# Educational Model for Training Doctoral Students in Systems Neuroengineering

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## I. Introduction

Neurotechnologies for basic science research and healthcare have opened new and exciting opportunities to create bi-directional interfacing systems that can directly link our brains with the outside world. At the University of Minnesota, we have developed an educational model for training doctoral students in this field of *Systems Neuroengineering*. Our program, which is part of the National Science Foundation's Integrative Graduate Education and Research Traineeship (NSF-IGERT), is motivated by the notion that future breakthroughs in this rapidly-growing field of research will be made by engineers who understand the fundamental issues and principles of neuroscience, and by neuroscientists who are truly competent in engineering concepts and tools [1]. The following is meant as a guide for those educators interested in building a training program in *Systems Neuroengineering* at their institution.

## II. Program Curriculum

Our training program brings together a diverse group of students who have a strong interest in neuroengineering and have enrolled in one of four doctoral programs on campus including biomedical engineering, electrical engineering, mechanical engineering, and neuroscience. Students in our program also enroll in a 12-credit neuroengineering minor that consists of five core courses:

(1) Systems Neuroscience
(2) Introduction to Neuroengineering
(3) Neural Decoding and Interfacing
(4) Neuromodulation
(5) Practicum in Neuroengineering,

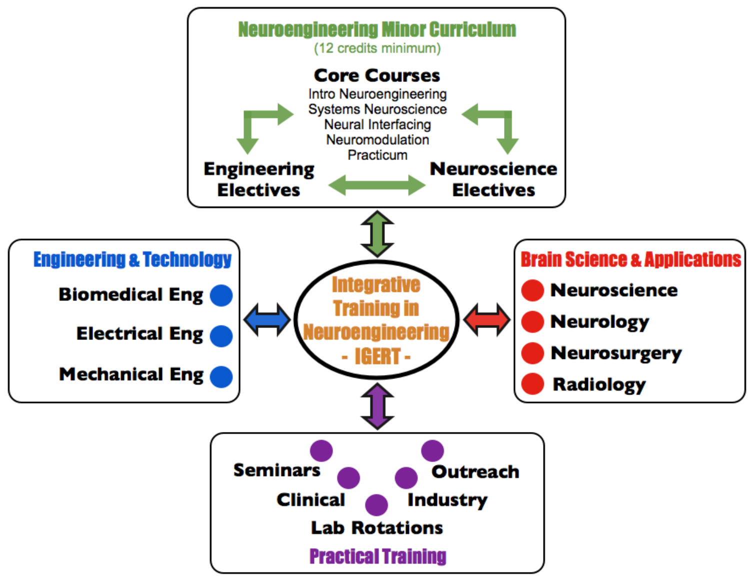


**Figure 1.** Our approach to Integrative Training in Neuroengineering

and a series of technical electives that allow students to further specialize within the field of *Systems Neuroengineering*. The core courses include hands-on computational and/or wet-lab experiments to engage students in the learning process. Students have opportunities to dissect a human brain and spinal cord, develop skills in computational modeling to guide them through the process of engineering neurotechnology, perform electrophysiological experiments to further develop their intuition, and build statistical analysis routines to study large, multi-modal data sets. The practicum course also provides students with opportunities to actively think through the processes of developing grant proposals, filing intellectual property, and translating neurotechnologies.

## III. Research Training Program

Our program requires students to select joint thesis advisors, with one mentor from engineering and one mentor from basic or clinical neuroscience, and then perform a summer lab rotation in their co-mentor's research laboratory. We have found that these cross-disciplinary lab rotations have a large impact in motivating students to integrate knowledge and think creatively on their research topics. Our students have reported that such interdisciplinary lab rotations are invaluable experiences.

One of our primary programmatic goals is to develop a strong future workforce in the field of *Systems Neuroengineering*. In conjunction with the practicum course, students in our IGERT program participate in a summer industrial internship at Medtronic Neuromodulation during their second year, enabling each student to get hands-on experience with the commercialization process for neurotechnology. We have also found integrating outreach activities into the training program provides students with opportunities to develop their leadership skills as well as their abilities to communicate their research to the general public. Currently, students are leading outreach efforts to educate the public about neuroengineering through events at local museums and K-12 schools.

## References

[1] He B (ed). *Neural Engineering, 2nd edition*. 2013, New York: Springer.

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