Liu, L., Zhu, X., Shen, Y., & Li, W. (2011). Preparing high school students for college biomedical engineering through laboratory technology activities. *International Journal of Technology in Teaching and Learning,* 7(1), 79-92.

Preparing High School Students for College Biomedical Engineering through Laboratory Technology Activities

Leping Liu
Xiaoshan Zhu
Yantao Shen
Wenzhen Li
University of Nevada, Reno

This article presents the authors' experiences to prepare high school students for college biomedical engineering (BME) through a series of laboratory technology activities. High school teachers and students were first provided an orientation to the field of biomedical engineering, with lecture presentations and hands-on technology activities. Then, workshops were conducted over the academic year of 2010-2011, and laboratory technology activities were completed through a summer camp in 2011. Students' common knowledge and study interests in biomedical engineering were assessed at the end of each workshop and the summer camp. The use of hands-on technology activities did help in developing their interests and foundation knowledge in the BME area.

Keywords: biomedical engineering, learning technology, STEM education

INTRODUCTION

With the rising demands in life science industries and the increasing research interests in highly interdisciplinary biomedical engineering (BME) (National Science Board, 2010; Raju & Clayson, 2010), many universities have been implementing new

---

**Leping Liu is Professor and Chair of the Department of Educational Psychology, Counseling, and Human Development; *Xiaoshan Zhu and Yantao Shen are Assistant Professors at the Department of Electrical and Biomedical Engineering; Wenzhen Li is a doctoral candidate at the Department of Educational Psychology, Counseling, and Human Development. All four authors are at the University of Nevada, Reno. Please contact the corresponding authors Dr. Leping Liu at liu@unr.edu, and Dr. Xiaoshan Zhu at xzhu@unr.edu*

initiatives to establish and expand biomedical engineering (BME) programs. A college degree in BME instantly identifies a candidate as having training in both engineering and life science, and strengthens the candidate competency in job markets.

Over more than two decades, recruitment has been one of the critical issues in college STEM (science, technology, engineering, and mathematics) education (Crumpton-Young et al. 2010; DeGrazia, Sullivan, Carlson, & Carlson, 2000; Fifolt & Abbott, 2008; Franchetti, Ravn, & Kuntz, 2010). Many efforts have been made to attract, screen, and select qualified students from high schools or community colleges (Lam, Srivatsan, Doverspike, Vesalo, & Mawasha, 2005; Jiang, Doverspike, Zhao, Lam, & Menzemer, 2010; Wilhelm, She, & Morrison, 2011; Yelamarthi & Mawasha, 2008). Most of the time, career planning or pre-engineering preparation programs have made impact on student decisions to study in engineering (Gold, 2002; Mosley, Liu, Hargrove, & Doswell, 2010; Power, Brydges, Turner, Gotham, Carroll, & Bohl, 2008).

In this article, we will introduce our experiences in a grant project to prepare high school students for college biomedical engineering. The project, titled *Preparing High School Students for College Biomedical Engineering*, was funded by the US Department of Education and the Nevada System of Higher Education. Through this project, we have provided high school teachers and students with conceptual knowledge framework of college biomedical engineering, field experiences, and laboratory technology activities. The orientations, workshops, seminars, and summer camps, especially the laboratory technology activities, did help in developing high school students' interests and conceptual knowledge for their future study in the BME area.

PURPOSES AND OBJECTIVES OF THE PROJECT

The purpose of this project was to explore strategies, methods, and activities that encourage high school students to (a) gain more understanding and interests in college biomedical engineering, and (b) develop their future studies and career in the field of biomedical engineering. Three objectives were set for the project and used to guide through and project activities:

Objective 1. To develop the teaching expertise of high school teachers in BME.
Objective 2. To enhance student understanding of the BME discipline.
Objective 3. To increase students' hands-on experience and scientific interests.

Based on the objectives, four activities were planned, designed, conducted and evaluated, including (a) an orientation workshop for high school teachers, (b) BME lab tours for high schools students and teachers, (c) BME seminars for high schools students and teachers, and (d) a comprehensive summer BME camp for high school students.

PROCEDURES AND ACTIVITEIS OF THE PROJECT

PARTICIPANTS

The participants of the project included a total of 162 students and six teachers from three high schools in a northern Nevada school district. We first contacted the school district to identify potential high schools and teachers, mostly high school science teachers. Then we sent out invitation and call for proposals to them. After reviewing the proposals, we accepted the teachers who showed their motivation and interest in the field of BME to participate our project.

After completing the orientation workshop and having gained a basic understanding of BME, the teachers were then asked to recruit students from their schools with another call for students' proposal. Finally, those who had the potential and some initial interests in BME were accepted to the project.

ORENTATION WORKSHOP FOR TEACHERS

The first activity of the project, orientation workshop to high school teachers, was organized and conducted by two biomedical engineering faculties in the Department of Electrical and Biomedical Engineering at a northern Nevada university. Six high school teachers participated in this workshop; and it was conducted in two sections. The first section was an introduction to BME. One faculty presented the very fundamental concepts in biological microelectromechanical systems (bioMEMS), biosensors, and bionano-technology. The other faculty presented the fundamental concepts in bioinstruments, biosignal processing, and biomechanics. In each topic, basic research methods or tools, their applications in solving biomedical problems, and the perspective of research and development (R&D) were introduced.

In the second section, the high school teachers were invited to visit the laboratories with the demonstration of several experiments (from the basic principles to the experimental operation steps and the experimental results). The high school teachers were encouraged to run the demonstrated experimental projects under the guidance of the two faculties. These experimental projects were:

1. Water/gas separation in microchannels using nanoporous membranes,
2. Study of magnetic microbead based enzyme chemistry,
3. Force feedback based biomanipulation,
4. Game-enhanced brain-computer interaction.

The demonstration and Laboratory experiences were to help the teachers to further enhance their understanding of BME. More importantly, these were the same experiments that were later used in Summer Camp with students. By providing the teachers with training on these experiments at the beginning of this project, the biomedical engineering faculty had prepared the teachers to be active facilitators during the summer camp.

BME LAB TOURS

In the second activity, 52 high school students from three high schools attended the BME lab tours. In the lab tour, students were introduced the fundamental research questions in two biomedical labs. The importance of the research questions to research communities was explained to students to help them understand why these research questions are worthy of being explored. The faculties also described the research methods, demonstrated the lab instruments used in the research, and explained experimental results and conclusions.

For example, one faculty introduced the concepts of biomarkers related to diseases, and then explained to students why the sensitive detection of biomarkers in human fluids (bloods, urines, etc.) is of importance in early diagnosis and timely treatment of diseases. Then, the applications of highly bright fluorescence nanoparticles as labels for highly sensitive detection were described (including the concept of fluorescence). The fluorescence measurement instrument (microplate reader) and fluorescence spectrometer in the lab were introduced to students. Referring back to the poster, the experimental results were explained to show students how the application of fluorescence nanoparticles can improve the assay sensitivity.

Another faculty focused on basic biomedical instruments, and presented the fundamental design criteria and configuration of basic biomedical instruments. He also reviewed popular sensor/transducer and actuator technologies commonly used in current biomedical research and health care, basics of biomedical imaging technology consisting of fundamental principles of optical and electronic microscopes, and basics of biomedical measurands such as signals from human body. Interesting applications of bioinstruments in the current basic biomedical research, clinical diagnoses, and health care were also presented.

The lab tours brought students into a practical and visual BME environment, which motivated them to attend further seminars and to learn more about BME.

BME SEMINARS

After the lab tours, BME seminars were conducted in three high schools. A total of 89 students attended the seminars. Discussions and presentations were done on several topics. The first topic was the current and future status of BME. For example, R&D importance to human health, the increase of college education in this area, and the BME job market perspective and sustainability. Second, the fancy BME research example demonstrations through videos and extensive images. Third, the general college entrance requirements and application steps, the efforts by GotoCollegeNevada.org to promote high school student enrollment into colleges, the BME program at the grant host university and other universities, the summer camp led by the BME program at UNR, etc.

The seminars reinforced students and teachers' understanding about studies, research, and future applications in the field of BME.

BME SUMMER CAMP

Finally, in the last activity, a BME summer camp was developed and implemented. 21 high school students attended the 5-day BME summer camp hosted in the Department of Electrical and Biomedical Engineering at a northern Nevada university. Four BME projects were carefully designed and developed by the biomedical engineering faculties. Students completed the projects under the directions of the BME faculties and high school teachers. The four projects focused on four foundational topics (See Figure 1.).

In the first project *Water/Gas Separation in Microchannels Using Nanoporous Membranes*, a microseparation method using hydrophilic or hydrophobic membranes with microfluidics channels in two different separation modes were presented and taught to students; and students assembled the device using a fluidics microchip and nanoporous hydrophobic or hydrophilic membranes, implemented a fluid pump driving circuit, and tested the gas/water separation in microchannels.

Figure 1. *Some fundamental concepts in BME covered by four summer-camp projects*

In the second project *Study of Magnetic Microbead Based Enzyme Chemistry*, students first studied the concepts of the β-gal and FDG system (Figure 2). They then immobilized the different amounts of β-gal on microbead surfaces, and checked how the fluorescence signal magnitude of the produced fluorescein molecules is related to the amount of β-gal on the bead surfaces. The reactions were performed in microplates. The magnetic beads facilitated separation and washing steps in the enzyme reaction, due to their easy collection by magnets.

In the third project *Force Feedback Based Biomanipulation*, the students (operator) were allowed to operate the integrated microforce sensing system in the lab to manipulate/measure the embryos or cells and receive both visual and haptic feedback from these micro bio-entities on the computer screen and the operating joystick in the real-time. While conducting the hands-on experiments, the students learned how to set up the sensor and samples, tune the gains of both the microforce sensor and the haptic joystick, and record the raw data via the friendly software interface during such a hands-on manipulation. Through this hands-on implementation, the students gained intuitive tactile and visual experience from micro/nano worlds and directly understand significance of bioinstrumentation and applications.

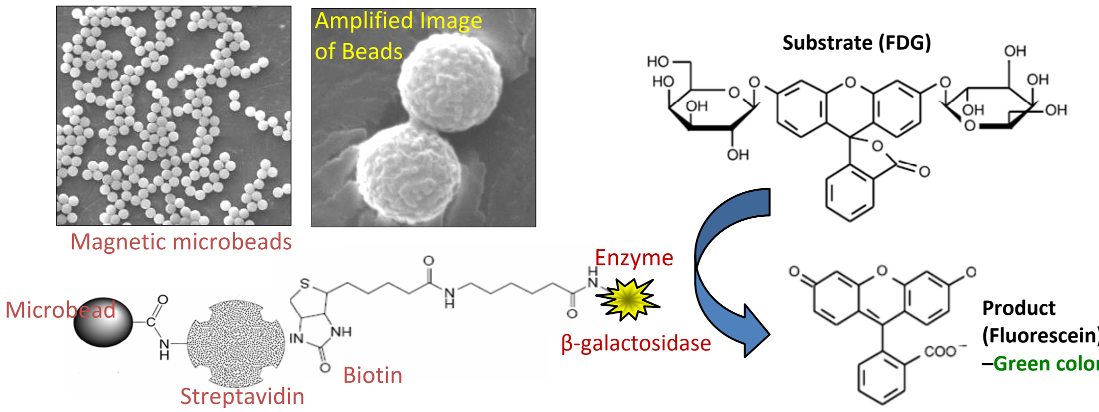

Figure 2. *Schematic of magnetic microbead based enzyme chemistry (the conversion of FDG by enzyme β-gal to fluorescein which emits green color with blue light excitation)*

The fourth project, *Game Enhanced Brain-Computer Interaction (BCI),* is a direct communication pathway between a brain and an external device. It is aimed at assisting, augmenting or repairing human cognitive or sensory-motor functions, and providing neural feedback for machine control. The students in the summer camp were provided electro-encephalography (EEG) headset and software interface. They measured their raw brain signals through neuro-signal acquisition, adjusted functional buttons on the interface to effectively and efficiently play the games, and reported the measurement channel results and their brain activity maps. Through this hands-on option, the students learned how to collect brain signals and interface their mind with the physical devices, as shown in Figure 3.

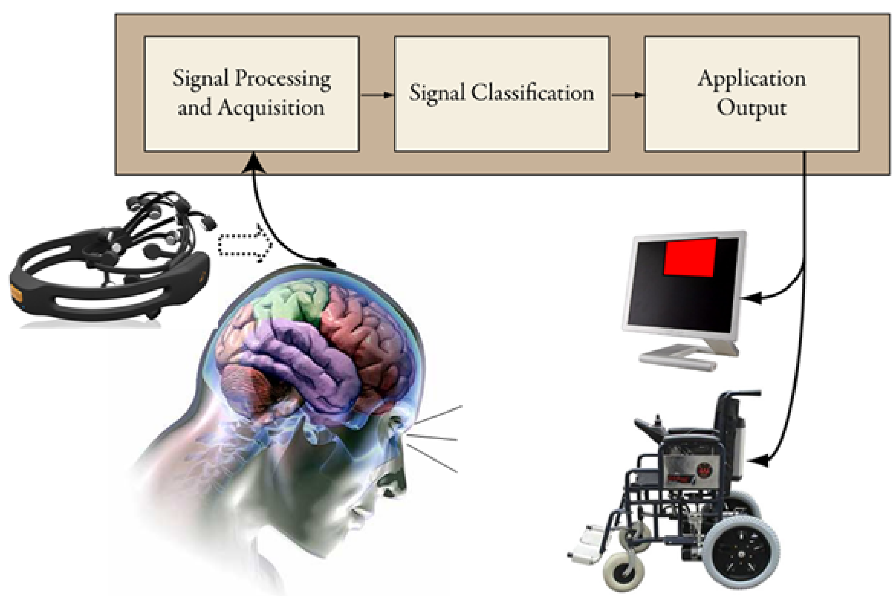

Figure 3. *Schematic of game enhanced BCI interface operation*

In all four projects, students have learned the fundamental concepts, completed the laboratory technology activities, been exposed to research methods in the BME field, and initiated some goals for their future studies and career in the field of biomedical engineering. In summary, the teachers' orientation workshop, students' lab tours and seminars, and the summer camp were implemented as planned.

EVALUATION AND FINDINGS

In each of the four activities (the teachers' orientation workshop, students' lab tours and seminars, and the summer camp), formative and summative assessment were performed. Observations, surveys, interviews, and content evaluations were conducted. The methods, procedures, and results of the evaluation are reported as below.

EVALUATION OF ACTIVITY ONE: WORKSHOP FOR TEACHERS

To the high school teachers who attended the workshop, a pre-test was given on their knowledge of the fundamental concepts in biomedical engineering. After the workshop, a post-test was given to examine the effectiveness of the workshop in increasing the understanding of the fundamental concepts in BME. A sign test was conducted and yielded a significant result ($p<.001$), and the result indicates the training workshop significantly improved the participants' knowledge in Biomedical Engineering.

Upon completion of the workshop, the participants (teachers) were also given a survey asking about their experiences of the training workshop. All of the participants reported positively in the items regarding the activities in the workshop, the resources provided by the presenters, the organization and the pace of the workshop, the expertise and helpfulness of the presenters. To gain an insight of the participants' experiences in the workshop, a group interview was given asking about their comments on the workshop. The participants all spoke positively about their experiences, but they did come up with some comments and suggestions for the improvement of the implementation of the future activities.

The participants all agreed that the information presented was very good and valuable. However, some of the information presented was beyond their understanding. They felt the workshop presented too much detailed information (in science) that was hard to understand without solid background knowledge in engineering or biology, and suggested less detailed information in the future workshop that would match the learning styles and the background knowledge of high school students.

As an anticipated outcome of this workshop, all the teachers were prepared to participate and help in the summer camp later.

EVALUATION OF ACTIVITY TWO: BME LAB TOURS

The lab tours include two lab experimental demonstrations, a university library visiting and a short welcome presentation. A survey was given to the students at the end of the lab tour (See Appendix A.) The results of the survey were as the following:

- 67% of the participants responded that it was their first time to take a lab tour in a college/university.
- 81% of the participants either agreed or strongly agreed that the tour helped them gain an understanding on what research the BME labs they visited are doing.
- 83% of the participants either agreed or strongly agreed that the instruments in the labs are clearly demonstrated.
- 83% of the participants either agreed or strongly agreed that research topics of

the labs are clearly presented.

- 43% of the participants responded that they would possibly consider BME as one of their future learning areas in college.
- 65% of the participants responded that they were going to search for more information on such websites as GotoCollegeNevada.org, collegeboard.com, une.edu/admission, avid.org, and effi-k12.org.
- 74% of the participants responded that they would like to attend a similar lab tour in BME department.
- 90% of the participants expressed that they would like to share their lab tour experiences with their parents, friends, and teachers.
- 88% of the participants expressed that they would recommend the lab tour to their friends.
- 83% of the participants responded that they would like to attend the seminar on BME education and program admission process given by the BME faculty in their high school.

Based on the descriptive statistics from the surveys of the lab tours, more than 80% of participants from the three schools gained a good understanding on BME. The goal of the lab tours was successfully achieved. It should be noted through the surveys, the project team members also learned: (a) for more than 60% participants, it was the first time to attend a lab tour; and (b) around 80% of the participants expressed they enjoyed these tours and would like to recommend their friends to attend if there were chances in future. The conclusion from the project team members is that the lab tours could be very interactive activities or platforms to educate students and stimulate their interests.

EVALUATION OF ACTIVITY THREE: BME SEMINARS

At the end of each seminar, a survey was given to the participants (See Appendix B). The results of the survey were as the following:

- 78.4% of the participants either agreed or strongly agreed that they had gained some understanding of Biomedical Engineering (BME) and its importance in human health after the seminar.
- 58.3% of the participants either agreed or strongly agreed that they understood the college application process
- 51.6% of the participants reported that they understood the college application process at GotoCollegeNevada.org.
- 60% of the participants reported that they understood the admission requirements at the University of Nevada Reno.
- 51.7% of the participants expressed that they would like to share what they had learned from this seminar with my friends
- 59.3% of the participants either agreed or strongly agreed that the seminar materials were clearly presented.

The results showed that at least 50% students strongly agreed or agreed with the statements in the survey form, and they did enjoy the experiences from the seminar. It should be noted that only 15% students in the seminar attended the previous lab tour organized by the presenters. It can be concluded that the seminar helps to promote more students to understand BME concepts and college entrance and application information.

Some strategies to enhance the student participation and learning in the next project cycle will be discussed in the conclusion section of this article.

EVALUATION OF ACTIVITY FOUR: BME SUMMER CAMP

The evaluation of the 5-day summer camp was performed in two parts. The first part was the evaluation on student learning from the four BME projects, which were examined by four 10-question quizzes at the end of each project. The second part was the evaluation of students' perceptions and satisfactions about the camp activities, which was done through an exit-survey (See Appendix C).

The results from the four quizzes have showed that all students have achieved the expected learning goals with excellent scores:

- In the quiz of Project 1, all students obtained a full score of 100 points.
- In the quiz of Project 2, 20% of the students obtained 80 of 100 points, and 75% of students received a perfect score of 100 points.
- In the quiz for Project 3, all students received a full score of 100 points.
- In the quiz of Project 4, approximately 80% of the students obtained a perfect score of 100 points, 20% of the students received scores ranging from 80 to 90 points

The summer camp evaluation survey results have showed that:

- All the participants reported that they had learned new things on Biomedical Engineering in the summer camp.
- All the participants agreed that they enjoyed the opportunity to do hands-on activities
- 89.4% of the participants agreed that the summer camp increased my interest in considering Biomedical Engineering as a possible career path.
- 94.7% of the participants agreed that the pace of this summer camp was appropriate.
- All the participants agreed the activities were engaging and stimulating.
- All the participants reported the instructors were well prepared and knowledgeable.
- 94.7% of the participants reported that the instructors were helpful and supportive.
- All the participants responded that this summer camp met their expectations.
- All the participants reported the showcases presented by college undergraduates were informative for me to understand the college life.
- 94.7% of the participants reported that through the four hands-on experiments, they understood that BME was a broad research area.

Comments about the value of the summer camp were summarized, and the students felt that (a) they all enjoyed the experiences and learned from the camp projects, (b) they liked the lab experiments, especially the use of technologies in these activities, (c) they appreciated the opportunities to learn more about biomedical engineering, and more career options for their future, and (d) they may want to explore their college studies in the BME area.

THE RESPONSES TO HANDS-ON TECHNOLOGY ACTIVITIES

Among all the activities, the lab technology experiences have generated many positive responses. During the lab tours, seminars, and summer camp, students were exposed to different types of biomedical engineering technologies, especially when doing projects focused on integrated bio-analytical systems and bioinstrumentation. Integrated bio-analytical systems is an area to apply bioMEMS and nanotechnology into biosensing for clinical diagnosis, environmental monitoring, food safety, homeland security and so on; bioinstrumentation is an area to apply electronics and measurement principles and techniques to develop devices used in the diagnosis of physical, physiological, and biological factors in man or other living organisms and the related treatment.

Students expressed that the hands-on technology experiences in these two areas did bring them into a new world where they were willing to explore more, or even develop their future career. More importantly, they felt curious about the BME technologies, and motivated to learn more through doing the hands-on technology activities. This did agree with research findings in the literature that students would be more motivated to learn when they enjoy the learning process (Liu & Johnson, 1998; Liu, Maddux, & Johnson, 2004), and the content learning would be more effective when the use of technology is carefully designed with instructional design principles and technology integration theories (Liu & Henderson, 2003).

CONCLUSIONS AND IMPLICATIONS

Overall, all four activities were successfully implemented, and the objectives set at the beginning were fully achieved. Based on our experiences and what we have learned from all the activities, several conclusions could be reached.

First, university STEM educators may start pre-engineering recruitment early with high school students; and an efficient way is to prepare them with college engineering foundation knowledge, hands-on experiences students, academic interests, and career motivation.

Consistent with literature (Genesan, Das, Edwards, & Okogbaa, 2004; Mosley, Liu, Hargrove, & Doswell, 2010; Wilhelm, She, & Morrison, 2011), our project demonstrated a KDTRA procedure (*Knowing, Doing, Thinking and Reinforcing*, and *Aiming*) of college BME preparation. Knowing foundation knowledge exposes the BME field to the students and initials their exploration. Hands-on lab activities allow students to learn from doing and gain more practical experiences about what/how to learn in this area. Being aware of research and developmental trends in the field would increase or reinforce students' academic interests, so that they may gradually develop their career goals in the field of BME.

Secondly, besides the biomedical engineering technologies used in the lab, more instructional technology applications need to be integrated into the orientation presentations, workshops, and the projects, which could be more efficient in creating an interactive learning environment.

When talking about technology integration, three factors are usually involved: (a) content information, (b) technology used for teaching and learning, and (c) instructional design principles, based on which the technology is used to achieve the best learning of the contents (Liu & Henderson, 2003). In the literature, multimedia instructional materials, courseware, or applications has been used in similar pre-engineering programs to prepare pre-engineering students, and turned out to be effective (Mbarika, Bagarukayo, Shipps, Hingorani, Stokes, Kourouma, & Sankar, 2010; Mosley, Liu, Hargrove, &

Doswell, 2010; Mott, Chessin, Sumrall, Rutherford, & Moor, 2011). In our further projects, we may use more simulations in the workshop presentations, or design more interactive multimedia applications to provide a simulated environment for students to experience.

Thirdly, in a pre-engineering preparation project, we need to develop a mentoring program and provide mentoring to high school teachers and students. Supported by literature, mentoring has been an important factor to successful practice in education settings (Fifolt, 2006; Fifolt & Searby, 2010; Gibson & Angel, 1995).

The key to a successful mentoring program is to recruit and train qualified mentors. In our further projects, we may (a) invite and select mentors from current engineering students, or graduates over years; (b) train the mentors with necessary knowledge, skills, and methods to work with potential pre-engineering students; and (c) include the mentoring activities as part of the grant project. We may need multiple levels of mentoring, such as one-to-one mentoring, one-to-many mentoring, or group mentoring.

We have described our *Preparing High School Students for College BME* project, introduced our experiences, and summarized our findings. It is the authors' hope that our experiences could be of help or benefit to other STEM educators' work.

REFERENCES

Crumpton-Young, L., McCauley-Bush, P., Rabelo, L., Meza, K., Ferreras, A., Rodriguez, B., Millan, A., Miranda, D., & Kelarestani, M. (2010). Engineering leadership development programs: A look at what is needed and what is being done. *Journal of STEM Education, 11*(3/4), 10-21.

DeGrazia, J., Sullivan, J., Carlson, L., & Carlson, D. (2000). Engineering in the K-12 classroom: A partnership that works. *Proceedings of the American Society for Engineering Education/ Institute of Electrical and Electronics Engineers (ASEE/IEEE)Frontiers in Education Conference*, (Kansas City, MO), p. 18-22.

Franchetti, M., Ravn, T., & Kuntz, V. (2010). Retention and recruitment programs for female undergraduate students iengineering at The University of Toledo, Ohio, USA. *Journal of STEM Education, 11*(5/6), 25-31.

Fifolt, M., & Searby, L. (2010). Mentoring in cooperative education and internships: Preparing protégés for STEM professions. *Journal of STEM Education, 11*(1/2)17-26.

Fifolt, M. (2006). *Students' perceptions of mentoring in a university cooperative education program* (Doctoral dissertation, University of Alabama at Birmingham, 2006). *Dissertation Abstracts International,68,* 486. (ERIC Document Reproduction Service No. ED504793).

Fifolt, M., & Abbott, G., (2008). Differential experiences of women and minority engineering students in a cooperative education program. *Journal of Women and Minorities and Science and Engineering, 14*(3), 253-267.

Genesan, R. Das, T. Edwards, C. & Okogbaa, G. (2004). Challenges in enhancing science education in elementary classrooms through university-school district partnerships. *Proceedings of the American Society for Engineering Education/ Institute of Electrical and Electronics Engineers (ASEE/IEEE) Frontiers in Education Conference*, (Savannah, GA), pp. 1-5.

Gibson, L. K., & Angel, D. L. (1995). Mentoring: A successful tool for developing co-op students. J*ournal of Cooperative Education, 30*(3), 48-55.

Gold, M. (2002). The elements of effective experiential education programs. *Journal of Career Planning & Employment, 62*(2), 20-24.

Jiang, Z., Doverspike, D., Zhao, J., Lam, P., & Menzemer, C. (2010). High school bridge program: A multidisciplinary STEM research program. *Journal of STEM Education, 11*(1/2), 61-68.

Lam, P. C., Srivatsan, T., Doverspike, D., Vesalo, J., & Mawasha, P. R. (2005). A ten year assessment of the pre-engineering program for under-represented, low income and first generation college students at the University of Akron. *Journal of STEM Education, 6*(3/4), 14-20.

Liu, L., & Henderson, N. J. (2003). An information technology integration system and its life cycle: What is missing? *Computers in the Schools, 20* (1/2), p. 93-106.

Liu, L., & Johnson, L. (1998). A computer achievement model: Computer attitude and computer achievement. *Computers in the Schools, 14*(3-4), 33-54.

Liu, L., Maddux, C., & Johnson, L. (2004). Computer attitude and achievement: Is time an intermediate variable? *Journal of Technology and Teacher Education, 12*(4), 593-607.

Mbarika, V., Bagarukayo, E., Shipps, B. P., Hingorani, V., Stokes, S., Kourouma, M., & Sankar, C. S. (2010). A multi-experimental study on the use of multimedia instructional materials to teach technical subjects. *Journal of STEM Education, 11*(1/2), 24-37.

Mosley, P., Liu, Y., S., Hargrove, K. S. K., & Doswell, J. T. (2010). A pre-engineering program using robots to attract underrepresented high school and community college students. *Journal of STEM Education, 11*(5/6), 44-54.

Mott, M. S., Chessin, D. A., Sumrall, W. J., Rutherford, A. S., & Moor, V. J. (2011). Assessing student scientific expression using media: The media-enhanced science presentation rubric. *Journal of STEM Education, 12*(1/2), 33-42.

National Science Board (2010). Preparing the next generation of STEM innovators: identifying and developing our nation's human capital. Retrieved on June, 1 2011, from http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf

Powers, S.E., Brydges, B., Turner, P., Gotham, G., Carroll, J.J., & Bohl, D.G. (2008). Successful Institutionalization of a K12 – University STEM Partnership Program. *In: Proceedings of the 115th Annual ASEE Conference & Exposition* (Pittsburgh PA, June, 2008, on CD, Session # AC 2008-1652).

Raju, P. K., & Clayson, A. (2010).The future of STEM education: An analysis of two national reports. *Journal of STEM Education,* 11(5/6), 25-28.

Wilhelm, J., She, X., & Morrison, D. C. (2011). Differences in math and science understanding between NSF GK-12 participant groups: A year long study. *Journal of STEM Education, 12*(1/2), 55-68.

Yelamarthi, K., & Mawasha, P. (2008). A pre-engineering program for under-represented, low-Income and /or first generation college students to pursue higher education. *Journal of STEM Education, 9*(3), 5-11.

Appendix A
Biomedical Engineering (BME) Lab Tour Survey

1. Was this your first tour to a lab in a college or university? ___Yes ___No
2. If no, how many tours have you had in the past year?
   ____2 or 3 times _____4 or 5 times ____more than 5 times

For item 3-10 below, on a scale of 1 to 6, please rate your level of agreement with the following statements.

1= Strongly Disagree 2=Disagree 3=Somewhat Disagree
4= Somewhat Agree 5= Agree 6=Strongly Agree

3. The lab tour helped me gain an understanding on what research BME labs are doing.
4. The instruments in the labs are clearly demonstrated.
5. The research topics of the labs are well presented.
6. I would possibly consider BME as one of my future learning areas in college.
7. After this tour, I am going to search for more information on such websites as *GotoCollegeNevada.org, collegeboard.com, unr.edu/admission, avid.org (Advancement Via Individual Determination national program),* and *egfi-k12.org.*
8. I would like to attend a similar lab tour given by BME faculty members at UNR in the future.
9. I would like to share my lab tour experience with my parents, friends, and teachers.
10. I would recommend the lab tour to my friends.
11. The BME faculty members are to give a seminar in your high school to introduce BME college education and college admission process. Would you like to attend this seminar (with your parents)? ______Yes _____No
12. Please leave your comments and/or suggestions for future lab tours if you have any.

Appendix B
Seminar Survey

On a scale of 1 to 6, please rate your level of agreement with the following statements.

1= Strongly Disagree 2=Disagree 3=Somewhat Disagree
4= Somewhat Agree 5= Agree 6=Strongly Agree

1. After the seminar, I have gained some understanding of Biomedical Engineering (BME) and its importance in human health.
2. After the seminar, I have understood the college application process.
3. After the seminar, I have understood the college application process at GotoCollegeNevada.org
4. After the seminar, I have understood the admission requirements at the University of Nevada Reno.
5. I would like to share what I have learned from this seminar with my friends.
6. The seminar materials are clearly presented.
7. Do you have contact information of Dr. Zhu or Dr. Shen in case you have any questions on BME education at UNR? ____Yes _____No
8. Have you attended the BME Lab Tour we have hosted at UNR? ___Yes __No

Appendix C
Summer Camp Survey

I. On a scale of 1 to 9 (1=Strongly Disagree, 9=Strongly agree), please rate your level of agreement with the following statements:

1. I have learned new things on Biomedical Engineering in the summer camp.
2. I enjoyed the opportunity to do hands-on activities.
3. The summer camp increased my interest in considering Biomedical Engineering as a possible career path.
4. The pace of this summer camp was appropriate.
5. The activities were engaging and stimulating.
6. The instructors were well prepared and knowledgeable.
7. The instructors were helpful and supportive.
8. Overall this summer camp met my expectations.
9. The showcases presented by college undergraduates are informative for me to understand the college life.
10. Through the four hands-on experiments, I understand that BME is a broad research area.

II. Please provide your feedback to the following questions:

1. Is it the first time for you to attend a summer camp? If the answer is No, what kind of other summer camp(s) you attended before? What were the activities in your previous summer camp?
2. What is valuable about this summer camp?
3. What needs to be improved in the summer camp?

ACKNOWLEDGMENT OF SUPPORT AND DISCLAIMER

This study was funded by the US Department of Education and brought to you by the Nevada System of Higher Education. Opinions, findings, and conclusions expressed herein do not necessarily reflect the position or policy of the Nevada System of Higher Education, and no official endorsement should be inferred.