An Innovative K-12 Science and Engineering Initiative

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***Abstract* – The outreach program of the Biomimetic MicroElectronic Systems Engineering Research Center (ERC) is an innovative initiative designed to integrate science and engineering principles into the K-12 curriculum. For the past two years, approximately 630 students in grades 3, 4 and 5 at Murchison Elementary School were supported in experiential learning that promoted the understanding of fundamental science and engineering principles. Essentially all MES students are minority students who are underrepresented in STEM professions.**

ERC faculty and students, in collaboration with MES teachers, designed a series of modules which use BMES research as focal points. Lesson plans are age-appropriate, standards-aligned and incorporate problem-based learning exercises demonstrating scientific discovery. Student motivation and learning was facilitated by ERC mentors who served as role models in the classroom.

Formative and summative assessment strategies were used in the outreach program and included student Science Attitude Surveys and measurements of student achievement in science content and process. Results indicate that significant science achievement was attained by a majority of students but the degree of success was influenced by their English proficiency. The elementary outreach component is part of a larger BMES ERC effort to establish and sustain a STEM pipeline that extends from K-12 to graduate school.

Index Terms – education outreach, language proficiency, science and engineering modules, underrepresented minorities

INTRODUCTION

Engineers utilize the principles and theories of science and mathematics to design, test, manufacture and maintain products that are important to the health, safety and quality of life of a nation's citizenry. The development, prosperity and security of a nation are directly correlated with advancements made in the engineering field.

There are, however, significant economic demands placed upon individuals interested in pursuing engineering as a profession. A bachelor's degree in engineering is required for almost all entry-level engineering jobs. In 2006-2007, the average cost of tuition and fees charged at four-year public colleges in the U.S. was $5,836 and tuition and fees charged at four-year private U. S. colleges averaged $22,218. When considering total costs (including tuition and fees, room and board, books and supplies, transportation and other expenses) the cost of a bachelor's degree in 2005-2006 was $12,796 for in-state students attending four-year public colleges and universities, and $30,367 for students at four-year private colleges and universities [1].

In addition to the economic demands, there are rigorous educational requirements for those interested in pursuing engineering as a career. Admissions requirements for undergraduate engineering schools include a solid background in mathematics (algebra, geometry, trigonometry, and calculus) and science (biology, chemistry, and physics), with courses in English, social studies, and humanities.

Considering the financial and intellectual challenges, why would anyone choose to become an engineer? Although the educational and financial demands of the engineering professions are high the U.S. Department of Labor projects that between the years 2004 and 2014 there will be on average, a 24.5 percent increase in the demand for engineers [2]. As a group, engineers earn some of the highest average starting salaries among those holding bachelor's degrees. Compared with most other workers, a smaller proportion of engineers leave their jobs each year which may reflect a general satisfaction with their jobs. The engineering profession may also appeal to individuals who are naturally creative, inquisitive, analytical, and detail oriented, characteristics that are important to being successful in the field.

Despite the promising job outlook, competitive salary and potential appeal, there has been a steady decline in the number of U.S. high school students who plan to major in engineering in college and fewer potential engineering majors are completing rigorous college preparatory programs and graduating in the top quarter of their high school class [3]. This situation has raised concerns among leaders in the engineering fields of a shortfall in the number of well-qualified engineers in the coming decades.

The demographics of the U.S. are also shifting with the nation becoming increasingly more diverse. In the decade ending in 2000, the minority population has increased by 43 percent and in 2005 minorities comprised 33.1 percent of the U.S. population [4].

In California, the changes in demography are even more pronounced. Approximately 56 percent of the state's population is minorities with persons of Hispanic or Latino origin forming the largest subgroup at 35.2 percent of the total [5]. Today women, African Americans, Hispanics, American Indians and persons with disabilities make up two-

thirds of the U.S. workforce. This cohort of individuals represents a potential resource of future engineers that can bring a diversity of experiences and make the U.S. more competitive in the global marketplace. Historically, however, these subgroups are underrepresented in the engineering and science fields with women comprising 25 percent, African Americans 6.9 percent and Hispanics 3.2 percent of the science and engineering workforce in the U.S. [6].

To meet the demands of the nation's engineering labor force, the recognition of the importance of early education intervention and the implementation of challenging curricula that capture and sustain students' interest in science and engineering is critical. Research shows that children as young as 5 or 6 years old already show the ability to think scientifically [7]. It is imperative that the educational system design learning environments that prepare these students for success, otherwise they are in danger of losing their sense of wonder and curiosity and will be lost from the engineering pipeline. Typically, this "turn-off" to science begins during middle school years and, with the exception of the biological sciences, the percentage of college students seeking degrees in science and engineering disciplines has seen an absolute decline in the number of degrees conferred annually since 1985 [8].

IMPLEMENTATION AND RESULTS

The BMES ERC, in partnership with Murchison Elementary School (MES), has established the Science for Life (SFL) outreach program. This comprehensive and innovative initiative is designed to increase the science literacy of children by integrating science and engineering principles into the 3rd, 4th and 5th grade curricula. MES is a typical urban school in the Los Angeles School District and represents a microcosm of the challenges faced by many inner city elementary schools including limited resources to deliver a rigorous science curriculum to a majority of its students. One hundred percent of MES students fall below the poverty line and 99.5 % are Latinos. Approximately 66% of MES students are English language learners and they come from families with limited formal education. This cohort of students typically scores poorly on science and math achievement tests as measured by the National Assessment of Educational Progress (NAEP) [9]. It is not surprising, therefore, that inner city minority students rarely consider science or engineering as career pathways.

Science is a discovery process and forms the foundation of engineering. Success in science and early exposure to engineering applications will increase the likelihood of choosing engineering as a career goal. With this in mind, BMES ERC scientists and engineers in collaboration with MES teachers have designed three Science for Life modules that are rich in hands-on activities. The modules are composed of a series of 8 lessons, each approximately 90 minutes in duration and are taught in the classroom during the regular science instruction time. Each grade specific module has a unifying theme focused on BMES ERC testbed research. The lessons are age-appropriate, interest-provoking, and are aligned with the Los Angeles Unified School District (LAUSD) and the California State science standards. The modules introduce MES students to fundamental scientific principles and are rich in inquiry-based activities that demonstrate the scientific method of discovery; emphasizing analytical skills over simple memorization. Scientific principles of prediction, observation, measurement and interpretation are embedded into each of the activities as are practical engineering applications. The elementary classroom is transformed into a virtual laboratory with the students being scientists and engineers conducting actual experiments utilizing appropriate technology and solving relevant problems.

As is typical of most elementary school teachers, MES teachers are education generalists and have not majored in the sciences. Understandably, the MES teachers initially expressed some concern about designing and implementing a rigorous science curriculum that had engineering elements embedded into its design. To address their concerns, a series of consultations and training sessions were scheduled between the elementary teachers and university scientists, engineers and pedagogy specialists. A wide range of issues including science content, mastery of technological skills and teaching strategies necessary to effectively teach the modules were covered. This collaboration between MES teachers and university professionals resulted in the development of lesson plans that are challenging and yet age- and grade-level appropriate. It also fostered mutual respect between the pre-college and university educators.

A key feature of the Science for Life outreach program is mentoring (Figure 1). Prior to lesson plan implementation, MES teachers divided their students into three groups of approximately 10 students each. The regular classroom teacher worked with one group of students and SFL mentors worked with the other two groups. BMES ERC-affiliated faculty, graduate, undergraduate and high school students served as mentors. Training sessions for SFL mentors were scheduled to familiarize the instructors in the science content and skills covered in the lessons. Additionally, SFL mentors were advised in pedagogy to facilitate student learning. A 10:1 ratio of mentor to students facilitated the mastery of science content and skills and enabled a rapport between mentors and students. Most MES students (and teachers) have not had direct contact with individuals who have such enthusiasm for and experience in science and engineering, let alone someone so close to their own age. This mentor-student interaction fostered the perception among the elementary students that science and engineering can be exciting and "cool".

FIGURE 1

ERC MENTORS SERVE AS ROLE MODELS AND FACILITATE MOTIVATION AND LEARNING OF SCIENCE AND ENGINEERING

Program assessment is a key component of the Science for Life initiative. A variety of assessment strategies was used and included student Science Attitude Surveys, debriefing of mentors and MES teachers and pre- and post-science competency tests. The measurement instruments served as formative assessments and enabled teachers and mentors to modify lesson plans and activities to meet the specific needs of the students.

Results of the student attitude survey to the question "I like science" indicate that on average, 89% of all 3rd, 4th and 5th grade Murchison students report that they like science. When the data are disaggregated according to gender (Figure 2), an average of 86 percent of males and 92 percent of females state that they like science and there are no marked differences among the various grade levels. At this point in their education, the MES students are receptive to science and we have them in the pipeline.

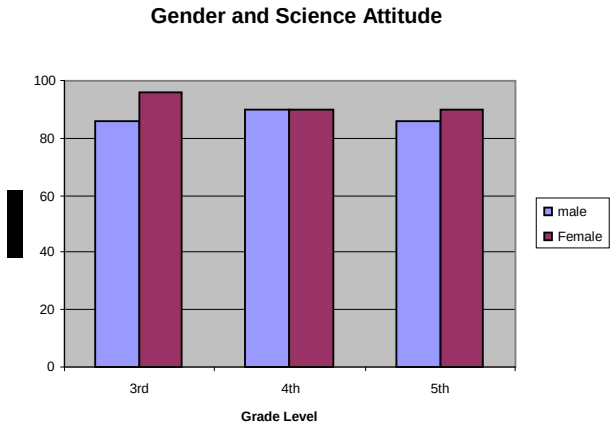

FIGURE 2
EFFECTS OF GENDER AND GRADE LEVEL ON STUDENT ATTITUDES TOWARD SCIENCE . (N = 101/100, 97/102, AND 100/130 MALE/FEMALE, IN GRADES 3, 4 AND 5, RESPECTIVELY).

Murchison Elementary School is typical of many schools in the Los Angeles School District in that many MES students (~ 66%) are limited in English language proficiency as determined by the California English Language Development Test (CELDT). Consequently, we were interested to ascertain whether the language proficiency of the students influenced their attitudes toward and/or success in science. Towards the end of the first year of the study we began to record the English proficiency of the students and, in accordance with their CELDT scores, classified students as low English proficient (LEP) or high English proficient (HEP). Figure 3 shows the relationship between English language proficiency and student attitude towards science. It can be seen that regardless of their English language proficiency the majority (>80%) of elementary students report that they like science.

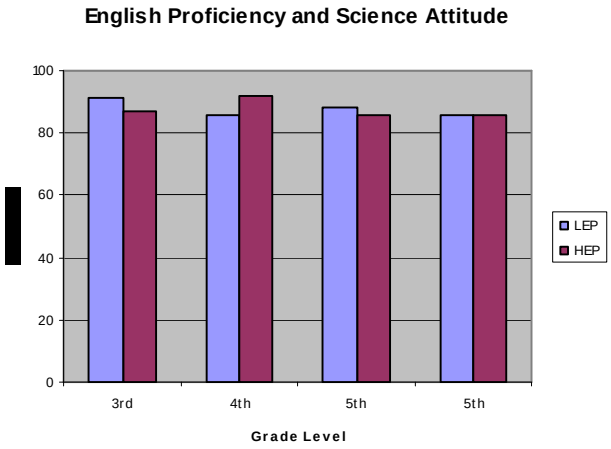

FIGURE 3
EFFECTS OF ENGLISH LANGUAGE PROFICIENCY AND ATTITUDES TOWARD SCIENCE. (N = 55/54, 49/51 AND 70/161, LEP/HEP IN GRADES 3, 4 AND 5, RESPECTIVELY). NOTE: ENGLISH LANGUAGE PROFICIENCY SCORES WERE COLLECTED TOWARDS THE END OF THE FIRST YEAR OF THE STUDY. CONSEQUENTLY, ONLY 5TH GRADE RESULTS ARE SHOWN FOR BOTH YEARS OF THE STUDY.

Student scores on multiple choice science competency tests (Figure 4) signify that there are significant differences between the pretest and posttest results, indicating that students are learning the content and skills presented in the lessons.

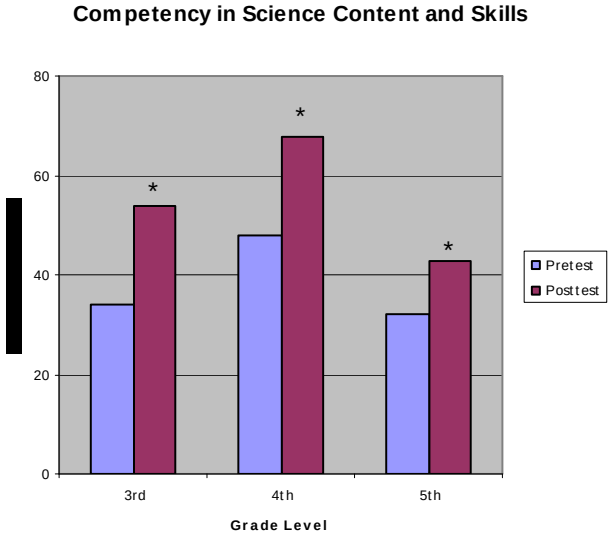

FIGURE 4
ASSESSMENT RESULTS IN SCIENCE COMPETENCY BEFORE AND AFTER OUTREACH INTERVENTION. THE PERCENTAGE OF STUDENTS CORRECTLY ANSWERING QUESTIONS SIGNIFICANTLY INCREASED ($p < 0.01$) AFTER MODULE IMPLEMENTATION IN ALL GRADE LEVELS. (N = 201/198, 199/196, 230/225 PRETEST/POSTTEST, IN GRADES 3, 4 AND 5, RESPECTIVELY).

When students are disaggregated into low English proficient (LEP) and high English proficient (HEP) subgroups both language cohorts, except the 5th grade class of 2006, demonstrated significant learning of science content and skills following the outreach intervention. However, mastery

of the material was significantly greater for HEP students than it was for LEP students.

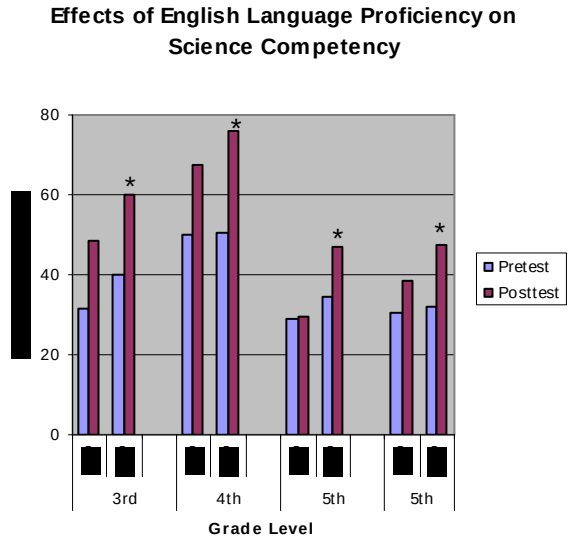

FIGURE 5
SCIENCE COMPETENCY RESULTS WERE DISAGGREGATED INTO LEP AND HEP SUBGROUPS. BOTH SUBGROUPS OF STUDENTS DEMONSTRATED SIGNIFICANT LEARNING OF SCIENCE CONTENT AND PROCESS, EXCEPT FOR THE 2006 5TH GRADE, FOLLOWING INTERVENTION. HEP STUDENTS SCORED SIGNIFICANTLY HIGHER ($P < 0.01$) THAN LEP STUDENTS IN ALL GRADE LEVELS TESTED.

CONCLUSIONS

The BMES ERC outreach program, in partnership with Murchison Elementary School, has capitalized on the young children's enthusiasm for science and has designed and implemented a series of science and engineering modules for the 3rd, 4th and 5th grade classrooms. University scientists and engineers have collaborated with MES teachers in assuring that the lesson are age-appropriate, standards-aligned and use ERC research as focal and reference points. ERC-affiliated mentors went into the classroom during the regularly scheduled science class and guided the students in experiential activities that helped them learn science by doing science. Results from science competency assessment tests indicate significant student achievement in science literacy following outreach intervention. Student success directly correlated with English language proficiency and high English proficient students scored significantly higher than those with more limited language proficiency. We are interested in modifying our curriculum so that all students, regardless of their English language proficiency, will equally benefit from our initiative

The Science for Life outreach program is introducing science and engineering principles to a cohort of students who typically have limited access to resources. The SFL mentors are effective role models and bring their enthusiasm for science and engineering directly into the classroom. This type of early intervention will increase the number and diversity of U.S. citizens becoming scientists and engineers, thus ensuring the nation's science and engineering competitive edge well into the future.

ACKOWLEDGMENT

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