Engineers Communicating with the Public: Collateral Benefit of a Pre-College Program in Bioengineering

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Abstract – A weeklong camp was developed for rising 8th through 12th graders to introduce them to bioengineering, and to give undergraduate research interns and graduate students an opportunity to present their research at the middle school level. Presentations and hands-on activities were led by or assisted by students in bioengineering. Surveys were developed to gauge the camp's effectiveness at introducing bioengineering to the pre-college students, as well as to assess the impact of the college students' facilitation roles.

The surveys indicated positive opinions about bioengineering as a career or education option for the pre-college group as a result of the experiences of these students during the camp. Also, the camp was regarded as beneficial to the college student facilitators. These results indicate that the value of a pre-college enrichment program is multiplied when college students are encouraged to participate and convey information on topics related to their research to a non-technical audience.

Keywords: Bioengineering, biomaterials, pre-college enrichment, communication skills

INTRODUCTION

In spite of the many technical innovations and advances in this country, high school students' achievement in science and math lags behind that of other developed countries. New information from the Program on International Student Assessment ranked the US 24th out of 29 of the world's wealthiest countries in the ability of 15-year-olds to solve real-life math problems [1]. This is especially pronounced in middle and high school grade levels, and points out the need to increase interest in math, science and engineering for these students. In order to have a population that is knowledgeable, as well as a well-prepared workforce, a fundamental change in the way we introduce pre-college students to math, science and engineering is needed [2]. It has been shown that summer science and engineering enrichment programs are successful at exposing pre-college students to new technology and concepts, which then stimulates their interest in science and technical fields [3]. In particular the field of bioengineering is attractive to students, as it introduces technical and scientific concepts in a way that is real for young people. Most of these students know individuals who have benefited, or have benefited themselves, from bioengineered devices ranging in complexity from knee braces to pacemakers. This familiarity makes the technology accessible to students, and makes it adaptable as a teaching tool. Bioengineering is focused on improving the quality of life through the application of engineering to medicine, and fulfills students' desire to help people. This is particularly true for pre-college females [4]. Thus it is an ideal vehicle for introducing science and technology in a way that piques students' interest and encourages inquiry.

In addition to finding ways to enhance pre-college science education, it is equally important to train science and engineering majors in college to convey technological concepts at an appropriate level for the general public. A scientifically literate populace is beneficial for several reasons, including the promotion of scientific research, and the ability for citizens to make informed decisions about legislation, business and education. Support for the advancement of scientific and technical research depends on the public's understanding of the impact and relevance of that research [5]. Communication skills developed in undergraduate and graduate education are typically focused

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at a technical level, for example to convey information at professional meetings and conferences. However, communicating objectives and methods to people outside of one's field is at least as important as technical communication. Particularly in the area of biomedical or behavioral research, this is a required element when working with human subjects. Guidelines set by the Department of Health and Human Services for this purpose state that "The manner and context in which information is conveyed is as important as the information itself…. Because the subject's ability to understand is a function of intelligence, rationality, maturity and language, it is necessary to adapt the presentation of the information to the subject's capacities" [6]. A comprehensive training program for students and researchers in bioengineering should include development of these communication skills. There is a need to broaden the experience that students get in college beyond professional presentations, and to provide the skills necessary to communicate technology at levels that the general public can understand.

METHODS

A weeklong camp called "Bioengineering: Building A Better You," (abbreviated as Bioengineering, BABY!) was developed for rising 8th through 12th graders, and was held during the summer of 2004 on the campus of Clemson University. The objectives of this program were two-fold: to expose middle and high school students to the field of bioengineering, and to give undergraduate and graduate students in the Department of Bioengineering at Clemson University an opportunity to present their research at a middle school grade level. In most areas of the country, 6th to 8th grade reading and comprehension is generally accepted as a level that the general public can understand.

Pre-college students were recruited through a university-wide summer program called Summer Science, Engineering and Architecture Enrichment Program. Undergraduate research interns, graduate students and faculty from the Department of Bioengineering conducted laboratory tours and demonstrations, and made presentations on topics related to their research. Through various activities and demonstrations using bioengineered devices, concepts such as friction, motion, biomaterials, and surface phenomena were introduced to the pre-college students. Presentations were made on the following topics, and specific interactive and hands-on activities included:

- Orthopaedics – bones, ligaments and tendons, osteoporosis, fractures and fracture fixation, arthritis and joint replacements
  - Activity: Using foam models of femurs with fractures, bones were fixed with metal plates and screws to simulate orthopaedic implants.
- Cardiovascular – blood vessels, heart valves, cardiovascular disease and vascular grafts
  - Activity: Simulated graft material was sutured onto pig arteries using surgical sutures and surgical instruments. Demonstrations and instructions on tying surgical knots were given to students.
- Tissue engineering – cell culture techniques and absorbable polymer scaffolds
  - Activity: Simulated tissue (gelatin) that contained simulated cells (ground black pepper) was digested with an enzyme (bromopapain in commercial meat tenderizer). "Cells" were harvested using filter paper, then rinsed and put in a delivery system (clear hair gel). A syringe was used to deliver the cells to fill a void created in the "tissue" of a plastic animal model.
- Biomaterials – types of materials, protein interactions with materials in the body, surface chemistry
  - Activity: student used Zoobs® (interlocking toys that mimic biological structures; Infinitoy, Inc., Burlingame, CA, www.infinitoy.com) to build models of surfaces, after participating in a discussion of strategies for protein/surface interactions. Zoob "proteins" were made by instructors and used to test the surface interaction strategies that the students came up with.

Students went on daily tours of bioengineering research laboratories and an animal research facility. A career discussion panel was organized with professionals from industry, academe, a clinical research lab and graduate students, to field the pre-college students' questions about education and career paths. Team-building and communication exercises using bioengineering props were used as icebreaker activities, and also served to illustrate communication across the different disciplines within bioengineering. The last day of the camp was capped off with a "Jeopardy"-style game show, where students competed in teams to test their newfound knowledge of bioengineering.

A survey was developed to gauge the camp's effectiveness at introducing the field of bioengineering to the pre-college students. The survey questions pertained to the students' familiarity with engineering and bioengineering, and their interest in pursuing careers in these fields. Questions are listed in Table 1. The survey was given to all camp participants on the first and last days of the camp. The students' answers on pre-camp and post-camp surveys were compared and the number of students whose answers indicated an increased understanding or awareness of engineering or bioengineering was tallied.

Table 1. Pre- and Post-camp survey questions given to pre-college students on the first day and last day of the weeklong camp.

Pre-camp Survey:
Name or Nickname (optional):_____
Age and Grade entering in Fall 2004:_____

1. Please indicate your awareness / interest in Engineering:
   a. I don't know what Engineers do.
   b. I know what people do in Engineering, but have no interest in it.
   c. I am considering Engineering as one possible career.
   d. I am planning a career in Engineering.
   e. I cannot imagine a career in anything other than Engineering.

2. Please indicate your awareness / interest in Science:
   a. I don't know what Scientists do.
   b. I know what people do in Science, but have no interest in it.
   c. I am considering Science as one possible career.
   d. I am planning a career in Science.
   e. I cannot imagine a career in anything other than Science.

3. Why did you come to this camp?

4. What are you expecting to get out of this camp?

Post-camp Survey:
Name or Nickname (optional):_____
Age and Grade entering in Fall 2004:_____

1. Please indicate your awareness / interest in Engineering:
   a. I don't know what Engineers do.
   b. I know what people do in Engineering, but have no interest in it.
   c. I am considering Engineering as one possible career.
   d. I am planning a career in Engineering.
   e. I cannot imagine a career in anything other than Engineering.

2. Please indicate your awareness / interest in Science:
   a. I don't know what Scientists do.
   b. I know what people do in Science, but have no interest in it.
   c. I am considering Science as one possible career.
   d. I am planning a career in Science.
   e. I cannot imagine a career in anything other than Science.

3. What did you get out of this camp?

4. How has attending this camp affected your educational or career plans?

5. What did you like best about the camp?

6. What improvements would you suggest?

The undergraduate and graduate students who assisted with the camp were the focus of a second survey, which measured their perception regarding the value of their interaction with a non-technical audience. It also allowed feedback on the students' opinion of, and their interest in continuing to work with, pre-college enrichment programs. The survey questions are listed in Table 2. The survey was given to these students approximately one month after the workshop ended.

Table 2. Post-camp survey given to undergraduate and graduate students who helped with the camp activities.

Please circle the number that best describes your response to the following statements:				
1) I am confident of my ability to communicate technical information to pre-college students.				
1	2	3	4	5
strongly agree	agree	not sure	disagree	strongly disagree
2) Interacting with pre-college students (leading lab tours, discussions or activities) has helped me develop my communication skills.				
1	2	3	4	5
strongly agree	agree	not sure	disagree	strongly disagree
3) I value the opportunity to interact with pre-college students.				
1	2	3	4	5
strongly agree	agree	not sure	disagree	strongly disagree
4) I will volunteer to help with pre-college student programs in the future.				
1	2	3	4	5
strongly agree	agree	not sure	disagree	strongly disagree
5) Did participating as a volunteer with the "Bioengineering, BABY!" program benefit you? If so, how?				
6) Are you willing to volunteer with this or other pre-college programs in the future? Why or why not?				
7) What suggestions would you make for future pre-college outreach programs?				

RESULTS

A total of sixteen rising 8th – 11th graders enrolled in the camp, ranging in age from 13 – 17 years old. The students were from seven states in the southeast (Florida, Georgia, Ohio, North Carolina, South Carolina, Tennessee and Texas). The distribution of participants by grade level is summarized in Table 3, along with the results of the quantifiable questions on pre- and post-camp surveys.

Table 3. Age distribution of campers, and results of pre- and post-camp surveys. One student out of the sixteen who attended the camp did not respond to the surveys. Increased awareness or interest in engineering or bioengineering was determined by a change in students' responses to question on the surveys from pre- to post-camp. The number of students' whose answers increased from pre- to post-camp is followed by a percentage of the total number of students responding.

Grade level of campers	**8th**	**9th**	**10th**	**11th**	**Total**
Number of campers responding to survey:	3	7	3	2	15
# (%) increased awareness/interest in Engineering or Bioengineering:	3 (100)	4 (57)	0 (0)	0 (0)	7 (47)
# considering Bioengineering as education/career goal after attending camp	1	1	0	0	2

For the post-camp questions that were related to the effectiveness of the camp in introducing the field of bioengineering, twelve of the 15 respondents said they gained a better understanding of what bioengineering is and what bioengineers do. Three responded that they now have an idea of what graduate school and laboratory research entails. In response to question 4, "How has attending this camp affected your educational or career plans?" ten students indicated that the camp had a positive influence on their plans (considering a degree and/or career in science, engineering or bioengineering). Two students indicated that their camp experience would discourage them from working in a research environment. Three students responded that camp had no influence in either direction on their educational or career plans; two of these three were rising 10^{th} graders.

A total of nine out of 18 undergraduate and graduate student facilitators responded to the survey. Three of the students had graduated, and three others were unavailable at the time the survey was given out. Three students chose not to respond. The responses to questions answered with a numeric score are summarized in Table 4. All student facilitators who responded to the survey indicated "Yes" to the questions, "Did participating as a volunteer with the "Bioengineering, BABY!" program benefit you?" and "Are you willing to volunteer with this or other pre-college programs in the future?" Written comments mostly indicated a desire to see more college student facilitators involved, and a continuation of the program for the benefit of both the pre-college and the college students. All students responding with written comments said that it was good practice, for a variety of reasons. One indicated that it was beneficial to describe their research without using "jargon"; two found the opportunity to disseminate information about the department and the research that goes on there beneficial; three wrote that it will help them communicate with others outside of their field. Several of the respondents (3) indicated that communicating to a non-technical audience helped them understand their own project better, and gave relevance to the work being done in their laboratories. Other comments for improving the camp suggested more hands-on activities, and making lectures and discussions more interactive for the campers.

Table 4. Average scores for college student facilitator questionnaire for questions with responses on a scale of 1 to 5, with 1 meaning "Strongly agree" and 5 meaning "Strongly disagree." A total of 9 student facilitators responded to the questionnaire.

Question:	**Average score of responses**
1) I am confident of my ability to communicate technical information to pre-college students.	2.2
2) Interacting with pre-college students (leading lab tours, discussions or activities) has helped me develop my communication skills.	1.6
3) I value the opportunity to interact with pre-college students.	1.6
4) I will volunteer to help with pre-college student programs in the future.	1.7

DISCUSSION

It has been demonstrated that science education is more effective when instruction is related to real-world problems. The field of bioengineering applies engineering principles to solve real problems in the life sciences, merging the fields of biology, medicine, chemistry, physics and engineering. Because of the interdisciplinary nature of bioengineering, and its appealing applications to life in the real world, it is an ideal medium to introduce basic and applied science and engineering topics in exciting and innovative ways. In addition, this pre-college enrichment program capitalizes on the creativity of college students to integrate technical information into meaningful learning opportunities for all students. Thus in a broader sense, it provides the opportunity for professional development for college students, and the development of a population that has a better understanding of science and technology.

The impact of the camp in terms of introducing engineering as an education or career alternative appeared to be greater for the younger students participating in the camp (rising 8^{th} and 9^{th} graders). Many of the older students had previously participated in either summer enrichment programs or other engineering-related activities. The fact that they were attending the camp indicated at least a minimum level of interest in the topic for all participants from the start, but for older students it was based on *a priori* knowledge about the field. In contrast, the younger students' participation was based more on curiosity and a desire to find out more about the field. The fact that several students were able to rule out careers in research based on their camp experience indicated that the camp was successful in giving a realistic view of what research in a technical field entails.

Because the sample size is small, it is not possible to draw conclusions beyond these observations about the impact of this program on pre-college education. However, with the knowledge that educating our population about current technologies and concepts in engineering and science is beneficial [2], the camp was at least successful in conveying the importance of such work. These students will be of voting age within a few years, and will ultimately make decisions on how our nation supports science and engineering. They will also define how well prepared our workforce is in meeting the technological demands of the future.

One of the most remarkable outcomes of this project was the willingness of the undergraduate and graduate students to volunteer their time as facilitators in the camp. The general impression given by these students was that this was an enjoyable and beneficial break from their usual research or coursework. Based on written comments, all students who were actively involved in making presentations about their research realized the immediate benefits of condensing technical information into a form that was understandable to the general public. The process of distilling information to yield only what is critical, relevant and understandable is not necessarily straightforward, and is certainly not an innate skill for engineering students. In addition, developing hands-on activities based on technical concepts takes creativity and time that is not likely to be ordinarily set aside for this type of work by

college students. The skills used to make effective presentations to different types of audiences are best attained through practice and exposure to real situations in which the skills can be used, and therein lies the benefit of this type of activity for college students. It is often difficult to justify time spent outside of the classroom or laboratory, especially for graduate students. However, engineering education programs that value the development of students not only as technically competent but also as professionally well-rounded will consider time spent on outreach activities as an investment in their capacity to succeed in the real world.

The college students appeared to grasp the importance of not just conveying information that was accurate, but also of making that information appropriate and interesting for the audience that they were addressing. In the field of biomedical research and technology this is particularly important, because of the increasingly close relationship between technology and health care delivery to the general public. Finally, the process of refining technical information for use in hands-on activities and presentations was helpful to the graduate students in an unexpected way, boosting their own motivation for conducting their research through the positive feedback from their audience. The graduate students took obvious pride in eliciting reactions of all kinds from the pre-college students when "showing off" their expertise.

CONCLUSIONS

The opportunity to expose pre-college students to engineering and science concepts and train the next generation of scientists and engineers is a particularly appropriate outgrowth of the field of bioengineering because of its interdisciplinary nature. The impact of a weeklong summer enrichment program in bioengineering, geared towards rising 8^{th} to 11^{th} graders, was most pronounced in the younger-aged participants in terms of broadening their awareness of engineering as an education and/or career option. Since college students in bioengineering facilitated many of the activities and presentations for this program, a collateral benefit was that these students were able to hone their skills in communicating at a level appropriate for the general public. The communication of technical information to a non-technical audience is a practice that is not usually accessible to engineering students through their normal collegiate activities, and thus multiplies the value of this summer enrichment program.

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