

ARTICLE

Developing a Team-taught Capstone Course in Neuroscience

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Capstone courses are becoming increasingly visible on college and university campuses. In this paper, we describe a capstone experience for undergraduate students pursuing our neuroscience concentration. The course is intended to provide an in-depth and interdisciplinary examination of contemporary topics in the field of neuroscience, and is designed for students who have completed the majority of requirements for the concentration. We describe the evolution of such a course,

the goals and objectives of the course, and offer a workable model for similar courses in the context of a liberal arts institution. We summarize the positive aspects of such a course, describe the challenges involved in creating a course of this nature, and offer suggestions for successful similar capstone courses in Neuroscience.

Key words: Team taught course, Neuroscience concentrators, Capstone, Undergraduates, Neuroscience Programs, Liberal Arts Institutions

As the number of undergraduate programs in neuroscience continues to increase, so does the tremendous variability in curricula for undergraduates interested in neuroscience. For example, while many colleges have developed majors and minors in neuroscience, and in some cases, departments of neuroscience, other institutions have developed concentrations in neuroscience, while still others require a set of courses (usually in Biology and Psychology) designed to provide a “focus” in basic neuroscience (e.g., Ramos et. al., 2011).

At Denison University, our neuroscience concentration is designed to complement the student’s major through a number of foundational courses, advanced elective courses, and two neuroscience courses, including a 400-level capstone experience. What follows is a brief overview of how our neuroscience concentration has developed over the years, including a summary of the coursework required for, and other experiences related to, our concentration. We then present a detailed description of some of the student learning activities typically incorporated into our Neuroscience capstone, summarize some of the student evaluations of the course, and offer what we feel are the strengths and persistent challenges of such a course.

OVERVIEW OF THE NEUROSCIENCE CONCENTRATION

In keeping with the mission of a liberal arts education, Denison’s neuroscience concentration provides our students with a challenging interdisciplinary perspective on the complex relationships between brain and behavior. In this way, students who pursue the concentration are exposed to a number of perspectives within neuroscience, from cellular and molecular analysis to broader, more molar systems approaches to behavior.

Students pursuing our neuroscience concentration are most often Biology or Psychology majors, although there have been a few Biochemistry majors completing the concentration. Since 2000, we have had close to 70 students earn the concentration, with an additional nine

students completing self-designed majors in Neuroscience, Cognitive Neuroscience, Social Neuroscience, or Psychobiology.

Our curriculum is structured in such a way that all neuroscience students must complete Introductory Psychology and Introduction to the Science of Biology prior to enrolling in our Introduction to Neuroscience (NEUR 200) course. NEUR 200 emphasizes the “basics” of the field, including cellular physiology, ionic movements, refractory periods, receptor dynamics, post-synaptic potentials, neuropharmacology, and neuroanatomy. The two introductory courses are also required for the 200- and 300-level elective courses in Psychology or Biology. Students must also complete four courses (including NEUR 200) designed to provide breadth in the concentration. Throughout the remainder of their tenure at Denison, neuroscience students must complete Biological Psychology, Biological Psychology Research, two upper-level electives depending upon the student’s major and area(s) of interest, and our capstone course, Advanced Neuroscience (NEUR 400). Table 1 summarizes the neuroscience curriculum, identifying pre-requisite courses, courses required for breadth, and more advanced required and elective courses that offer depth in the concentration.

THE CAPSTONE COURSE: ADVANCED NEUROSCIENCE

Over the last several years, capstone courses have become increasingly more visible on college and university campuses. Indeed, the capstone experience is now fairly commonplace in smaller, private colleges, as well as in large public institutions (Badway and Grubb, 1999). Capstone courses are believed to provide valuable experiences for students, including opportunities for synthesis and integration of information (e.g., Henscheid et al., 2000), further development of critical thinking and writing and speaking skills (Cuseo, 1998), and an ideal environment for assessing student learning (Moore, 2005). In our program, the capstone experience for all neuroscience students is Advanced Neuroscience (NEUR

Two foundational courses (pre-requisites for NEUR 200 and for upper-level Biology and Psychology courses):

BIOL 150: Introduction to the Science of Biology
 PSYC 100: Introduction to Psychology

Four courses for breadth in the concentration (can be taken in any sequence; CHEM 131 and BIOL 201 must be taken concurrently):

NEUR 200: Introduction to Neuroscience
 PSYC 200: Research Methods
 CHEM 131: Atoms and Molecules
 BIOL 201: Cell and Molecular Biology

Six courses for depth in the concentration (can be taken in any sequence; PSYC 350 and PSYC 351 must be taken concurrently, and electives must be from different departments):

PSYC 350: Biological Psychology
 PSYC 351: Research in Biological Psychology
 BIOL 349: Introduction to Neurophysiology
 Two electives* from designated upper level courses in
 PSYC, BIOL, CHEM, Philosophy of Mind, Artificial
 Intelligence,
 NEUR 400: Advanced Neuroscience (capstone)

Table 1. The neuroscience curriculum. *Specific elective courses in PSYC, BIOL and CHEM can be identified and described by visiting the appropriate department website at <http://www.denison.edu/academics/departments/neuroscience/>.

400). This course is designed for juniors and seniors who have completed the majority (if not all) of the courses required for the concentration. Typically, the course enrolls 15-25 students, and is taught in the spring semester. From the inception of our Neuroscience program, we envisioned NEUR 400 to be a course that brings together critical concepts and ideas from the students' previous coursework in a format emphasizing discussion of primary literature and incorporating multiple learning activities and projects throughout the semester. Unlike the introductory course in Neuroscience, NEUR 400 addresses contemporary molar issues in Neuroscience. Importantly, our Advanced Neuroscience course is team taught by faculty from Biology, Psychology, Chemistry, Philosophy and Computer Science. In this way, students are exposed to "cutting edge" issues within a number of sub-fields of Neuroscience by faculty whose primary interests reflect those issues and problems. One faculty member serves as the instructor of record (this person receives teaching credit for the course) and is responsible for the course organization and administration (syllabus creation, coordination among participating faculty, development of assignments, and grading). At Denison, the instructor of record rotates every two years between the Psychology and Biology departments.

In recent years, the course topics and readings have examined visual attention and computational neuroscience, autism, biochemistry of memory formation, explicit and implicit memory systems, amnesia, face recognition and cognitive neuroscience, artificial intelligence and face recognition, neuroscience of consciousness, neurophilosophy, nervous tissue differentiation and central

nervous system development, glia and glioma, stress and neurodegeneration, affective neuroscience, educational neuroscience, and cultural neuroscience. Each faculty participant assigns research articles and will typically lead either one, two, or three class meetings that can include lectures and research presentations, student-led discussions and presentations, or active learning exercises. Students are also asked to post on Blackboard, an on-line course management system, two or three discussion questions or talking points on the reading assignments prior to each class meeting.

LEARNING ACTIVITIES AND ASSIGNMENTS

Several different assignments have been designed to help students enhance their ability to read and critique neuroscience research, develop an integrative understanding of neuroscience core areas, examine the intersections that connect neuroscience with other disciplinary areas in sciences, arts, and humanities, and explore the relevance of neuroscience to contemporary issues and personal applications. We present three of the activities below.

Neuroscience in the News

The dissemination of neuroscience research to scientists, educators, professionals, and the general public has increased through the availability of internet sites. In particular, the range and complexity of neuroscience research introduces unique challenges for the presentation of informative and useful research summaries to an informed lay audience. Thus, the goal of this activity is to provide students with an opportunity to read a primary research article in a neuroscience journal and then to prepare and deliver an oral presentation about that research article to classmates in a session that is known as *Neuroscience in the News*.

Each student selects a research article from any field of neuroscience published in the past three years based upon his or her personal interests. Then they prepare a 5-minute presentation that will model the format of a news release and that will be similar in content and style to the *Neuroscience News* reports on the webpage of the British Neuroscience Association (BNA; <http://www.bna.org.uk/news/>). In the presentation, the students' objectives are to explain why they selected the particular research article; describe the most significant theoretical issues, methods, and results; summarize the most meaningful conclusions including the importance or relevance of the research and/or its applications; and identify how the research contributed to an enhancement of personal knowledge and interests in neuroscience. It is stressed to the students that their *Neuroscience in the News* presentation should be understandable to an informed lay audience as much as to neuroscientists. Students can augment their oral presentation with a small number of PowerPoint slides or video clips in order to show results, equipment, or other pertinent information. Some of the recent *Neuroscience in the News* presentations include "Does Sleep Deprivation Put You in a Better Mood?", "Exercise Training Increases

the Size of the Hippocampus and Improves Your Memory,” “Videogames and Cognitive Training in the Elderly,” “Brain-Machine-Brain Interfaces: A New Way to Connect to the World,” “Brain Imaging: Visualizing the Developing and Maturing Brain,” and “Therapeutic Potential of Omega-3 PUFAs for Peripheral Nerve Injuries.” Following each presentation, there is a short period of questions and discussion among the students.

Brain Briefings

Many of our neuroscience students have educational and career goals involving the application of basic neuroscience research to medical, clinical, educational, or other professional settings. Therefore, in this assignment, pairs of students work together to develop a *Brain Briefing*, a written document that explains how basic neuroscience research has relevance to a general audience of policy makers in clinical, health, educational, or other fields and professions (e.g., sports, law, economics, and robotics). The model for this assignment is the *Brain Briefings Newsletter* published online by the Society for Neuroscience (SFN) (Lom, 2005) and more recently posted at the website, BrainFacts.org (<http://www.brainfacts.org/>), a public information initiative of The Kavli Foundation, the Gatsby Charitable Foundation, and the SFN.

Students first review several *Brain Briefings* on the website in order to get a grasp of the content, format, and style of these papers. Then, each pair of students identify a particular area of application (e.g., medical treatments for Alzheimer’s disease) that can be informed by neuroscience and conduct an online search to find four to six relevant research articles. The students’ *Brain Briefing* report is not meant to be a research abstract; rather, their goal is to follow the format of the SFN Brain Briefings and provide information on recent neuroscience research that has exciting and valuable applications to neurological, psychological, and medical contexts. Each briefing has a limit of 1000 words and includes references and one or two visual objects (e.g., research data, brain images, or other illustrations). The evaluation of the *Brain Briefing* is based upon how well students identify and explain the connections between the research outcomes with the potential applications. Examples of *Brain Briefings* produced in the most recent class include “An Eye Toward the Future: Sight Restoration through Neuroengineering and Visual Prosthesis,” “Alzheimer’s Dementia,” “Sleep and Your Emotions,” “Neuromarketing,” “Transcranial Direct Current Stimulation: Shocking New Therapeutic Possibilities,” and “The Neural Truth: Religion as an Anesthetic.”

Neuroscience Case Studies

Case studies are a type of non-experimental research methodology that typically investigate one individual in depth or over time. Case studies have traditionally been used in neurological research and education. Recently, case studies have also been used effectively in neuroscience pedagogy (Meil, 2007) and are frequently

included in textbooks and in popular books written by neuroscientists or neurologists (e.g., Oliver Sacks). This assignment is a major and culminating project for the course and the overall learning goal is to develop a deep understanding of the neurological condition that is presented in the case study through the evaluation and synthesis of contemporary neuroscience research.

Each student completes this assignment independently. Students choose a case study after examining the “Strange Brains and Case Studies” internet resource compiled by William Meil and Jeremy Skipper, <http://lablab.hamilton.edu/lab-teaching/strange-brains-and-case-studies>, or other resources noted by the instructor (e.g., Ramachandran, 2004; Bogousslavsky and Boller, 2005; Sacks, 2007, 2010). Students can also select case studies from other sources of their own choice. The 12-page written report for this project has three parts: 1) case description, 2) literature review, and 3) research proposal (cf. Meil, 2007). In part one, students are asked to describe the most salient aspects of the case. For example, who was the person and what happened to them? How did their condition influence their life? Why did you choose this case in order to deepen your study of neuroscience? In part two, the literature review should include articles that help to answer questions such as what are the typical symptoms and what are the neurobiological or neuropsychological basis of the condition? How is the condition treated and what is the treatment prognosis? In this section the students are asked to evaluate and synthesize the results of at least eight empirical articles and to discuss how the literature review is relevant to course topics and readings. In the final section of the paper, students identify at least one unanswered question about the condition described in the case (causes, symptoms, or treatment) and then propose an experiment to address this question. The research proposal includes rationale, hypotheses, participants, materials and apparatus, procedures, and statistical analyses. Finally, students are also asked to describe the potential significance of the proposed research for the field of neuroscience.

The final three class meetings of the semester are devoted to oral presentations of the case studies. Each presentation is 12 minutes in length and can include PowerPoint slides. In the presentation, students describe the very most salient aspects of the case in terms of the underlying neurological issue. They also explain their decision to choose the case and how the case is important for the study of neuroscience. Students briefly present the key research goals, methods, results, and conclusions from only two of the research articles selected from the literature review. The students also explain why or how these two articles have relevance to an understanding of the case study. Finally, each student describes how the case study project has enhanced their study of neuroscience and the neuroscience topics that have been examined in the course. Short periods of questions and discussion follow each presentation. The topics of the case studies chosen by students have included Creutzfeldt-Jakob disease, Capgras syndrome, post-traumatic stress

disorder, autism, Tourette's syndrome, amnesia, epilepsy, dissociative identity disorder, Charles Bonnet syndrome, and auditory and visual hallucinations.

STUDENT EVALUATIONS OF THE COURSE

Students are strongly encouraged to provide written feedback and rating scale responses for the course as part of the end-of-semester course evaluation program in place at Denison. Recent efforts on our campus have resulted in increased student participation in the course evaluation process by carving out class time during the last week of classes for this purpose. In NEUR 400, participation rates for course evaluations are high, typically at 93% or better.

Students have evaluated the course quite favorably. In the past few offerings, the majority of students' numeric ratings consisted of "very good" to "excellent" evaluations on items such as the course is challenging, their interest in Neuroscience increased, their knowledge of the subject increased, and that faculty were clear, well-prepared, provided useful feedback, and were effective in their teaching. The written comments reflect these ratings. For example, one student commented that "If I could I would take (the class) over again... there has not been a single week that I did not learn something completely new." Another member of the class reflected, "the depth of the material was something that I had not been exposed to previously; this gave me an extreme increase in knowledge of the subject matter."

We were particularly interested in student feedback regarding the team taught nature of the course, as this is something that the majority of undergraduate students have little or no experience with. Generally, this was viewed as a positive aspect of the course. As one student noted, "I like the variety of instructors and the variety of topics covered"; while another wrote "The use of professors from different backgrounds presenting their primary focus of work and research to us was excellent," while still another student commented "I really liked the idea of having different faculty come in to teach on a subject that was an area of expertise for them. We had a wonderful group of faculty who were really passionate about what they were teaching." Finally, one student stated "emphatically, the best part about this course has been the exposure to different professors through the rotation schedule." Some students, however, found that having multiple instructors for the course was confusing and challenging, as noted by the following student comment, "Sometimes the switching of instructors can feel a little sporadic. It's hard to switch gears that quickly," while another adds, "it was difficult to follow where the class was headed each week. The class felt scattered because we jumped from one topic to another so quickly." Denison's required course evaluation form only contains a short list of course and instructor questions. In the future, we plan on administering an additional evaluation form in order to obtain information from specific open-ended questions about course content, organization, learning activities, and team-teaching.

REFLECTIONS ON THE CAPSTONE: STRENGTHS, CHALLENGES AND SUGGESTIONS

An integrative capstone course in Neuroscience can provide a valuable culminating experience for students of the discipline (Wiertelak and Ramirez, 2008). We feel satisfied that our course challenges students to think about some of the larger contemporary issues and questions in Neuroscience, to read and digest primary literature in the field, and to engage in multiple learning opportunities that enable integration of concepts and ideas acquired in previous courses. However, we do recognize that there are important challenges that our Neuroscience faculty continue to discuss regarding ways to improve the course as our Neuroscience program evolves.

First and foremost, as a highly interdisciplinary field, Neuroscience requires collaboration from individuals across departments. We feel that a successful team-taught capstone course in Neuroscience, therefore, depends on faculty who are committed to an interdisciplinary Neuroscience program, and who are willing to commit several hours out of their already busy schedules to the preparation that is necessary in order to meet with the class over two or three sessions with no monetary compensation or teaching credit provided. We have been quite fortunate over the years to have colleagues from across disciplines eager to engage with our students in the capstone course. Most recently, eight faculty participated and represented the departments of Biology, Chemistry, Computer Science, Philosophy, and Psychology. In addition, guest lecturers from Denison's library and Ohio State University also presented research. Of course, when faculty are on leave or unable to participate for other reasons, the course content must be changed or modified in order to accommodate this change, or other faculty representing the same or some different area must be asked to participate in the course. Also, it is our hope to have more faculty from other disciplines including the social sciences, humanities, and the arts participate in NEUR 400 in future semesters in order to highlight the importance of neuroscience in the interdisciplinary focus of a liberal arts college (Ramirez, 2007).

In addition to the importance of a core group of interested and willing faculty, the instructor of record also has a critical role in the success of such a course. S/he presents three to four lectures on neuroscience research and throughout the semester must keep the class on track, provide linkages and continuity between topics and speakers and bridge the topics coherently, particularly when faculty speakers change. The instructor also is responsible for developing all of the learning activities and assignments described in this paper. However, our Neuroscience faculty have contributed ideas and support for these assignments which share a focus on integration and application of neuroscience research. These learning objectives address the goals of a capstone course within the structure of our neuroscience curriculum but we recognize that there are other learning goals and assignments that could be present in a capstone course.

The course instructor also is solely responsible for grading all of the assignments, exams, and student participation. Therefore, the instructor does have a challenge in ensuring that students will develop their integrative knowledge of neuroscience from the ongoing flow of topics, presenters, and learning activities that occur during the semester. Student comments regarding course flow reinforce the importance of this role, and we continue to work on this in our discussions of our curriculum, particularly when the instructor of record changes between departments.

Another important consideration in planning for a Neuroscience capstone course is that enrolled students should be near the end of their college career, preferably seniors or second-semester juniors. This is essential for the types of class discussions and thoughtful conversations that add to the success of such a course. The course as we design it assumes that students have mastered the basics of Neuroscience and have completed adequate coursework that enables them to think critically, ask probing questions and offer meaningful comments in the classroom. For this to be the case, Neuroscience curricula must be carefully structured around common core courses as well as prerequisite courses necessary for subsequent electives.

Finally, the success of an interdisciplinary and team-taught course depends, in part, upon multiple levels of support. There must be support from faculty across disciplines as we have already discussed, but also support from multiple departments and the administration. Because the instructor of record earns one teaching credit for designing and coordinating NEUR 400, this may very well put some strain on the home department of the instructor in terms of course offerings, enrollments, etc. Having one of his/her courses a Neuroscience course means that one fewer course in the home department (Psychology, Biology, for example) can be taught during that semester. Clearly, then, it is imperative that there be departmental support for the program, transparency in what the commitment to NEUR courses will be, how frequently they will be taught (every year? Every other year?), and how many members of the department will be contributing regularly to the Neuroscience courses and other activities associated with the concentration. On our campus, we had several departmental (primarily within the Psychology and Biology departments) discussions as the Neuroscience program was in its early stages, and we continue to discuss particular aspects of the NEUR concentration and courses in departmental staff meetings as necessary; In addition, Neuroscience faculty meet regularly to plan future NEUR course offerings, discuss staffing issues, enrollments, and consider other important agenda items relevant to our Neuroscience program. Because our concentration and the capstone course require the involvement of multiple faculty representing multiple departments, it also is essential to have the support of a campus administration that encourages and rewards interdisciplinary efforts from faculty (Flint and Dorr, 2010).

Developing an integrative capstone course in any discipline can be rewarding and challenging. Careful

planning and communication with colleagues—both within and across departments—are key when creating an integrative and team-taught course for students of Neuroscience.

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