The Engineering for Health Academy: A Specialized Secondary Program Preparing High School Students for a Career in the Biomedical Engineering Profession

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Abstract

The Engineering for Health Academy (EHA) will offer students in grades 10 through 12 at a large inner-city high school, a new and innovative course of study comprised of 4 integrated classes focused on biomedical engineering (BME). The major goals of the EHA are 1. to introduce high school students, including English language learners, under-represented minorities and at-risk students to all aspects of the biomedical engineering field in terms of the broad spectrum of career opportunities; 2. to design and implement a series of integrated courses that are experiential in nature, standards-aligned and directly relate content knowledge and skill mastery to student-centered BME projects; 3. to place third year EHA students in university biomedical engineering research laboratories or in internships with local biomedical engineering industry partners and 4. to prepare students to undertake and succeed in a rigorous postsecondary engineering education pathway.

Professional scientists and engineers from the Biomimetic MicroElectronic Systems (BMES) Engineering Research Center (ERC) at the University of Southern California (USC) will collaborate with educators at the high school on curricular development and implementation. EHA students will visit university and industry research laboratories and have access to university mentors and equipment. As students will learn engineering by doing engineering, they will be active participants in their education, making what they learn relevant and personally meaningful. Additionally, pedagogy specialists from the Rossier School of Education at USC will work with EHA teachers on developing effective teaching strategies and designing formative and summative assessment instruments.

The Engineering for Health Academy offers an alternative to a more traditional educational model and will prepare pre-college students to undertake a challenging postsecondary engineering education. A longitudinal study of EHA students as they progress through their education and career trajectory will inform the continued development of the EHA program.

Introduction

Engineering utilizes scientific knowledge and theory and applies mathematical tools to develop technologies and products that are critically important to the health, safety and quality of life of a nation's citizenry. Biomedical engineers employ engineering principles and practices to analyze and solve problems in biology and medicine. Biomedical engineers play an increasingly important role in the enhancement of health care, whether it is working with other medical professionals in the design of medical instruments, devices or software or conducting research needed to solve clinical problems. According to the U.S. Department of Labor, the demand for biomedical engineers will increase much faster than average for all occupations over the next decade *[1]*. There has been a steady decline, however, in the number of high school students reporting interest in pursuing engineering as a profession and fewer potential engineering majors are completing rigorous college preparatory programs and graduating in the top quarter of their high school class *[2]*. This development has raised concerns among leaders in the engineering fields of a shortfall in the number of well-qualified engineers in the coming decades.

In an attempt to introduce high school students to engineering and provide them with a curriculum that prepares them for the rigors and challenges of a college engineering course of study, the Biomimetic MicroElectronic Systems Engineering Research Center at USC has partnered with a local high school in the establishment of the Engineering for Health Academy. By its very nature, engineering can be used to demonstrate to teachers and students the relevance and importance of science and mathematics in their everyday lives. The EHA offers the high school students an opportunity to undertake an in-depth investigation focused on biomedical engineering. Students will learn science and engineering by doing science and engineering. The design, development, implementation and assessment of the Engineering for Health Academy will be described in this paper.

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Engineering for Health Academy Program Design/Description

The EHA will utilize a small learning community (SLC) model to provide students with a more personalized and supportive environment that integrates a rigorous standards-based curriculum in an identifiable context with a unified and focused vision. As both science and engineering are processes, students will be active participants, not casual recipients, of their education and apply their knowledge and skills to the completion of classroom and science fair projects. EHA students will benefit from a curriculum that is current, challenging and relevant.

Scientists, engineers and pedagogical experts will work cooperatively with EHA teachers on curricular development. Visits to university laboratories and local biomedical engineering industry partners will be scheduled and university faculty and students will visit the high school classrooms to lead discussions and perform demonstrations. EHA teachers and students will have access to university equipment and resources which will enhance the classroom experience. In addition, university faculty and students will serve as mentors and consultants to teachers and students on classroom and science fair projects. Parent of EHA students will be invited to attend field trips to serve as chaperones and active learners in the experience and they will be encouraged to visit the classroom to more effectively participate in their child's education.

A school counselor will be designated to administer to the EHA students. The counselor will become familiar with all aspects of the EHA program including college and industry BME requirements so he/she can better serve the EHA students. The counselor will meet with each student at least once a semester to ascertain the progress of the students. They will also meet with parents to describe the demands and expectations of post-secondary BME programs and help them navigate through the financial aid application process.

Teacher Training

Engineering utilizes scientific knowledge and theory and applies mathematical tools to solve practical problems through the development and use of technologies. By its very nature, engineering offers a powerful opportunity to demonstrate to teachers and students the relevance and importance of science and math in their everyday lives. Although there are myriad factors that influence a student's learning and interest, research indicates that teacher quality is a major factor that influences student motivation and learning *[3,4]*. A major goal of the EHA, therefore, is teacher preparation. Although all EHA teachers are veteran teachers and accomplished in their respective fields, they are not biomedical engineers by training and they have had limited exposure to the field.

Engineering for Health Academy teachers will be offered the opportunity to participate in a Research Experience for Teachers (RET). This summer externship will match teachers with university laboratories where participants will gain direct hands-on experience in biomedical engineering under the mentorship of university faculty members and Ph.D. students. In addition to becoming an integral part of a research team, the EHA teachers will attend professional development workshops focused on effective teaching strategies, working with students with diverse needs, and the development of authentic assessment instruments.

On-going consultations with university scientists, engineers and pedagogy specialists will be available for EHA teachers as the teachers prepare the curriculum for the core courses. This collaboration between university and high school faculty will ensure that EHA course content will be up to date, relevant and responsive to college and industry expectations and demands. EHA teachers will also be encouraged to attend science and engineering education conferences. In-services on the use of EHA related technology including SMART Boards, audience response systems, BioRadio devices and CAD software will be scheduled. Additional workshops will be offered on grant writing and the development of concept inventories. Very importantly, EHA teachers will be encouraged to identify and attend professional development programs related to the EHA and that address their own specific needs.

Other members of the EHA small learning community, including the counselor and administrators, will participate in professional development workshops that inform these stakeholders of the spectrum of biomedical engineering career opportunities, as well as the academic, ethical and professional demands of the field.

Curriculum Development

The EHA will utilize a novel approach to incorporate current BME research into the educational process. Students will transition through a series of three integrated core courses in grades 10 through 12. Each EHA course will be standards-aligned, rich in hands-on activities, project-oriented and meet university entrance requirements. Curricular development will be driven by current/future anticipated needs of the BME field so that graduating EHA students will have advanced preparation for the demands of a rigorous post-secondary college program.

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Biomedical engineering will be a unifying theme for each course and there will be a horizontal (over-time) integration of content knowledge and skills development. The knowledge and skills developed in the 10th grade course will serve as the foundation for the two 11th grade EHA courses. These three core classes will prepare students for success in the 12th grade capstone class where students participate in a research project in a BME laboratory at USC. The following are brief descriptions of the EHA core courses:

Chemical Foundations of Biomedical Engineering (grade 10): This course will introduce students to the fundamental concepts of chemistry that will provide a solid foundation for students continuing in the Engineering for Health Academy. The basics of mathematics, engineering (and some electronics) principles as they relate to biological systems will be emphasized whenever possible. The course curriculum will be rich in hands-on activities assuring that students are active participants in the discovery process and not merely casual observers. Carefully planned pacing will allow students to better comprehend previously covered concepts/material by designating instructional time to assure proficiency before moving on to new material. Students will be required to participate in the high school's annual science and engineering fair. Presentations by university biomedical scientists and engineers and visits to USC research laboratories will augment classroom activities when appropriate and available. The historical development and a survey of major areas comprising biomedical engineering will also be covered. The course will prepare students to integrate biomedical science and engineering principles in the 11th grade EHA courses.

Biomedical Engineering: Challenges and Solutions (grade 11). This course will build upon the chemical principles introduced in the Chemical Foundations of Biomedical Engineering class, relating them to human physiology. The following principles and their relationships to organ and system physiology will be emphasized: The Ideal Gas Law, bioelectric potentials, diffusion/osmosis, fluid dynamics, chemical kinetics and thermodynamics. Organ systems and their associated biomedical prosthetic devices that will be investigated in this course include: nervous system (retinal prosthesis, hippocampus implant, cochlear implants), muscular system (artificial limbs and the BION®), cardiovascular system (pacemaker), respiratory system (artificial lung), renal system (dialysis devices), and endocrine system (glucose pumps). This course will be closely aligned with the Computers for Biomedical Engineering course. Students will use sophisticated technology, for example, CleveLabs BioRadio to collect physiological data and then store it in computer programs such as MATLAB and LabVIEW. In the EHA computer class, the students will learn how to manipulate and analyze the data.

Computers for Biomedical Engineering (grade 11): This course is designed to provide support to the program by providing the students access to computers and the skills needed for success in the EHA curriculum. The class will cover a comprehensive range of applications. Starting with the basics, word processing, spreadsheets, databases and presentation software, the class will move on to more specialized applications such as mastery of MATLAB and LabVIEW computer programs. With SolidWorks, a computer assisted design program widely used in the engineering field, the students will learn to design and test biomedical devices.

Field Experience in Biomedical Engineering (grade 12): Students in this course will be given an opportunity to apply their content knowledge, specialized skills and familiarity with technology that they acquired in the EHA core courses in a BME research laboratory at USC. University mentors will provide the necessary support and resources to enable EHA students to execute a successful research project. Students will become familiar with the relevant literature, receive training in scientific methodologies, generate and analyze data, and gain first-hand experience working collaboratively in cutting-edge research environments.

Instructional Strategies

Students in the 10th and 11th grade EHA courses will be divided into small collaborative study groups consisting of 5 students per group. Criteria used to select groups members include: learning style type, content knowledge, reading levels and English language development. Educational research indicates that the ideal study group includes students of mixed learning styles *[5]*. Study groups will be composed of students with different skills, aptitudes, language proficiency and preferences for processing information. Additionally, at-risk students will be integrated among high achieving students. It is hoped that study group members will complement and support one another and learn the importance of working as a team.

University undergraduate/graduate BME student mentors will work with each study group. Mentoring relationships are invaluable *[6]* and EHA students will benefit from the wisdom, experiences, and perspectives of knowledgeable mentors and role models. EHA classes will be rich in hands-on activities that demonstrate the connection between course content and practical applications. Students will enter science fair projects into the high school science and engineering fair. Projects are judged by professionals from local educational and professional institutions. Participation in the science fair requires students to organize and present information visually and hone effective verbal communication skills.

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Student Selection

Two primary objectives of the EHA are to inform students about professional opportunities in biomedical engineering and to prepare them to undertake a rigorous post-secondary BME course of study. In an effort to inform students about the EHA, all 9th grade students were invited to an Engineering for Health assembly. A description of the EHA opened the assembly and was followed by a keynote presentation by a prominent biomedical engineer who spoke about the opportunities facing biomedical engineers as they tackle real-world BME challenges. The speaker emphasized the role biomedical engineers increasingly play in the next frontier of medicine and health care. A panel of six university BME students closed the assembly, discussing their BME experiences and answering questions from the high school students. Following the assembly, surveys were distributed to all 9th graders to ascertain their understanding of BME and the EHA program. Students could indicate their interest in enrolling in the EHA on the survey.

Students who are interested in applying to the EHA complete an application which asks the students to answer the following questions: 1. Why are you interested in the Engineering for Health Academy? 2. What skills do you have that will help you be successful in the Academy? 3. What are you expecting to learn from the Academy? 4. What are your educational and professional goals after high school?, and 5. Why are you willing to make a 3-year commitment to the Academy? The application has a Student and Parent (Guardian) Statement of Commitment that both the student and parent (guardian) must sign.

To help assure the selection of a cohort of 30 to 35 students who are most likely to succeed in the EHA and reflect the school's overall enrollment, it is important that specific selection criteria be used. The admissions committee will use the information the students submitted on their applications as well as academic grades, grade point averages, and math and science and English standardized test scores in the selection process. All 9th graders were also administered the Felder Learning Style Index and, although the results will not be used as a selection criteria for admission into the EHA, they will be used to assign students to particular study groups within the EHA courses. An admissions committee composed of all EHA instructors, the EHA designated counselor, and two university partner members will review the EHA applications.

Assessment:

A variety of formative assessments will be used throughout the EHA core courses to ascertain what students know (and don't know). This information will be used to inform students, teachers and parents of the degree of student mastery of course content and skills development. Although many of the more traditional types of formative assessments (teacher observations, quizzes and tests) will be used by EHA teachers, some more specialized forms of assessments will also be employed. For example, although concept inventories are becoming more common at the college level, and an increasing number of validated tests are available, concept inventories are generally not available at the high school level. EHA teachers, however, will develop concept inventories for their courses in order to evaluate whether students have an accurate and working knowledge of key concepts in each of the core courses. Students will be administered the tests at the start of each course to establish a baseline of knowledge and to provide the instructors with clues as to the ideas, scientific misconceptions, and/or conceptual lacunae, with which students are working, and which may be actively interfering with learning. At the end of the course, students will again be administered concept inventories and analysis of the results will be an indicator of student learning.

Audience-response system technology (clickers) will also be used in EHA courses to facilitate the evaluation of student mastery of content and to identify concepts that are difficult for students to understand. Research has shown that clickers may also improve student motivation and participation in class *[7]*. Because the technology allows for immediate feedback of student responses, the EHA teachers can use this information to tailor the lesson to meet the specific needs of the students.

The analysis of the various forms of formative assessment utilized in EHA courses will not only be diagnostic of student learning and achievement but it will also, very importantly, drive modifications in teaching strategies and curriculum, making them more responsive to the particular needs of the students.

Direction for Future Research

This past year has been a planning year for the Engineering for Health Academy. At present, EHA teachers have been selected and they have been involved in professional development activities that have acquainted them with many aspects of the biomedical engineering field. Collaborations between the high school EHA instructors and faculty and students at the university have been established. Current 9th graders have been informed about the EHA and baseline data on potential EHA students have been collected. Interested students have completed and submitted EHA applications and the first cohort of students will be selected by June 2008. The first class of 30-35 students will enroll in the 10th grade Chemical Foundations for Biomedical Engineering in September 2009.

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In terms of broad impact, we expect that this program will inform the broader education community, particularly the high school and college communities invested in educating future generations of engineers. With fewer high school students expressing an interest in pursuing engineering as a profession and fewer potential engineering majors completing rigorous college preparatory programs, initiatives such as the Engineering for Health Academy may serve as a pre-engineering model nationally that will provide high school students with an engaging introduction to biomedical engineering and prepare them for success in a high demand profession.

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