Works in Progress: Generating Interest in Biomedical Engineering through Exploration of the Design Process

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At the time of this work, Marcia Pool was an Instructional Laboratory Coordinator in the Weldon School of Biomedical Engineering at Purdue University; she is now a Lecturer at the University of Illinois at Urbana Champaign. At Purdue, she oversaw and assessed junior level laboratories, bioinstrumentation and biotransport, developed and implemented sophomore and junior professional development courses, and taught and mentored students in the Senior Design Capstone course. Marcia collaborated with Women in Engineering in on-campus events to establish interest in biomedical engineering and continues to do so in her new position. She is also actively engaged at the local and national level with the biomedical engineering honor society, AEMB.

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Dr. Groh joined the Purdue Women in Engineering Program (WIEP) in 2009. She received a B.S. in microbiology from Purdue University, and a Ph.D. in microbiology from the University of Oklahoma. Prior to joining WIEP, she was the Graduate Programs Coordinator in the Purdue Weldon School of Biomedical Engineering. As Associate Director of WIEP, Dr. Groh administers the undergraduate Mentee & Mentor Program and the Graduate Mentoring Program, teaches the Women in Engineering seminar, and oversees WIEP's K-12 outreach programming.

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Allison Sieving is the Laboratory and Assessment Coordinator for the Weldon School of Biomedical Engineering at Purdue University. She received her B.S. in Biology from Bowling Green State University. She earned her M.S. and Ph.D. degrees from the Basic Medical Sciences and Biomedical Engineering programs at Wayne State University, respectively. At Purdue, her work focuses on developing and implementing undergraduate laboratory and lecture courses that address the evolving needs of biomedical engineers, creating outreach activities that build knowledge and appreciation of the field of biomedical engineering, and managing the ABET assessment program for the Weldon School of Biomedical Engineering.

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Introduction

Increasing motivation of pre-college students in Science, Technology, Engineering, and Mathematics (STEM) fields is a recurring goal, and there is a need to establish a pathway through which the student interest in STEM is reinforced. To increase interest in biomedical engineering (BME), we developed outreach modules which enabled students to explore and build knowledge of the engineering design process by utilizing their problem solving skills.

The engineering design process is defined as an "[iterative], decision-making process in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs"[1]. When employed, the engineering design process is a continuous cycle of improvement involving: problem identification, brainstorming, concept generation, implementation, and verification of the design. These engineering design process skills are not unlike decision making skills employed in real-life. However, describing engineering to pre-college students in these foreign terms may be intimidating[2] which may inhibit students from pursuing engineering in college. Therefore, there is a need to advertise engineering for what it is: implemented problem solving.

Engineers are natural problem solvers and seek challenge. Allowing novice engineers (pre-college students) to practice and develop their problem solving skills through design allows them to connect concept with implementation and verification thereby enhancing understanding and interest while reducing apprehension to "engineering". As students achieve success in small design projects, their confidence is increased[3] and their problem solving skills are further cultivated. Many outreach projects are similar to cookbook laboratory exercises; these projects may develop initial interest but once the problem is solved, interest may not remain. In contrast, developing outreach modules around the engineering design process is similar to employing problem-based learning in a classroom: active participation, concept understanding, and decision making is required of students.

We developed three modules in which high school and middle school students participating in Women in Engineering outreach experiences were able to gain an appreciation and interest in BME by employing the engineering design process. These projects serve as an advertisement for engineering as implemented problem solving.

Outreach program descriptions and activities

The Purdue University Women in Engineering Program (WIEP) is committed to increasing the number of women studying engineering, and one approach is through outreach to pre-college girls. For this project, hands-on, BME, problem solving activities were created for three different outreach programs offered by WIEP: Introduce a Girl to Engineering Day (IGED), For Your Imagination (FYI), and Exciting Discoveries for Girls in Engineering (EDGE). Complete details (handouts, worksheets, etc.) of the activities can be found here: https://engineering.purdue.edu/WIEP/AboutUs/WIEP_Publications

IGED is a one day, on-campus program held in conjunction with National Engineers' Week which introduces engineering concepts to 10th - 11th grade girls. Each participant attends three hands-on engineering activities based on interests. For the BME activity, a ventricular assist device (VAD) support system (concept generated from an altruistic project conducted by KCI, Inc.) was developed and introduced participants to the use of VADs to sustain life for congestive heart failure (CHF) patients. For this activity, the need to minimize patient discomfort due to VAD pumps was introduced. Participants worked in groups to design a support device to relieve pulling and shifting movements of the external VAD pumps. Participants were provided with a model VAD device, and design constraints were introduced by limiting resources used to construct the device. Teams documented brainstorming, concept generation, implementation, and verification testing in a workbook. Finally, participants shared their design with the group, emphasized strengths of the design, and identified areas for future design iteration.

FYI is a one-day, on-campus program held in summer for 7th - 9th grade girls who are at a critical age for losing interest in STEM and for choosing important pre-college courses for undergraduate STEM majors[4]. Participants rotate through three hands-on engineering activities. For FYI, we selected an activity from TEACH Engineering in which participants design and build a device capable of removing an object embedded in an ear canal[5]. Active learning was encouraged following a brief introduction to the activity. Participants used the chalkboard to share design ideas which allowed facilitators to quickly identify synergies and make immediate corrections on misconceptions. In this activity, participants developed skills in and understanding of brainstorming, design iteration, design constraints, and testing.

EDGE is a week-long residential camp for 10th - 11th grade girls. In groups, campers design and build engineering-based projects and participate in experiments during laboratory tours. Engineering is stressed as a profession where creativity and imagination are used to solve problems for the benefit of society. For EDGE, we developed a three day (9 total contact hours) mini-design project based on a BME capstone senior design project in which each team worked to develop a "smart" gown which could replace traditional hospital gowns and measure physiological signals (heart rate and respiration). Day 1 consisted of introducing participants to BME, brainstorming ideas for obtaining signals and implementing into a gown (sketch documented) and equipment overview. Day 2 involved building, design iteration, and verification testing; it also included gown assembly and planning for a scientific style poster. Day 3 began with an introduction to giving a professional presentation and continued with developing the poster; the day concluded with participants presenting their posters and solutions to their parents.

Preliminary results

At the end of each outreach program participants were asked to complete a short survey evaluating the program and hands-on activities (Purdue University Institutional Review Board approval: 1312014317). Written evaluations for each BME activity were analyzed for themes to determine if participants enjoyed the design activity and identified elements of the design process (e.g., brainstorming). Evaluations were grouped into two themes: (1) interesting activity (non-design oriented comments) and (2) hands-on/design oriented comments. For instance, "creating a device" and "how hands-on it was" were classified as "hands-on/design oriented".

The percentage of respondents listed for each major theme was calculated. Total participants and open comments for each activity were: VAD in IGED 2012 (75, 67), VAD in IGED 2013 (76, 51), object removal in FYI 2013 (94, 90), and "smart" gown in EDGE 2012 (64, 19).

Identification of the design process as "best part" of the experience was indicated in each module: VAD (2012: 55 %, 2013: 39 %), object removal (70 %), and "smart" gown (26 %). Contributing factors to variability include: program format, question delivery, comment rate, participant age difference, and volunteer engagement with participants throughout activity.

Data from the IGED surveys further indicated that participants leave with a better understanding of engineering (3.2 to 4.6 from pre- to post-event) and gain more confidence to choose engineering as a career (3.1 to 3.8 from pre- to post-event) when using a Likert scale (1 – 5 with 1 being completely disagree and 5 being complete agree).

Additionally, anecdotal data from all programs support that hands-on design activities engage student interest. Many participants stay in contact with activity mentors they meet during these programs and are further influenced to keep engineering on the forefront of their choices for college. Specifically, many parents and participants comment about a new interest in BME.

Summary and conclusions

Incorporating the design process into outreach activities increases participant's self-exploration of the problem and stimulates minds, thereby enhancing interest in engineering. Design process activities can be developed from a variety of sources, including complex projects, if the project is broken into and presented in terms of design process activities appropriate to age and skill level of participants, in order to reduce participant anxiety to solve a complex problem. In each outreach program, participants were able to actively practice and identify engineering activities without hesitance; this achievement provides participants a foundation of success on which future experiences can build to increase overall participant confidence in engineering abilities. Finally, comments indicated design process elements were important to participant enjoyment of the activity.

References

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