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Biomedical Learning Experiences for Middle School Girls Sponsored by the Kansas State University Student Chapter of the IEEE EMBS

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Abstract—**Learning experiences for middle school girls are an effective means to steer young women toward secondary engineering curricula that they might not have otherwise considered. Sponsorship of such experiences by a collegiate student group is worthwhile, as it gives the group common purpose and places college students in a position to mentor these young women. This paper addresses learning experiences in different areas of biomedical engineering offered to middle school girls in November 2008 via a day-long workshop entitled "Engineering The Body." The Kansas State University (KSU) Student Chapter of the IEEE Engineering in Medicine and Biology Society (EMBS) worked with the KSU Women in Engineering and Science Program (WESP) to design and sponsor these experiences, which addressed the areas of joint mechanics, electrocardiograms, membrane transport, computer mouse design, and audio filters for cochlear implants. Fifty five middle-school girls participated in this event, affirming the notion that biomedical engineering appeals to young women and that early education and recruitment efforts have the potential to expand the biomedical engineering talent pool.**

Keywords—**Biomedical education, female student recruitment, student chapter activities, women in engineering**

I. Introduction

Group activities with a service-learning component can be important to the health of a collegiate student organization, as they promote a shared sense of achievement and attract purpose-driven students [1–4]. IEEE EMBS student chapters have found service projects to be effective for recruitment and retention of chapter members while enhancing students' biomedical engineering toolsets [5–7]. Given the gender diversity in the KSU Student Chapter of the IEEE EMBS [6, 8], chapter members agreed that service projects sponsored by the organization could play a meaningful role in the recruitment of female students into the various quantitative science and engineering degree programs represented by the chapter members. The KSU EMBS student chapter therefore collaborated with the KSU WESP program through the Girls Researching Our World (GROW) initiative [9] to devise learning experiences for junior high girls that would elevate their interest in biomedical engineering and increase the likelihood that they would pursue collegiate science and engineering degrees. This approach is consistent with other outreach efforts that promote biomedical engineering interests in young students [10–12].

This paper summarizes a one-day workshop for middle school (6th to 8th grade) girls entitled "Engineering The Body" developed by KSU EMBS student chapter members. Section II describes the workshop agenda and summarizes individual sessions. Section III addresses lessons learned from the event.

II. Workshop Agenda and Session Descriptions

A. Workshop Agenda & Opening/Closing Sessions

The day-long workshop agenda is listed in Fig. 1. The 55 participants were divided into 5 groups of 10-12 girls; each group took part in four of the five biomedical sessions.

In the opening session, EMBS members tasked the girls with taking on the role of a biomedical engineer for a day. They explained what biomedical engineers do and why it is important. A hands-on icebreaker activity was incorporated into this session to spur participant creativity. The girls were divided into small groups, and each group was given a bag full of pipe cleaners, paperclips, Styrofoam cups, and rubber bands. They were asked to design a strong cast to repair a broken bone (a Popsicle stick broken in half – see Fig. 2). The team with the winning design was to be given a small prize during the closing session.

During the closing session, representatives from each group came to the front of the auditorium and described their experiences, their favorite activity, and things that they learned. The winners of the morning design contest were then announced, and the girls gathered their mementos from the day before they drove home.

9:00–9:20 a.m.	Registration
9:30–9:50 a.m.	Opening Session
10:00–10:50 a.m.	Biomedical Session #1
11:00–11:50 a.m.	Biomedical Session #2
12:00–12:30 p.m.	Lunch
12:40–1:30 p.m.	Biomedical Session #3
1:40–2:30 p.m.	Biomedical Session #4
2:40–3:00 p.m.	Participant Surveys
3:05–3:30 p.m.	Closing Session

Figure 1. Workshop agenda.

Fig. 2. Two participants with their 'bone cast.'

B. *"Code Blue Shirts" – Unobtrusive Electrodes*

The "Code Blue Shirts" session was a repeat from a Fall 2007 event [7]. Participants learned that quality of life can be enhanced for some individuals through wearable, unobtrusive health monitoring technology that allows them to pursue normal daily activities. Session leaders explained how the heart works and described the physiologic processes represented by an electrocardiogram. Every participant received a set of snap-on Ag/AgCl electrodes. Each electrode pair was then connected to a CB Sciences C-ISO-255 electrocardiograph, and these data were sent through an iWorx ETH-255 bioamplifier and a National Instruments (NI) connector block to a personal computer running an NI BioBench virtual instrument. An electrocardiogram was acquired from each participant (see Fig. 3). Each small team of 3-4 girls was then tasked with embedding electrodes inconspicuously into a T shirt.

C. *"Blood Scrub" – Membrane Transport*

The "Blood Scrub" session addressed kidney function and the related engineering principles (i.e., mass transfer). Osmosis, concentration gradients, and mass transfer were discussed before the girls split into smaller groups. Each group received a piece of cardboard with holes (a "membrane" – see Fig .4), blue jelly beans (water molecules), and large bags of jelly beans (molecules). The girls were asked to see which molecules would permeate the membrane, where the holes were too small for the large organic molecules, but the water molecules could move across the boundary. This helped them visualize osmosis and predict what would happen if the concentration of an organic molecule was higher inside or outside the cell.

Each team filled a sausage casing with a sugar solution and tied off the ends to make a "cell." After weighing the cell, they submerged it in a hypertonic, hypotonic, or isotonic solution made with water and sugar. The cell was weighed again an hour later. The girls compared the original and final masses then tried to predict the type of solution outside of the cell, requiring them to apply their knowledge of concentration gradients and mass transfer. Participants saw how osmosis works and used the scientific method to hypothesize, experiment, and make conclusions.

Fig. 3. Electrocardiogram acquisition.

Fig. 4. "Blood Scrub" participants with a cardboard 'membrane.'

D. *"Mousing Around" – Tremor-Resistant Computer Mice*

Computer mice present hurdles for Parkinson disease sufferers because tremors affect pointer placement on the screen [7]. The "Mousing Around" session introduced this disease using the National Parkinson Foundation web site [13] and two videos. The first video was an interview with Michael J. Fox [14], where Parkinson disease was evident as he trembled involuntarily throughout the video. In the second video, a woman explained how the disease affected her daily routine [15]. She mentioned trouble operating a computer mouse, which segued into a hands-on project. To simulate Parkinson tremors, the girls attempted to connect dots in a straight line using Microsoft Paint while the mouse rested on a vibrating box (see Fig. 5). Each group then received a handout outlining the engineering design process. The girls recognized that they had identified a need and defined the design problem. Next they generated ideas for new mouse designs to address these tremors. After 5 minutes of brainstorming, teams received materials to build a prototype: play dough, construction paper, duct tape, pipe cleaners, balloons, and other craft materials. Each group explained their design to the rest of the groups.

Fig. 5. Mentor illustrating the effect of tremors on mouse pointer placement.

E. "Bionic Joints" – Joint Mechanics

The "Bionic Joints" module taught participants how novel prosthetic limbs could utilize pressure-driven systems. The laboratory compared pneumatic and hydraulic systems to illustrate how engineers evaluate competing solutions. Participants were asked to build an artificial arm or leg model out of tongue depressors and duct tape. This minimal frame was to be driven with a system consisting of two 10 mL syringes connected by a 45 cm length of aquarium tubing such that depressing the plunger of one syringe would pressurize the air in the tubing and force the other plunger upward. After strategically attaching the second syringe's plunger and tube to the tongue depressor frame, participants could control their prosthetic limb models by applying a force to the first syringe's plunger. After experimenting with different syringe and tongue depressor arrangements, the groups were asked to comment on their air-powered designs. Participants noted that the pneumatic hose could be easily integrated into prosthetic assemblies and that the hose length could be adjusted to convey the forces over a wide range of distances. When prompted to list a weakness in their creations, they noted that a small delay existed between the time the first plunger was pressed and the upward response of the second plunger. They commented that this lag time would be a weakness, since a prosthetic application requires short response times to be useful.

Participants were then asked to design a water-powered system to reduce or eliminate this lag time. These hydraulic-system tests supported the hypothesis that a water-powered system will respond more quickly than an air-powered system. The teams were asked to relate this finding to compressibility and offer a recommendation as to which type of design would be best suited for prosthetic limb applications.

F. "Can You Hear Me Now?" – Filters In Cochlear Implants

An instrumentation design challenge is limiting noise or removing it from a system. In the "Can You Hear Me Now?" module, this challenge was introduced for cochlear implants. The module first defined noise in terms of static in a TV picture or a radio station's audio signal. Next, the session organizers contrived a scenario where participants would repair a defective cochlear implant that was susceptible to noise. A 3D animation [16] was shown to illustrate cochlear implant operation. On each laboratory bench, a cochlear implant was emulated by a small breadboard circuit that merged music from a PC headphone jack (desirable audio) with a high-pitched tone from a signal generator (noise). The goal of each team was to realize a suitable second-order Butterworth low pass filter to separate the high-pitched tone from the music by choosing components from a selection of capacitors and resistors.

Fig. 6. Participants adjusting their syringe-based hydraulic system.

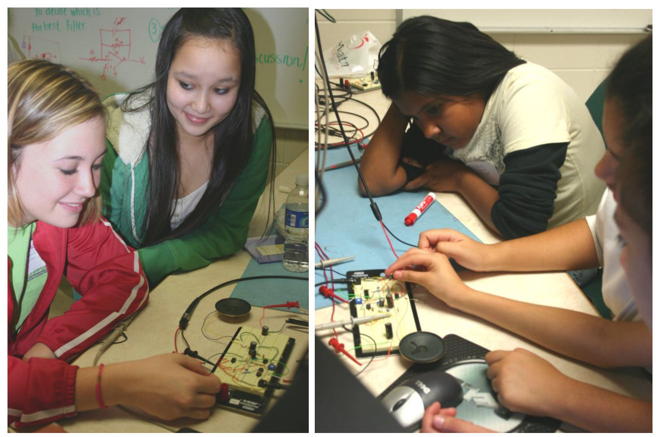

Fig. 7. Audio filter adjustment.

III. Results & Discussion

The workshop was positive for attendees, EMBS sponsors, and WESP mentors. The specific lessons learned are too numerous to list here but can be organized into broad themes. To begin, participants were truly interested in the material and embody a ***bright and creative engineering talent pool***. The "Bionic Joints" session leader observed the girls clearly demonstrating their capacities to think like engineers and evaluate the feasibility of using pneumatics versus hydraulics in prosthetic systems. All session leaders saw girls creatively consider design variables to make engineering decisions.

Another theme relates to ***session planning***. Schedule flexibility is important, since participants are rarely on time. The number and background of student mentors are also factors: one mentor per small group is ideal, and a mentor's understanding of the tools/concepts drives a session's success. Pre-workshop run-throughs with mentors (and ideally young girls) are critical. Sessions move quickly, and teams often finish early, so filler material and design challenges should be on-hand. Real laboratories are preferred venues; girls like to ask questions about the equipment in the room. Laboratories easily become crowded, so space is needed for belongings (e.g., coats and backpacks) that girls will inevitably bring.

The third theme relates to young girls' ***developmental readiness***: some concepts are too advanced to convey quickly. For example, concentration gradients and osmosis were difficult for younger students to grasp, and the filtering session leader found it hard to explain filters and frequency selectivity to some participants. Systems cannot be complicated: mentors should be able to learn them quickly so that girls do not have to wait for an "expert." Brainstorming can also be awkward at this age; one or two girls will often take over and leave the others out, who may then disengage and play off to the side. Regarding attention span, these girls are attentive to 'lecture' material, but only for a few minutes at a time. Verbal and interactive sessions are ideal, as unstructured time is an invitation for them to revert to playing. Participants like exercises that involve audio, video, and/or games. Background music helps them relax, especially if they choose the songs. These sessions are new environments with new people, so the girls can be easily distracted: the temptation to play is ever-present, and play can become rowdy. High-end equipment should be stored away, as this rowdiness is coupled with participants' propensity to handle nearby objects and their naivety regarding the expense of research-grade equipment. Session tools should therefore be robust, and maintenance resources and people should be available to fix systems that go down.

On a positive note, this developmental stage is endearing. Middle school girls do not like using jelly beans in an experiment unless they simultaneously eat jelly beans. When the girls found out that a hydraulic system minus the tubing equals a squirt gun, their attention became diverted in an entertaining way. They like things that they can build or use then take home, and if one girl gets a memento, everyone else wants one. Participants like attention for their accomplishments, so wrap-ups at the end of the individual sessions and the entire workshop are important and can be a highlight of the experience; singing and dancing can play a role in these wrap-ups.

IV. Conclusion

This paper highlighted biomedical learning experiences for young women hosted by the KSU Student Chapter of the IEEE EMBS and the KSU WESP program. The overall experience was a resounding success. Participants left with a better understanding of biomedical engineering, the design process, and the value of team work. The organizers' hope is that these experiences will spark an early interest in science and engineering and lead to greater female enrollment in quantitative degree programs. From the perspective of the KSU EMBS student chapter, this workshop encouraged officer leadership, organization, flexibility, and cohesiveness. EMBS members and other student mentors gained teaching experience and the motivation to host similar activities in the future.

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