

# CELEST

## The Center of Excellence for Learning in Education, Science, and Technology

Stephen Grossberg

Department of Cognitive and Neural Systems, Boston University, Boston, Massachusetts, USA

steve@bu.edu; <http://www.cns.bu.edu/Profiles/Grossberg>

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The Center of Excellence for Learning in Education, Science, and Technology (CELEST; <http://cns.bu.edu/CELEST>) began on October 1, 2004. Funded by a five-year \$20,000,000 grant by the National Science Foundation of the USA, this new Center brings together leading scientists, educators, and technologists from Boston University, Brandeis University, Massachusetts Institute of Technology, and the University of Pennsylvania to study autonomous real-time learning systems by integrating experimental and computational brain science, biologically inspired technology, and classroom innovation.

To achieve this goal, CELEST will carry out four types of mutually reinforcing and integrated activities in order to better characterize autonomous real-time learning systems: (1) quantitative behavioral and brain modeling of both normal and abnormal learning processes during perception, cognition, emotion, and action; (2) interdisciplinary cognitive and neuroscience experiments to probe these processes and to test model predictions; (3) development of neuromorphic machine learning algorithms, or algorithms that are based on brain learning models, for incremental fast learning about complex and rapidly changing environments in large-scale engineering and technological applications that are important in many areas of society; and (4) integration of research and education through contributions to educational technology, curriculum development, and early career recruitment of underrepresented communities into scientific practice. I am happy to be the PI of this exciting new Center.

CELEST is organized into eight Thrusts and is governed by a Board of Directors, each of whom leads one Thrust. The five scientific research thrusts were designed to enable modeling of the complete perception/cognition/emotion/action systems that are needed to understand how the brain autonomously learns to control complex behaviors in real time within a changing world. Such systems are just as important for developing new engineering systems for intelligently processing huge amounts of data in unpredictably changing environments, and for providing practical insights into how to improve learning in the classroom:

1. Learning in visual perception and recognition: Laminar neocortical dynamics of adaptive behavior. This thrust carries out coordinated modeling and experimental work to clarify how the brain learns to see and to visually recognize objects and events in the world. It also provides a framework upon which models in all the five scientific thrusts can build to better understand how the laminar circuits of cerebral cortex are used to control intelligent behaviors.
2. Learning in audition, speech, and language. This thrust carries out coordinated modeling and experimental work to clarify how the brain learns to hear, speak, and understand language.

The remaining three scientific thrusts study higher-order processes that build on visual and auditory information processing:

3. Learning in cognitive-emotional interactions and planned sequential behaviors. This thrust carries out coordinated modeling and experimental work to characterize key aspects of how higher cognitive processes learn to represent information that is extracted by the visual and auditory systems; how cognitive processes interact with emotional processes to learn emotionally valued goals; and how sequentially organized plans and rule-like behaviors are learned to realize these goals.
4. Learning and episodic memory: Encoding and retrieval. This thrust carries out coordinated modeling and experimental work to understand how learning leads to memories of individual experiences, or episodes, that occur throughout our lives.
5. Learning in concept formation and rule discovery. This thrust carries out coordinated modeling and experimental work to discover how the brain learns to form higher-order concepts and rules, including numerical concepts that lie at the foundations of mathematical ability.

The technology research thrust is:

6. Learning in attentive recognition and neuromorphic technology. This thrust provides a central resource for defining, testing, organizing, and communicating biological models from the five scientific thrusts. It transitions biological models into a form that can be used in engineering and technological applications, notably applications involving multi-dimensional information fusion. The CELEST technology web site will be developed into an international resource of open source code, benchmark studies, and challenge problems.

The education thrust is:

7. Educational technology, curriculum development, and outreach. This thrust coordinates a Center-wide program of developing high school and college curricula that use models to explain how the brain works, notably how it learns. Learning about how brain mechanisms give rise to behavioral experiences is highly motivating to students of all ages. Web-based (see <http://cns.bu.edu/techlab> and <http://cns.bu.edu/education/celest> ) and printed educational materials are planned. CELEST graduate courses are incubators for creating new curriculum content, and Boston-area teachers and students will interact in multiple ways with CELEST faculty and students before the educational materials are used in classrooms and distributed

nationwide. Some of these materials may also be useful to experimental neuroscientists who are interested in using models of brain and behavior in their own research.

The diversity thrust is:

8. Diversity outreach. The diversity outreach program, guided by the CELEST diversity outreach committee, carries out multiple outreach activities to involve underrepresented individuals and communities in all CELEST educational, scientific, and technological programs.

CELEST faculty and students hereby work in teams ranging from small to large in size that cut across methods, departments, and schools to combine the interdisciplinary expertise that is needed to solve its targeted problems. Its members are excited by this new opportunity and welcome cooperative ventures that can enhance the Center's goals.

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