ARTICLE
Nora's Medulla: A Problem-Based Learning Case for Neuroscience Fundamentals

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Students work through this Problem-Based Learning Case in order to discover how Nora ended up blue lipped and non-responsive. By exploring fundamental mechanisms of neuronal communication, students examine facts, research concepts, and propose hypotheses about how Nora's physiology was disrupted to cause her respiratory distress. The dramatic context supports student learning at many levels – from systems neurophysiology to synaptic pharmacology. The case as written is used in an undergraduate course for non-science majors, but because the case focuses on basic fundamental neuroscience concepts, the case could be easily used in high school or other undergraduate courses that cover basic neuroscience.

Key words: Problem-Based Learning (PBL); active learning; case study; neurotransmission; receptor; agonist; antagonist; drug abuse; synaptic communication; pharmacology

CONTEXT

Nora's Medulla is a classic Problem-Based Learning (PBL) case in which the students are presented with an open-ended problem presented in an intriguing narrative. The students work through the case in small groups, following the story scene-by-scene. In each scene, students get new clues and facts about the case. Using an iterative process, the students must evaluate each new piece of information in order to propose and revise hypotheses about the problem.

We use this case as part of a three-case sequence in our undergraduate neuroscience course for non-science majors. Our first unit in the course is "Synaptic Communication" and we use three different cases over six class periods to teach our objectives for the unit. *Nora's Medulla* is the first case we use in the unit, but the case could be used for any classes that teach synaptic communication or mechanisms of addiction at an introductory level since the only background needed is high school level biology and chemistry.

While we've designed the overall course to progressively build up from a cellular/molecular level to a systems/cognitive level, we like that this case puts the molecular mechanism of chemical neurotransmission into an exciting and interesting physiological setting of respiratory depression. The case context motivates students to wonder about nervous system function in the hopes of understanding whether Nora will survive and what possible treatments could help her condition.

We've taught this non-majors neuroscience class six times and have implemented *Nora's Medulla* as our first case each semester. Typically, our class meets two times per week for three hours each session with 24 students. The students work through the cases in groups of four and we spend about 1.5 class periods (approximately 4.5 hrs) on this case. We generally implement the cases in PBL (see: University of Delaware, 2016) or Investigative Case-Based Learning (see: Bioquest, 2016) format. The key features of these formats include student-generated questions, student-generated research, and students using their research to support or refute hypotheses. Although we facilitate discussion during each scene of the case, the investigation and research questions are student generated. We use the case narrative and our facilitation to guide the students to ask and wonder about the content we need them to learn. Student materials and classroom implementation notes for this case are available from the corresponding author or from cases.at.june@gmail.com.

CLASSROOM MANAGEMENT OVERVIEW

During each scene of the case, we use the case text and our facilitation to guide the students to question, research and discuss the content objectives we've chosen. As the students work through the case, we ask them to create a list elaborating on the following:

a) what they know based on their reading of each scene and their previous knowledge;
b) what terms and concepts they don't know;
c) what questions do they have/what else would they like to know to move forward in understanding the case;
d) what hypotheses are best supported by the facts, as they (the students) know them now?

The concepts listed under the above part b) "don't know" and some questions from part c) "like to know" are called "Learning Issues" (LIs) and are a fundamental part of the iterative process of finding and evaluating information. Example LIs for this case include: What can cause "blue lips"? How do we breathe? Can drugs affect breathing? Students divide the LIs amongst the group members and then research their assigned issues and report the findings back to their group. Students do most of the LI research online, but we also sparingly use mini-lectures when all groups/students have generated similar questions about complex ideas/concepts fundamental to our case objectives, or when time or available web resources are limited.

When students report back and share their LI research, they use an iterative process of refining their hypotheses

and defining what information is necessary for moving forward through the subsequent parts of the case. For example, between scene 1 and scene 2 of the case story line, students select LIs to research and spend some class time working online to learn about the issues. Prior to reading the second scene, the students review their LI research from scene 1. Considering the new information presented during LI reports, students revise previous hypotheses, debate evidence, and create new hypotheses before moving to scene 2.

Learning Objectives

Content Objectives

At the end of the case, students will be able to:

- Define the function of, and draw/label in the context of a diagram, the following terms: neurotransmitter, neurotransmitter receptor, and synapse.
- Describe a basic role of the diaphragm, medulla oblongata, and phrenic nerve in respiration.
- Compare and contrast the effects of agonists and antagonists at a post-synaptic neurotransmitter receptor (e.g., heroin vs. naloxone).
- Compare and contrast endogenous and exogenous opiates using at least two examples (e.g., heroin, morphine, enkephalin, endorphin, naloxone, etc.).
- Describe the process of chemical neurotransmission including the role of pre-synaptic and post-synaptic cells, neurotransmitters, and neurotransmitter receptors.
- Describe how drugs can alter synaptic transmission using specific examples (e.g., heroin or other opiates).
- Give examples of neurons in different brain regions working together to coordinate a behavior (e.g., brainstem and spinal cord during respiration).
- Give examples of the nervous system influencing other body organs (e.g., brainstem and respiratory muscles).
- Give examples of malfunctions of the nervous system that cause disease (e.g., drug overdose).

Skill/Process Objectives

At the end of the case, students will be able to:

- Pose clear questions and hypotheses based on evidence.
- Find and use evidence to support pro and con arguments about a scientific question in written and oral presentations.
- Evaluate web information for accuracy and bias.
- Use specific examples to illustrate larger concepts in science and medicine in written and oral presentations.

CASE EVALUATION

Assessment Tools and Methods

Although students have generated LIs from each of the three scenes of the case, we ask them to formally write up one LI for us to grade as an assessment of learning gains after the case is completed. After completion of the whole three-case unit on synaptic communication, we use summative assessments of group presentations followed by a brief multiple-choice quiz to assess mastery of the unit objectives. In addition to assessment of content and process objectives, students are also asked about overall satisfaction with the course and our teaching methods.

Assessment Results

The LI assessment allows students to engage with content that is related to the case learning objectives and is a topic of their own interest. Each LI is evaluated on several measures, including accurate synthesis of research material and thorough evaluation of sources.

Example Learning Issue Topics – Unit 1	Select Evaluation Criteria		Average Grade
• Opiates & pain modulation • Effectiveness of heroin assisted treatment centers in the UK • Epidemiology of heroin abuse • Naloxone mechanism of action • Cocaine mechanisms of action • Social stress & depression	**Critical review of resources**	Thorough analysis of all resources including author's perspective	81%
	Summary writing	Concise synthesis of information; substantial depth of coverage of topic	82%

Table 1. Learning Issue research topics are in line with case objectives and are assessed by evaluating use of quality sources and synthesis of information.

Through design and implementation of group presentations, students display their understanding of case objectives. Group presentations require students to present accurate and detailed content from the unit in a creative and engaging way. The students themselves select the specific content, and the format and style is generally unique to each group. Further, we ask the students to connect the content to a broader context of society, culture and/or content from other courses.

Example Objectives Covered in Group Presentations	Select Evaluation Criteria		Average Grade
• Agonists vs. Antagonists • Mechanism of drug effects on synaptic transmission • Drugs of abuse and reward • Endogenous opioids • Pre- and post-synaptic mechanisms of neurotransmission	**Creativity & interest**	Presenters engaged the class with an interesting approach and/or activity.	93%
	Depth of coverage	Presenters covered at least 4 topics from the unit and they were presented clearly, accurately, and in depth.	86%
	Created context for the topic	Presenters related the topic(s) to content from other classes and/or society.	95%

Table 2. Group presentation topics are in line with case objectives and are assessed by creativity, depth of content and context for the topics.

End of unit quizzes allow us to probe understanding of specific concepts. We intentionally keep the quizzes brief and generally focused on higher-order concepts and skills rather than simple definitions or identification questions. Overall, students average 86% on the quiz questions that were most specifically from the objectives covered in *Nora's Medulla*.

Finally, students enjoy this case. Each semester students find the case narrative and characters compelling and are enthusiastic about the content. At the end of the course, students are asked to rate how 'useful' and 'engaging' the assignments are using a Likert scale. Although assignments were repeated throughout the semester such that *Nora's Medulla* only contributed to part of these data, students found the LIs and presentations to be quite useful and engaging.

"Usefulness in learning neuroscience concepts?"	Average class rating (1-5)
Learning issues	3.98
Group Presentations	3.67

Table 3. Students rated the assignments as very useful.

"How engaging or interesting were___?"	Average class rating (1-5)
Learning issues	3.48
Group Presentations	3.93

Table 4. Students rated the assignments as very engaging.

SUMMARY AND FUTURE DIRECTIONS

Overall, this case is an interesting and effective way to introduce fundamental neuroscience concepts of synaptic communication. By leveraging the strengths of a case-based teaching method, students not only master the content objectives, but also build research and communication skills.

One future goal for this case is to modify the narrative to cover process objectives that include quantitative reasoning skills. After having used the case with six different cohorts of non-science majors and exploring literature on quantitative literacy in majors and non-majors (Wright, 2005; Momsen et al., 2010), we've realized that our students could benefit from much more practice and development in quantitative literacy (Speth et al., 2010). By adding quantitative information in graphs or tables we will create a new version of this case that we hope will help students develop skills in understanding, interpreting, and drawing inferences from relevant data as they work through the case narrative.

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