Body Engineering Los Angeles

(NSF GK-12) STEM outreach by PhD students

Krishna Nayak, Andrea Hodge, Gisele Ragusa, Tara Chklovski, Maja Mataric

Viterbi School of Engineering, University of Southern California, Los Angeles, California, USA

Iridescent Learning Inc, Los Angeles, California, USA

Introduction:

Body Engineering Los Angeles (BE-LA) is a new program at the University of Southern California (USC) that aims to involve and prepare our best PhD students to become science, technology, engineering and mathematics (STEM) leaders of tomorrow through a fellowship that incorporates extensive training and K-12 classroom experience. The program's theme is body engineering, and emphasizes the concept that **the human body is a machine** that can be studied, experimented upon, analyzed, and augmented. This theme provides an attractive and engaging vehicle for introducing STEM concepts and university research to the K-12 classroom and leverages the overall strength of the Viterbi School of Engineering (a top-10 engineering school), several university research initiatives at the interface between engineering and biology, physiology, and health, and a large group of committed faculty. Research topics that will be translated to the classroom include: non-invasive sensing and imaging, speech articulation, hand articulation, neuromuscular control, cardiovascular mechanics, nutrition and metabolism, biological and biocompatible materials, vision, object recognition, and human-machine interaction.

Objectives and Educational Outcomes:

The three goals of this program are: (1) to enhance the communication skills, leadership skills, collaboration skills, and cultural sensitivity of at least 42 doctoral students who are actively engaged in research; (2) to utilize body engineering as a vehicle for introducing cutting-edge research topics into local-area middle school classrooms, thereby directly impacting interest and achievement of approximately 2000 middle school students; and (3) to develop a sustainable program at USC.

Current engineering doctoral programs, including ours, are geared towards training students in engineering analysis and independent problem solving. The students also author dissertations, publish peer-reviewed technical articles, and present their work at technical conferences. One of our objectives is to provide graduate fellows with unique training and experience in communication (particularly to lay audiences), leadership (in a classroom setting), collaboration (with middle school teachers), and cultural sensitivity (in working with diverse under-served populations).

Children are naturally interested in how the human body works. This interest is enhanced through (1) activities such as sports, singing, dance, acting, or other forms of expression, (2) experience with illness or disability themselves or within their families, and (3) exposure to technology through the popular media (e.g., cyborgs, robots, artificial voices and limbs). The human body is also an excellent venue to explore and demonstrate scientific and engineering principles, from basic phenomena like forces, strengths of materials, and fluid viscosity, to advanced topics like muscle control, vision, and perception. One of our objectives is to use body engineering as a novel vehicle for STEM teaching and learning. This theme lies at the intersection of engineering, biology, physiology, and health sciences, which are all well recognized frontiers of STEM research. We also feel that the process of studying the human body as both an impressive machine and a precious resource will lead to greater self-awareness, and better lifestyle choices (e.g. nutrition, exercise).

One of our objectives is for this program to become a permanent fixture at USC. To do this, our goal will be (1) demonstrating significant tangible benefits to all parties involved (graduate fellows, faculty, teachers, schools, and university); (2) achieving high visibility and fundraising; and (3) by institutionalizing the most successful features of the program. This program has received strong institutional support, with our dean providing funds for continuation of the program for three years (beyond what NSF supports), and for annual events that ensure visibility, fundraising resources, and continuation of the program. There is high likelihood that this program (or an effective subset) will be institutionalized and sustained indefinitely.

Developmental History:

Our program design builds upon lessons learned from a pilot program called Engineers as Teachers that has been offered through a formal course (ENGR 490) in our Aerospace and Mechanical, Biomedical and Industrial Systems Engineering departments. The course has been offered each semester since Fall 2007 and emphasizes developing STEM communication skills. Undergraduate students attend a 16-week, 32-hour training program, conducted by Iridescent (a local non-profit, and BE-LA partner in this project). Students work in pairs to plan and teach two Family Science Courses (each consisting of five, two-hour sessions) that are aligned with the California Science Standards. The undergraduates are partnered with graduate students, faculty members, and teachers (all volunteers), and develop complete lesson plans and pre- and post-tests for the following topics: Animal Locomotion, Biomechanics of Breakdancing, Bird-Flight Aerodynamics, Cardiovascular Mechanics, Heat Transfer and Energy Efficient Houses, Optics, Physics of Magnetic Resonance Imaging, Physics of Sailing, Renewable Energy, Science of Sporting Equipment, and Structural Color. The courses are attended by 3rd-12th grade students and their families. Teachers are also required to fill out feedback forms after each session on aspects that worked during the session, aspects that did not work, and suggestions for the next session. Note that our pilot project primarily involved undergraduates while BE-LA will primarily involve doctoral students.

Learning Activities/Materials that Will be Developed:

We have found that the human body is an excellent platform on which to explore scientific and engineering principles while engaging younger students. One can explore basic phenomena like forces and fluid viscosity, to high-level processes like muscle control, perception, reasoning and planning. Body engineering research topics are also closely aligned with the Science Content Standards for California Public Schools for our target audience of 6th-8th grades. Research has also shown that 6th-8th grade is a critical time for STEM programs, as this is a period when achievement and interest decline. We intend for fellows' research to reach the classroom through a combination of lectures, explanatory videos, hands-on experiments, and discussions. For example:

- A fellow researching biomechanics of the knee could develop lectures and desktop experiments to explain levers, balance, center of gravity, and distribution of forces. These then could be extended to study knee, elbow, and shoulder joints by building models or making measurements on one another. This could be compared to more detailed data obtained as part of the fellows' doctoral research.
- A fellow researching vascular hemodynamics around atherosclerotic plaques could develop lectures to convey the basic differences between fluids and solids, as well as viscosity and pressure, and desktop experiments to illustrate the effect of stenosis. These then could be compared to imaging and simulation data from the fellow's doctoral research.
- A fellow researching biological materials could develop lectures to convey concepts of force, stress, strain, and related material properties, and could use desktop experiments to illustrate how these are measured. A laboratory could be performed in which students test, for example, the tensile strength of one's own hair strands. Hypotheses could be developed and tested in the classroom comparing strength with thickness, color, and length. These could be compared with advanced testing methods or advanced materials from the fellow's doctoral research.

While universally relevant, this set of topics is not commonly addressed within the realm of K-12 education. Therefore, the results of this program may have educational implications far beyond the community of schools directly involved. The creation of a fertile venue to enable graduate fellows to develop diverse ways to communicate these research directions to diverse audiences will be a significant achievement.

Examples of what has worked and not worked:

We have learned several lessons from our Engineers as Teachers pilot project. To list a few:

- Introducing a small number of key ideas maximizes retention. For instance, the course on cardiovascular mechanics focused on the role of pressure, and the course on diving concentrated on the role of the center of mass.
- Inquiry-based activities increase STEM interest and efficacy. After such activity, 90% of K-12 students said their attitudes towards STEM or their perceptions of their own abilities had improved.
- Build on prior knowledge. Fellows benefit from some K-12 teaching experience early in their training so that they can identify the level of student knowledge.
- Assessments enable targeted instruction. Pre-tests are useful in identifying K-12 students' prior knowledge and misconceptions. Exit slips were handed out at the end of each session with questions such as: "What are you most proud of learning today?" or "Why does hot air rise?"
- Role models spark interest in STEM. The presence of role models sparks a persistent interest in STEM careers. BE-LA's focus on the 6th-8th grade which will give students sufficient time to develop the requisite skills, and to overcome gaps in academic achievement to successfully pursue a STEM career.

http://bela.usc.edu/
http://gk12.org/

Contact Info
213-740-3494
knayak@usc.edu