

Project title: RET Site: Research Experiences for Teachers in Neural Science or Neural Engineering (2019-2021)

<https://engineering.missouri.edu/departments/electrical-engineering-computer-science/neuro/neuro-research/neuro-nsf-ret/>

Funding source: National Science Foundation RET program - <https://www.nsf.gov/pubs/2017/nsf17575/nsf17575.htm>

No. of teachers per year/duration: 10 participants/year for a 6-week duration (2021: June 21 to Friday, July 30)

Teacher grades: 4th to 12th grades science, math and technology (priority will be given to teachers from rural schools)

Benefits for teachers: Training in neural sciences and engineering; stipend of \$7,000/teacher; \$2,000 worth of kits you can take back to your school; \$1,000 for travel including Conferences during following year.

Point-of-contact for applicants: Tyler Banks; TBanks@mail.missouri.edu (Ph. 210-519-8326)

Overview of project: The rapidly growing field of neural engineering aims to address the global challenge of not only understanding the functioning of normal and pathological brains, but also devising approaches to address neurological limitations and dysfunction. The field requires a workforce trained across the physical and life sciences. Training the next generation of scientists to meet this global challenge should begin at the K-12 level by incorporating engineering approaches, including the use of models, into STEM education. Towards this end, a multidisciplinary MU team proposes to host a 3-year RET site focused on **Neural Engineering**. Our objectives are to recruit teachers from rural schools that normally have smaller budgets and limited resources; and increase their research competency in neuroscience and neural engineering-based approaches that can be translated back to the classrooms, using the theme of neuroscience core concepts that are linked to school standards.

The RET Site includes an interdisciplinary team of faculty with expertise in different facets of neural engineering. Our program will increase research competency of teachers in core neuroscience concepts [1] and in engineering approaches, that are linked to national education [2] and technology [3] standards, respectively, increasing its relevance to teachers. Teachers will work on neural engineering projects and will develop curricula for K-12 classrooms. In addition to research skills, during the twice-a-week classes cited, teachers will also learn modern technological tools that will influence their classroom teaching, and explore the neurobiological underpinnings of learning and its link to improving student experience via group readings from an influential book on the science of learning and teaching.

Program Components: (i) Teachers will spend the bulk of the 6-week period in relevant labs engaging in research activities under the mentorship of a professor and graduate students, working closely on parts of on-going projects. Teachers will work with Lab personnel to develop a final project report using a template provided to them. (ii) The program will begin with a two-day orientation session that will introduce teachers to the research process including laboratory methods and safety procedures, to the development of curricular modules, and to modern technological tools relevant to classroom teaching. This orientation will continue during the afternoons for the next three days with additional individual 1:1 assistance in getting started with their research projects. To continue the process and provide a meaningful cohort experience, the PI and two graduate students will have 1.5 hour meetings (from 3:30 to 5 pm) at least once a week, throughout the remainder of the 6-week period, that will also include a group book reading using *Make it Stick*, an influential book on the science of learning and teaching. (iii) Teachers will develop curricular modules of topics they feel are appropriate for use in their classrooms, with assistance from the MU team, again using templates provided to them. Year-long follow up will focus on assisting teachers with their needs including with incorporating engineering approaches, curricular modules and technological tools into their classrooms, and with planning their conference presentations.

Sample Projects – starting next page

NOTE: Although team members (typically graduate or undergraduate students) will be available to provide input, you should be ready for independent work, i.e., to peruse the literature, perform internet searches, etc., with minimal input. This is different from the normal class-room instruction, and is one of the key traits of research, i.e., independent work. WE provide a list of 12 mentors and their areas of expertise below.

APPLICANTS CAN ALSO PICK A DIFFERENT MENTOR FROM THE SITE - <https://neuroscience.missouri.edu/>

If you want to check with a mentor not on the list of 12 provided, then do write to them to check about openings in their Lab, and make sure they are willing to host you....prior to listing their name.

A sampling of potential research projects of the 12 faculty mentors presently identified (others can be selected from MU's Interdisciplinary Neuroscience Program – see note at end of document) are provided below.

Research area: *Modeling of neurons/networks to study brain oscillations and their control*

Satish Nair, Project PI; Prof. of Electrical Engineering & Computer Science, Biological Engineering, and Interdisciplinary Neuroscience Program. The Nair lab collaborates with neuroscientists to develop model of brain circuits for several species including crabs, lobsters, rodents and humans, in collaboration with neuroscientists from MU and outside institutions. For details visit the [Nair Lab Website](#)

Teacher components: (i) Study mechanisms that synchronize firing of five large cells of the cardiac ganglia of crabs and lobsters that drive the single crab heart muscle (collaboration with Schulz Lab at MU); (ii) study how aversive memories are stored in the rodent brain during Pavlovian fear conditioning, i.e., what makes the neurons fire faster after fear learning (collaboration with Pare Lab at Rutgers University); (iii) similar to the above, study mechanisms that cause neuronal plasticity in specific rodent brain circuits after chronic cocaine. All projects involve computer models of neurons with parts being performed by teachers, and most programming by REU or graduate students.

Research area: *Mechanisms of neuronal homeostasis and compensation*

David Schulz, Prof. of Biological Sciences and the Interdisciplinary Neuroscience Program. The Schulz lab focuses on compensatory mechanisms at single cell and network levels that stabilize and ensure robustness of neuronal output using crustacean models. They combine single-cell electrophysiological analyses of cellular output with high-throughput quantitative expression analyses to understand both fundamental aspects of neural network function as well as responses to perturbation and injury. For details visit the [Schulz Lab Website](#).

Teacher components: (i) Identify changes in gene expression following neuronal compensation. Teachers would dissect out live stomatogastric nervous systems from the crab, *Cancer borealis*, record activity, injure descending neural pathways, and characterize changes in resulting output. Cells then would be collected subsequent to injury (with relevant controls) and mRNA copy number for genes of interest quantified via single cell qPCR. (ii) Use voltage-clamp techniques to identify changes in membrane conductance that accompany compensatory events underlying neuronal stability. Injured neurons would also be examined for changes in ionic currents as a result of injury, particularly we would examine potential pairs of compensatory currents such as calcium currents paired with potassium currents. Computational approaches would model these currents to probe compensatory interactions.

Research area: *Insect communication and social behavior*

Reginald Cocroft, Prof. of Biological Sciences. Research in the Cocroft laboratory focuses on how organisms make decisions, especially in the context of insect-plant interactions. For the insects, the decision might be to produce a signal, complete its life cycle, or feed on a plant. For the plants, the decision might be how strongly to defend itself against insect herbivores, or which direction to grow its roots. In the past few years the Cocroft lab has focused on how plants make use of mechanical cues generated by herbivores, especially the vibrations produced by feeding caterpillars. To characterize plant 'decisions', we analyze leaf chemistry, volatile compounds released by leaves, and electrical signals. To detect insect responses, we use lasers and other vibration-recording devices, because the insects we study communicate with other insects on the same plant by producing vibrational signals that travel through the plant. For details visit the [Cocroft Lab Website](#).

Teacher components: There are many possible directions for short-term research projects that investigate plant perception of mechanical vibrations. (i) Pollinators produce characteristic vibrations in the plants they visit. Recording the vibrations produced by pollinating insects, playing them back to plants, and measuring plant responses such as nectar production can tell us whether plants are making use of pollinator-produced vibrations. (ii) Electrical signals, measured on the leaf surface, provides a sensitive readout of a plant's perception of wounding by an herbivore. Do herbivore cues, such as the vibrations produced while feeding, increase the plant's response to damage?

Research area: *Precise manipulation of brain activity by light for treatment for movement disorders Ilker Ozden; Asst. Prof. of Bioengineering.* Research in the Ozden lab focuses on developing methods for precise control of brain circuits of Parkinsonian rodents using optogenetics to alleviate the symptoms. In this technique light-sensitive proteins (opsins) are genetically introduced into neurons of rodents. This enables control of the neuronal activity by tiny light beams. At the

same time, brain activity is recorded with electrode arrays at tens of locations simultaneously. For details visit the [Ozden Lab Website](#).

Teacher components: (i) Frequency analysis and machine learning algorithms to identify abnormal cortical oscillations in Parkinsonian motor cortex; (ii) Incorporate a variety of opsin types with existing models to predict opsin-specific effects of light stimulation on cortical activity.

Research area: *Molecular and cellular mechanisms of respiratory rhythms*

Lorin Milescu, Asst. Prof. of Biological Sciences. The Milescu lab investigates neuronal circuitry responsible for generating and modulating the respiratory rhythm. The primary objectives are to understand how neurons interact to produce distinct patterns of network activity. These questions are addressed in a brain slice preparation, combining electrophysiology, imaging, and computational techniques. For details visit the [Milescu Lab Website](#).

Teacher components: (i) Create “bionic” neurons to test ion channel mechanisms, by real-time coupling of a computational channel model to a live neuron; (ii) investigate the functional 3D architecture of the respiratory network, using confocal laser scanning microscopy and patch-clamp; and (iii) develop parallel algorithms for neuronal computation, to run on graphics processors.

Research areas: *Autism spectrum disorders research and stress effects on problem solving*

David Beversdorf, Professor of Radiology, Neurology, and Psychological Sciences, Director of Graduate Studies, Interdisciplinary Neuroscience Program. The Beversdorf lab focuses on several areas: exploration of the effects of the blood pressure and test anxiety drug propranolol on autism spectrum disorder (ASD), with brain imaging markers for this effect, as well as interaction between prenatal stress and stress genetics in etiology of ASD, and the impact of stress reactivity on medical comorbid conditions such as gastrointestinal disturbances in ASD. We also examine ways of mitigating effects of stress on creative problem solving in unaffected individuals. For details visit the [Beversdorf Lab Website](#).

Teacher components: (i) Effects of paced breathing exercises, as a proxy for meditation, on verbal problem solving tasks. (ii) Analysis of factors that interact with the impact of stress reactivity on gastrointestinal disturbances in ASD. The teachers will on most aspects with REU or graduate students, with a component identified for their independent work.

Neural Engineering - Application Area 1: Big data, Software/Cloud tools

Research area: *Big data in biology*

Dong Xu, Prof. of Electrical Engineering & Computer Science. The Xu lab conducts research on development of novel computational methods, algorithms, software and information systems, as well as on broad applications of these tools and other informatics resources for various biological and medical problems. Various research topics include application of deep learning in biological and medical data analysis and prediction, protein structure prediction, high-throughput biological data analyses, protein post-translation modification analysis, and tongue image analysis for health assessment. They also employ computational methods, with experimental data to study plants, bacteria, viruses, yeast, cancer, and neural systems. For details visit the [Xu Lab Website](#).

Teacher components: (i) use various high-throughput data, and apply neuroinformatics methods to predict biological networks for autism-related genes; (ii) develop part of a computational model for the molecular mechanisms leading to establishment of a nitrogen-fixing symbiosis in soybean; (iii) apply protein structure prediction and simulation tools to study proteins in plants; and (iv) apply machine-learning methods to study protein post-translational modifications.

Research area: *Cloud computing and big-data in neuroscience*

Prasad Callyam, Associate Prof. of Electrical Engineering & Computer Science. The Callyam Lab focus is on research and development in distributed and cloud computing, computer networking, networked-multimedia applications, and cyber security. His research sponsors include the National Science Foundation, the Department of Energy, VMware, Dell, IBM, Verizon, Cisco, Raytheon-BBN, the MU Coulter Translational Partnership (TP) Program, Huawei Technologies, Internet2 and others. His basic research on multi-domain network measurement and monitoring has been commercialized as ‘Narada Metrics’. For details visit the [Callyam Lab Website](#).

Teacher components: (i) How can a user working on computer A be authenticated and authorized using standard protocols to utilize an application residing on remote computer B (involves understanding computer communication protocols); (ii) how can the sequential running of different types of programs to solve a problem (i.e., workflow) be

automated to enable the user to be more efficient; (iii) how do we design appropriate performance metrics to capture user satisfaction in a data-intensive application involving multiple computers residing at different locations (distributed computing).

Research area: *CyNeuro informatics and analytics framework for neuroscience research*

Trupti Joshi; Asst. Prof. of Health Management and Informatics. Research in the Joshi lab focuses on developing comprehensive informatics frameworks for data integration and analytics to support genomics, multi-omics and neuroscience applications in plants, animals and biomedical domains. Techniques utilized include databases, content management systems, computational algorithm design, analytics workflow management systems, programming in Python, R, Javascript, etc. and web based interface design using PHP. For details visit the [Joshi Lab Website](#).

Teacher components: (i) Design analysis workflows for neuroscience research projects; (ii) Convert commonly used analytics workflows into high performance computing and cloud based resources using CyVerse and AWS resources; (iii) Develop CyNeuro framework and tools for querying and visualization of analyzed data; (iv) Integrate genomics datasets with corresponding neuroscience research questions and apply data mining and integration techniques.

Research area: *Automating multiple modeling packages in neural engineering*

Satish S. Nair, Electrical Engineering & Computer Science, Biological Engineering, and the Interdisciplinary Neuroscience Program. As part of his big-data research, the PI's group is involved in automating sequential use of software in neuroscience. This is ideally suited for teacher projects, particularly for math and science teachers interested in using analysis tools including excel, spreadsheets, plotting and databases.

Teacher components: (i) automate reading data from a text file, performing analysis using NEURON package, and plotting; (ii) Using python and MATLAB to automate the process of iteratively tuning a single neuron model using neuronal from databases, to investigate the effect of drugs, for example.

Neural Engineering - Application Area 2: Control/Robotics/Signal Processing

Research area: *Detection of gamma waves in the rodent amygdala during fear*

Dominic Ho, Prof. of Electrical Engineering & Computer Science. The Ho lab focuses on computationally intelligent and adaptive processing techniques to enhance, extract and analyze relevant information from sensor measurements. Our recent research is on the detection, estimation and analysis of brain waves. For details visit the [Ho Lab Website](#).

Teacher components: (i) detection of gamma waves in recordings from rodent brains from collaborator; (ii) analysis of waves from the human scalp during different states to detect and estimate various frequencies; (iii) signal enhancement and noise reduction for brain wave sensor measurements.

Research area: *Animal vs artificial robots – actuation, control, programming* (4-5th teachers only)

Satish S. Nair, Prof. of Electrical Engineering & Computer Science, Biological Engineering, and the Interdisciplinary Neuroscience Program. The elementary teachers in the program will work on research involving the comparative theme of “artificial” robot with a computer/sensors/structure-body vs “natural” robot with a human brain/sensors/body, since it is an important area of research in brain-computer interfaces. These projects use themes that are related to the control/robotics that the PI has worked on in the past, and neural modeling involving various species (crabs, lobster, rodents, and humans) that forms his present focus. Moreover, the topic is also at a level that will be accessible and appropriate for elementary teachers, and also engaging to elementary students.

Teacher components: (i) comparing the human sensory circuits (touch, vision, auditory, olfactory, and taste) with all neural circuitry details with the circuitry of the corresponding engineering sensor – five independent projects; (ii) comparing functioning of the human brain/body systems (decision making, transmission of information, actuation, sensing) with that of a LEGO robot at a systems level to implement specific functions such as motion, reaction to sensory inputs such as speech, color, sound, etc. and emotions such as ‘fear’ – more than 5 independent projects; (iii) comparing human and robot ‘control’ performance on tasks such as line-following (wheeled robot), posture stability (Segway robot), - 3 independent projects; (iv) comparison of brains of various species including insects, crabs, rodents, animals such as elephants, and humans – including number of neurons, sub-cortical vs cortical development, known functions, and how they vary across species – 3 independent projects, involving different comparisons, including biological and

neural circuitry details. Other research topics will also be designed based on the on-going projects in the lab, providing the teachers plenty of options to select one of their liking.

Research area: **Robotics and 3D imaging for modern agriculture** (4-5th teachers only)

Gui DeSouza, Assoc. Prof of Electrical Engineering & Computer Science. The DeSouza lab focuses on the use of computer vision for 3D modeling of the environment so robots can perceive, navigate, and interact, with both humans and elements of the environment. These technologies for 3D modeling allow for research, among other things, in modern agriculture: for estimating crop yield, analyzing phenotypes, predicting tolerance to abiotic stresses, genotype, etc. For details visit the [DeSouza Lab Website](#).

Teacher components: (i) understanding the challenges of modern agriculture with field studies, and (ii) understanding the design and control of robots for field phenotyping, including issues with deployment in the field. These are for elementary teachers only.

As mentioned earlier, APPLICANTS CAN ALSO PICK A DIFFERENT MENTOR FROM THE SITE - <https://neuroscience.missouri.edu/> If you want to check with a mentor not on the list of 12 provided, then do write to them to check about openings in their Lab, and make sure they are willing to host you....prior to listing their name.

NOTE: It is possible that your mentor pick(s) are out of town or that they do not have openings in their Lab during the present Summer – including the list of mentors on pages 2-4 of this document. So, feel free to check with them before you make your choices.

NOTES: The material in quotes “...” below are from the NSF solicitation at the RET program website
<https://www.nsf.gov/pubs/2017/nsf17575/nsf17575.htm>)

Please post all your materials at your website, including the list of equipment you wish to purchase (should also have contact information, website, etc. of vendors).

CURRICULAR MODULES: “Projects should be aligned with core areas of engineering and/or computer science. The research projects themselves should not focus on education or curriculum development but rather focus on ENG and CISE disciplinary scientific concepts.”

Our program requirement (as stated prior to acceptance into the program) is to prepare curricular materials (with both neural and engineering components) for submission to TeachEngineering.org.

The NSF solicitation states the following: “To fulfill NSF dissemination requirements, as well as to ensure long-term, free teacher/community college faculty access to the K-12 and/or community college engineering and computer science curricular materials that are created, RET Site awardees are strongly encouraged to publish the lessons or hands-on activities developed through the awards in the *TeachEngineering* digital library (<http://teachengineering.org/>) or other repositories that reach a national audience. While posting to a national portal is required, other means of dissemination of K-12 and/or community college engineering and computer science curricula may include posting lessons to the individual RET web site or portal and ensuring free access to educators.”

COPYRIGHT ISSUES: The curricular materials developed have to be submitted to TeachEngineering.org as a requirement that was agreed upon prior to start of the project. MU compliance officers have confirmed what was discussed during our meetings – all materials developed as part of the NSF grant is owned by MU that funded the teachers, and cannot be copyrighted individually. Also, all such publications should have MU mentors (undergrad, grad students, faculty, staff, or whoever assisted with the project) as co-authors, as is typically policy on all work performed at MU.

EQUIPMENT: “.....up to \$2,000 for the cost of materials, equipment, software, and other supplies for developing classroom instructions and experiments.”

Equipment funds, related to implementing the curricular module(s) developed as part of the Neuro-RET program at MU, can be requested any time you are ready, including up to a year beyond the summer research experience.

CONFERENCE TRAVEL: “Projects should include academic-year activities for the teachers and/or community college faculty to facilitate dissemination of their classroom modules to a broader audience and to provide opportunities for other teachers and/or community college faculty to incorporate the curricular materials and learning activities that the RET teachers and/or community college faculty develop during their RET participation. The Site proposal must include a request for support of a conference or other outreach activities designed to reach other local teachers and/or community college faculty not involved in a RET in Engineering and Computer Science Site project so as to inform them of the outcomes and materials developed as a result of the Site project.”

Presenting the poster on the book “Make it Stick” is also a viable option. Possible conference venues discussed were:
 Interface Conference - <https://dese.mo.gov/college-career-readiness/curriculum/interface-conference>
 STOM – <https://scienceteachersofmissouri.wildapricot.org/event-3262561>
 MCTM – <https://www.mctm.org/index.php/events-news/mctm-conference-and-institute/341-mctm-2019-conf>
 Other, including national ones?

The decision related to which conference to attend, if any, rests solely on the teacher. You can also collaborate and present work jointly, and so it is totally up to you. Hope that one of you can help bring potential science conferences to the attention of this group and help coordinate the presentation (with input from MU too) as appropriate. Similarly, one of you can help with do the same for the math teachers.