the case (Meil, 2007). Student feedback on this assignment indicated that students enjoyed the assignment, and that the assignment helped them to deepen their knowledge of biopsychology.

Sheldon (2000) applied a different type of exercise that used descriptions of individuals engaged in different tasks requiring activation of multiple brain regions. Students

were divided into small groups and were asked to identify the brain structures involved in a particular case with which they were presented. For example, one case described a woman engaged in painting as she listened to classical music. In this way, students could work together to apply information recently learned about the anatomy of the brain to real-life examples (Sheldon, 2000).

What follows is another relatively simple model of a case study project in a Biological Psychology course utilizing small group work, class discussion and peer evaluation. The organization of these projects will be described below.

ORGANIZATION OF CASE STUDY PROJECTS: OBJECTIVES

Two classes of Biological Psychology, with approximately 25 students enrolled in each section of the class, participated in the case study projects. Class met three days a week for 50 minutes per session over the course of a 14-week semester, with seven days of the semester devoted to student presentations and class discussion of the case studies (one case study every other week, on average).

There were a number of objectives for incorporating case study projects into the course. First and foremost, the projects allowed students to engage in the study of brain-behavior relationships throughout the semester using short, manageable vignettes of those having suffered some brain injury or disease. By collaborating with peers in small groups, the projects also allowed students work collectively to engage in in-depth analysis of the case (e.g., Sheldon, 2000), and to practice important oral communication skills during the presentation of the case study to the class. Group work in the college classroom setting has been found to have several advantages, including understanding concepts and applying critical thinking skills (e.g., Stanford University Newsletter on Teaching, 1999). Finally, the projects allowed for student engagement with material through larger class discussion based on student-created discussion questions following the presentation of the case study. Thus, the entire class was expected to participate in some aspect of the case study (presentation, discussion leaders or general class discussion) on every case study day.

STRUCTURE OF CASE STUDY PROJECTS

Neuroanatomy was first introduced to the students in the third week of the semester, and generally followed the chapter in the textbook (Carlson, 2012). Approximately five class periods were spent on introductory neuroanatomy. Briefly, students were introduced to the major divisions of the brain (forebrain, midbrain, hindbrain), the structures contained with each of these major divisions, and a general description of the functions associated with these brain regions. In addition, some general principles of neuroanatomy (development of the nervous system, e.g.) were introduced.

During the second week of class, students received detailed written instructions for the forthcoming case study projects, which began in the fourth week. The course instructor spent half of a class period going over the instructions with the class to insure that all students understood what they were being asked to do. Students were then asked to select their "top three" case studies from Sacks' *The man who mistook his wife for a hat* (Sacks, 1985). Some of the available vignettes highlighted cases of "loss" following brain injury or disease, while others emphasized behavioral "excesses" as a result of the damage. From these requests, the instructor assigned three to four students to a group. Students not presenting a case study on any given day participated in a discussion of the case following the presentation. In addition, three to four students were asked to serve as discussion leaders for that particular day. Thus, each student in the class was responsible for presentation of a case study, as well as for leading discussion for a different case. Discussion leaders were required to email the class five to eight well thought out questions to stimulate thought and discussion; these questions were distributed 24-48 hours prior to the case presentation.

Case study days began in the fourth week of the semester, and consisted of three major portions:

1. Case study days began with the instructor presenting a 15-minute overview of the anatomy relevant to the topic. For example, in the vignette "Witty Ticcy Ray," Sacks eloquently describes the challenges and triumphs of a man suffering from Tourette's Syndrome. The instructor introduced this topic with a 15-minute discussion of the basal ganglia, some of the important neural connections within the basal ganglia (shown on a colored handout provided to the students), and the neuropharmacology of the major structures in this system. Similarly, when the topic was aphasia, the instructor introduced the major neural structures involved in speech production and speech reception and the multiple brain regions involved in language (again a detailed colored handout was provided for students). Reference was always made to material that had been encountered earlier, when brain anatomy was covered as a chapter during the third week of the semester. Often, the same slides were again used as an effort to reinforce previous material that had been presented.

2. Small group presentations of the case followed the instructor's introduction to the anatomy relevant to the case. Students were asked to limit their presentation to 20 minutes, thereby leaving the final 15 minutes of the class period for discussion. Students were instructed to include the following pieces of information in their presentation, but were encouraged to add any additional information they wished (e.g., Meil, 2007; Kennedy and Hassebrock, 2012), including short video clips of the disorder, for example.

- A description of the general features of the case. Describe the subject/patient, describe the incident(s) that lead to the neurological condition, a description of individual's personality and behavior prior to the accident, injury or diagnosis, and the state of the individual following injury or disease.
- Some examples of the unique behaviors presented by

the individual described in the case study. Relate these behaviors to the structures affected by the injury or illness.

- The primary symptoms that characterize the condition in question? How is the condition or disorder typically diagnosed (describe the techniques or methods used in the diagnosis). What are the major strengths and weaknesses, if any, of these methods? Here, students were encouraged to identify the current methodologies used in the diagnosis of the condition or disease.
- Identification of some questions that remain unanswered or yet unclear about the disorder in question? To answer this, students were required to consult current literature to identify the current state of the disorder or disease, and to convey in a general way, the most recent discoveries or breakthroughs in our understanding of the condition described in the case study.

Presenters of the case study were given the flexibility to parse out the responsibility for these major components of the presentation, but all students were required to become familiar with all components of the case study, whether they were presenting that portion or not. All of the presentation planning took place outside of regular class time, so students were required to organize meeting times that were possible for all group members, and to work collectively on background research and presentation organization.

3. Following the presentation of the case, students engaged in a 15-minute discussion of the case, lead by the designated discussion leaders. The discussion was initiated by one of the pre-shared questions, but often was steered by student interest or other questions or comments that were raised by students not leading discussion. This format was followed for each of the case study days scheduled throughout the semester. A summary of the structure of case study presentation days (for a 50-minute class period) used is given below. This can be easily modified for courses meeting for longer periods of time.

Part 1 (15 minutes): Instructor presents anatomy (often with handouts to class) relevant to case

Part 2 (20 minutes): groups of 3-4 students present case to class, following general guidelines as described above

Part 3 (15 minutes): class discussion of case. Guideline questions distributed to class 1-2 days prior, but not necessary to stick within limits of pre-distributed questions

GRADING AND PEER EVALUATION OF CASE STUDY PROJECTS

Student presentations were graded on a number of criteria, including organization of the presentation, clarity of material being communicated, preparation and overall presentation style (professional appearance, confidence, etc). Discussion leaders were also graded on the quality of their prepared questions, and on their ability to generate class discussion.

Peer evaluation has been found to be a useful method to assess the contributions of individual members of a small group (e.g., Weimer, 2008). Given that the preparation for the case study preparation was done outside of the classroom setting, feedback from group members was useful to get a sense of group members who might not be contributing their fair share to the project, as well as those who might dominate the creation of the presentation project (Weimer, 2008). Peer evaluation of group members was obtained and used in the instructor's overall assessment of the group presentations. Students were asked to provide feedback on all group members (other than themselves) in the following categories: contribution to the content of the project, being present and on time for all group meetings, and how well the group member worked with others ("team player"). Overall, students reported quite favorably on the performance and engagement of their peer group members, stating that group members were on time for meetings, added useful information to the content of the project and acted as involved "team players." Peer evaluations were used only for instructor grading purposes, although in future iterations of the course, they will likely be completed by the entire class and subsequently shared with group members.

Students were assessed on their knowledge of case study material throughout the semester. Generally, material was incorporated into more "synthetic" exam questions that required students to think about larger issues within the discipline. For example, one question on the final exam required students to provide three different examples of how the study of brain injury or disease might illuminate "normal" functions of the brain, and what each of these tells us about how the brain works. In another question on the second class exam, students were asked to compare and contrast two disorders involving the auditory cortex, Wernicke's Aphasia and Tonal Agnosia on the basis of neuroanatomical changes and behavioral manifestations of each disorder.

STUDENT FEEDBACK OF CASE STUDY PROJECTS

Overall, students responded quite positively to the case study projects and reported that the projects were beneficial to their learning structure-function relationships. Eighty-five percent of students felt that they thought that it was "somewhat easier" or "definitely easier" to learn neuroanatomy and structure-function relationships when put in the context of some disorder or pathology. Open-ended comments supported this, as well. For example, one student commented, "I loved the Sacks readings, discussions and presentations," while another commented, "by providing the structure along with the case studies, …it makes the anatomy easier to digest." Still another student noted, "neuroanatomy is more fun to learn when it is combined with disorders/pathology. I think it is easier to learn a concept rather than memorizing a (structure) name." Writes another, "It makes it easier to understand what certain parts of the brain are involved in when relating it to interesting disorders… it is more exciting, too, because

I enjoy learning about the disorders." Another comments, "some structures are difficult to learn, and the vignettes help to further clarify." Finally, one student offered the following comment that the information gleaned from the vignettes in Sacks' book influenced her outside of the classroom, "I think about it and talk about it with my friends, too, which helps me to learn it."

In addition to the positive comments about course material, some students expressed their enjoyment in the opportunity to engage in class discussion with their classmates, and to hear their peers engage in class material. One student wrote, "It creates variety in the class to have presentations from our peers," while another commented, "I like the class because it includes a focus on discussion." Student discussion leaders were not given any specific instructions about the types of questions to prepare, other than to create questions that would likely lead to a healthy discussion by the members of the class. Interestingly, the questions often opened up discussions that focused on broader philosophical issues, such as consciousness and self-awareness (in the case of Sacks' vignette on The Disembodied Lady, for example). Similarly, over time students were able to pose questions that involved the comparison of cases, or that highlighted important differences between patients described in the cases.

Despite these positive comments, there were a few criticisms from students. Generally, these addressed the desire for even more time spent on the anatomy on presentation days. Said one student "I think the Sacks presentations help, but it might be useful to spend a little more time on the neuroanatomy of the disorders, because I feel it is condensed into a short period of time." A second student expressed a similar criticism.

ADVANTAGES AND DISADVANTAGES OF CASE STUDY PROJECTS

The model described in this paper presents a number of advantages, but also poses some challenges and limitations.

The major advantage of this model is that students continue to be introduced to brain structures and the relationship of structure to function throughout the semester in a context that is more understandable and enjoyable for students. Of course, neuroanatomy is a key part of learning Biological Psychology, and structure-function relationships are a key to all topics taught in a Biological Psychology course (e.g., Learning and Memory, Emotion, Sexual Behavior). However, case studies can serve to reinforce structure-function relationships already presented in previous sections of the course, as well as to introduce new structure-function relationships to students.

In addition, the case study projects described in the model allow students to collaborate with one another to understand a common problem and work collectively toward answering questions and understanding the nuances of the case being studied. Presenters of the case, as well as discussion leaders and other members of the class become actively engaged with case material and have the opportunity to closely examine phenomenon in detail and to share information with peers.

However, the model does pose some limitations and challenges for course instructors. Dedicating an entire class period to presentation and discussion of case studies means that less of something else can be taught. In a semester long Biological Psychology course meeting three days per week, for example, seven days dedicated to case studies might mean having to omit a unit (e.g., Emotion, Motivation) that might otherwise be covered in the semester. Instructors must therefore be willing to sacrifice some other content in order to integrate the case study projects throughout the semester.

Importantly, case study projects like the one described in this paper would only be effective in relatively small classes. At Denison, Biological Psychology is "capped" at 25 students; having classes that are much larger would make the case study projects very difficult, if not impossible, to implement.

Although the purpose of the present case study exercise was to provide semester-long exposure to neuroanatomy rather than to parallel material from the text in any systematic way, some instructors might wish to more closely "align" case study material to material from the major textbook being used in the class. For example, when teaching material about Alzheimer's Disease or other forms of dementia, some might opt to introduce case studies that focus on these disorders. This would likely be more easily done when considering a wider variety of sources from which case study material could be selected. To this end, there are many other very rich sources of case study material from which to choose. For the purposes of piloting this case study exercise, only one popular source (Sacks, 1985) was selected. In future iterations of the course, additional resources rich in case studies (e.g., Ramachandran, 1998) might be used.

CONCLUSION

This relatively simple model of a case study assignment described in this paper provides students the opportunity to collaborate with peers, to engage in discussion with other members of the class, to obtain practice in organization and oral communication skills, and to study in greater detail some rare and intriguing cases of individuals with injury or damage to the brain. The assignment is generally well received by students, and offers a way of integrating neuroanatomy and important structure-function relationships throughout the semester in a manner that is enjoyable for students. Although there are some limitations and challenges to using such a model, the model provides generous flexibility in terms of course material that can be used, small group structure, and the purposes for which evaluations might be used.

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Address correspondence to: Dr. Susan Kennedy, Department of Psychology, Room 404D Knapp Hall, Denison University, Granville, OH 43023. Email: kennedys@denison.edu