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Analyzing the Function of Cartilage Replacements: A LABORATORY ACTIVITY TO TEACH HIGH SCHOOL STUDENTS CHEMICAL AND TISSUE ENGINEERING CONCEPTS

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Compared to the demographics of the general population, a disproportionately low number of minorities and women are in engineering.[1] Although more women than men obtain bachelor's degrees, men earn a higher proportion of degrees in science and engineering than women.[1] Women comprised only 20% of national engineering undergraduate enrollment between 1999 and 2004.[2] Because engineering is not a subject typically taught in the K-12 curriculum, it is not an obvious career choice to most students, particularly if they are not exposed to engineering in their extracurricular activities or at home.[2] A lack of understanding of what engineers do is cited as being a reason for the scarcity of female engineers.[3] Thus, providing more information on what engineering is may increase women's interest in pursuing engineering careers.[3, 4]

Many interactive programs promote engineering awareness,[5, 6] including multi-day camps.[7, 8] A weeklong camp for high school students focusing on biomedical engineering was successful at familiarizing students with the field.[9] Other efforts to use interactive demonstrations and modules with biologically oriented content have been successful in the past, especially with K-12 students.[10, 11] Although others have included both chemical and bioengineering concepts in modules for high school girls,[8] to our knowledge no one else has described an activity that incorporates the tissue engineering of cartilage to encourage learning about chemical engineering.

The present program targeted female high school students to increase their knowledge about the engineering profession. The goals were to enhance awareness about both chemical

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AM	Sunday, July 24	Monday, July 25	Tuesday, July 26	Wednesday, July 27	Thursday, July 28	Friday, July 29
8:00		Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
8:30		Camp Overview HILL C103	Platform Shoes ARMS 1103	Platform Shoes ARMS 1103	Load Bus	Platform Shoes ARMS 1103
9:00					Field Trip * Indianapolis Zoo (Lunch Included)	
9:30		Team Building Activity				
10:00			Super Chair Project ARMS 1109	Super Chair Project ARMS 1109		Super Chair Project ARMS 1109
10:30						
11:00						
11:30		Lunch	Lunch	Lunch		Lunch
12:00						
12:30		Dorms to Change Clothes	Walk to Focus Area Location	Load Bus		Change for Banquet
1:00		Walk to Fountain	Engineering Focus Areas * BME - MJIS 1053 ChE - FRNY G124 Herrick - East Door	Industry Tour * Subaru of Indiana Automotive		Super Chair Project ARMS 1109
1:30		Group Picture			Engineering Speaker Behind the Scenes Tour Engineering "Hunt"	
2:00		Innovations in Engineering ARMS 1109				
2:30						Camp Wrap Up (ARMS 1109)
3:00				Load Bus		
3:30		Super Chair Project ARMS 1109		Super Chair Project ARMS 1109	*Wear Camp T-Shirts & have closed toe shoes!	Recognition Dinner for Campers & Families ARMS Atrium
4:00						
4:30						
5:00		Dinner	Dinner	Dinner	Load Bus	
5:30					Dinner Downtown IND Spaghetti Factory	
6:00	Check-In HILL C100		Load Bus	Load Bus		Check Out of Dorms
6:30		Load Bus	Bowling	Tropicanoe Cove	Load Bus	
7:00	Orientation Hillebrand Hall	All Fired Up Pottery Studio			Drive back to dorms	
7:30						
8:00	Camp Activities w/ chaperones HILL C30		Load Bus	Load Bus	Load Bus	
8:30		Load Bus	Camp Activities HILL C30	Camp Activities (No location)	Camp Activities HILL C30	
9:00		Camp Activities HILLC30				
9:30						
10:00	Rooms	Campers in Rooms	Campers in Rooms	Campers in Rooms	Campers in Rooms	
10:30	Lights out	Lights out	Lights out	Lights out	Lights out	

* Must wear closed toed shoes to these events

Activities:
Super Chair Project (CE, ME, ECE, MSE, BME) - Combines several disciplines to make one unique chair!
Platform Shoes (BME, CE) - Design shoes out of cardstock that are at least 2" tall and wearable!
Indianapolis Zoo (Various) - Looking at how engineering is integrated at a large zoo
Subaru Tour (ME, AAE, IE, ECE)
Engineering Focus Areas - Campers will choose an area for in-depth focus with a faculty member
Herrick Labs (ME, ECE, ENV)
Tissue Engineering (ChE w/ BME & MSE)
Physiological Signals (BME w/ ECE, ME, ChE)

ENGINEERING DISCIPLINES
ME - Mechanical
IE - Industrial
ChE - Chemical
ENV - Environmental
BME - Biomedical
MSE - Materials
ECE - Electrical and Computer
CE - Civil (Structural)
ABE - Agricultural & Biological
NE - Nuclear

Figure 1. *2011 EDGE Summer Camp schedule.*[16]

TABLE 1
Schedule of events for the focus session on "Analyzing the Function of Cartilage Replacements."

Activity	Time (minutes)
Welcome and Pre-survey	15
Chemical Engineering Overview	20
Panel Discussion	40
Tissue Engineering Overview	20
Review of Handout	10
Safety Overview	15
Laboratory Activity	60
Calculations	40
Discussion	10
Post-survey	10
TOTAL	= 4 hours

and tissue engineering to help students form stronger opinions about their future careers. To achieve these goals, students engaged in interactive discussions, a hands-on laboratory component, and a few typical engineering calculations. Social relevance and group work were both utilized to increase learning.[12-14] Educating students about science and engineering practices fits into the framework of K-12 education developed by the National Research Council (NRC).[15] The NRC lists activities students should engage in to learn science and engineering practices. The activity described in this manuscript utilizes the following NRC learning objectives: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using math and computational thinking; constructing explanations; designing solutions; obtaining, evaluating, and communicating information; and engaging in argument from evidence.

SUMMARY OF ACTIVITY

The activity described in this article is part of the Exciting Discoveries for Girls in Engineering (EDGE) Summer Camp sponsored by the Women In Engineering Program at Purdue University.[16] The EDGE Summer Camp schedule for 2011 is shown in Figure 1. The weeklong camp is for girls completing their freshman or sophomore years of high school. Advertisements for the camp are sent to students who indicate to Purdue University Admissions that they wish to receive more information about STEM careers. Students are selected based on a letter of recommendation from a teacher and an essay. During the camp, students receive an overview of Purdue engineering, participate in hands-on team activities, and spend a four-hour focus session exploring an area of engineering of their choice. Students choose one of the two or three focus sessions based on brief written descriptions provided by faculty members, who design and implement these focus sessions. For the past three years, we organized a focus session on "Analyzing the Function of Cartilage Replacements." The schedule of events for our focus session is outlined in Table 1.

This manuscript describes each activity, provides instructions for completing the activities, and shares the lessons learned based on survey data. Copies of the handouts given to the students can be found online at <https://engineering.purdue.edu/ChE/People/ptProfile?id=43169>.[17]

WELCOME AND PRE-SURVEY

After welcoming the participants and introducing the volunteers, a pre-survey was distributed to the participants. The survey was designed to ascertain the students' awareness of chemical engineering before participating in the session. Participants received a series of statements and were asked the extent to which they agreed or disagreed based on a Likert-type scale. We implemented the pre-survey in 2010, and it was composed of the first four statements shown in Table 2. In 2011 and 2012, we added the statement, "I think chemical engineering is a profession where you get the opportunity to help people." This statement was added based on research that shows that women may be unaware of the social impacts of engineers.[3, 4]

CHEMICAL ENGINEERING OVERVIEW AND PANEL DISCUSSION

A 20-minute PowerPoint presentation that described the chemical engineering profession was delivered to the participants. The presentation emphasized that chemical engineers work in teams and have high societal impact. The variety of fields in which chemical engineers work was described, and it was emphasized that tissue engineering was just one of the many areas. The laboratory activity was highlighted as just one example of what a chemical engineer could do, and other non-traditional opportunities such as venture capital and law were also discussed. After the presentation, the high school students engaged in an interactive 40-minute panel discussion with 3-4 graduate students from different research groups in chemical engineering. Often, half of the panelists had previous experience with high school outreach activities and had some industry experience through internships or co-ops. The graduate students introduced themselves, gave a short description of their research, and explained why they became chemical engineers. The participants were encouraged to ask questions about chemical engineering, engineering in general, or college life.

TISSUE ENGINEERING OVERVIEW

A 20-minute PowerPoint presentation provided a definition of and motivation for tissue engineering. After a brief overview of biomaterials, the presentation focused specifically on cartilage tissue engineering and background for the laboratory activity. We described cartilage tissue structure and function and the medical need for cartilage repair. In particular, we found that including YouTube videos of traumatic joint injuries captured the participants' attention. The participants learned about different cartilage extracellular matrix components and histological staining techniques used to visualize those components. The staining techniques led to a description of colorimetric assays used to quantify extracellular matrix components. The colorimetric reaction used in the laboratory activity was presented along with a basic description of spec-

TABLE 2
Pre- and post-survey results show changes in student awareness of attitudes toward engineering after participating in the activity.

Question	Survey	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Avg.	Std. Dev.	# of Responses
I am interested in chemical engineering.	Pre-Survey	0%	0%	20%	61%	20%	4.0	0.6	66
	Post-Survey	0%	2%	18%	50%	30%	4.1	0.7	66
I am interested in tissue engineering.	Pre-Survey	3%	3%	50%	29%	15%	3.5	0.9	66
	Post-Survey	3%	11%	29%	40%	16%	3.5	1.0	62
I understand what chemical engineers do.	Pre-Survey	0%	26%	54%	18%	2%	3.0	0.7	65
	Post-Survey	0%	2%	11%	60%	28%	4.1	0.7	65
I see chemical engineering as a desirable career option.	Pre-Survey	2%	0%	26%	47%	26%	4.0	0.8	66
	Post-Survey	2%	3%	17%	48%	30%	4.0	0.9	66
I think chemical engineering is a profession where you get the opportunity to help people.	Pre-Survey	0%	0%	9%	34%	57%	4.5	0.7	47
	Post-Survey	0%	0%	0%	36%	64%	4.6	0.5	47

trophotometric methods for detecting color. We learned that including a slide that described how to construct a calibration curve primed the participants for content they encountered later in the activity.

HANDOUT

We developed a handout to serve as a guide for the participants' laboratory experience.[17] The handout consisted of six separate sections: summary, background, safety information, calculations, protocol, and discussion questions. The summary section included a description of what we expected the participants to learn about tissue engineering and contained a brief overview of the tasks the participant would perform during the laboratory activity. The background section summarized the Tissue Engineering Overview presentation. The safety information consisted of an abridged version of the material safety data sheet (MSDS) on the chemicals used in the experiment. Initially, we included the entire MSDS for each chemical, but the students were overwhelmed by the lengthy text and were confused by unfamiliar acronyms. Subsequent versions of the handout contained an abridged version of the MSDS written in common English. The calculation section introduced the concept of material balances to the participants.

The last two sections related directly to the laboratory activity. The protocol section included the procedure to perform the experiment and a 96-well plate map for the participants to record their sample locations. To promote active decision-making during the experiment, the protocol was intentionally vague regarding details such as the exact number of replicates and plate layout. The discussion section asked students to comment on variations in replicates, explain the shape of the standard curve, and include estimates for unknown concentrations. Students were also asked to think about potential changes to the experiment and additional experiments that would be required to fully characterize replacement cartilage tissues. An instructor's version[17] of the discussion section containing appropriate answers to the discussion questions was distributed to the volunteers to facilitate an accurate and extensive discussion.

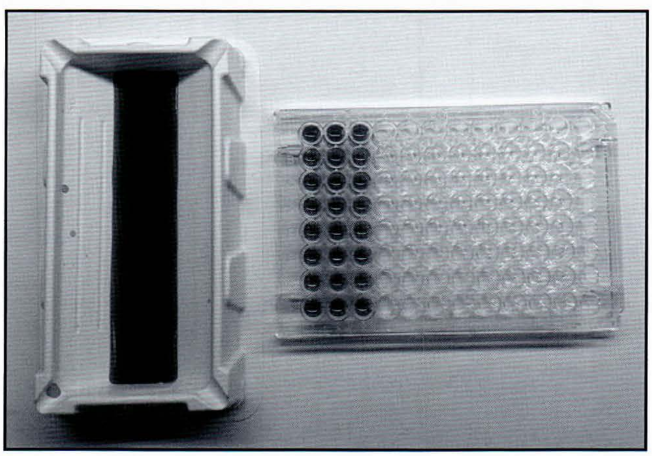

Figure 2. *Set-up of colorimetric assay for determining GAG concentration. (Left) 1,9-dimethylmethylene blue reagent in a reagent reservoir and (right) a 96-well plate in which the colorimetric assay is performed. After mixing the dye with samples of chondroitin sulfate, the solution changes to appear purple or pink, depending on the concentration of chondroitin sulfate. Liquid shown in photograph appears blue.*

To cater to students with different learning styles,[18] information within the handout was presented in text, graphs, and through a short verbal overview. Additionally, the handout provided a basis for conversations between the students and volunteers. For example, the abridged MSDS information was used to explain the industrial role of chemical engineers or to relate a personal experience in acquiring a new chemical for use in the laboratory.

SAFETY OVERVIEW

Before the participants began the laboratory activity, a graduate student who works in the laboratory on a regular basis delivered a 5-10 minute safety talk in the hallway outside of the laboratory. Most students were familiar with common laboratory rules from high school laboratories, such as no eating or drinking in the laboratory. We reminded them of these basic rules and gave a brief overview of the safety concerns specific to our laboratory, such as the presence of bacteria and toxic chemicals. The graduate student also explained the meaning of the hazard signs posted on the door.

Upon entering the laboratory, students put on personal protective equipment (safety glasses, laboratory coat, and gloves) and participated in a safety demonstration on appropriate techniques for donning and removing gloves.[19] To keep the experience interesting, shaving cream was used as a mock contaminant.[20] Participants attempted to remove "contaminated" gloves without spreading the shaving cream onto themselves or other students. Variants of this exercise include using different mock contaminants such as UV fluorescent powders and creams, which are sold commercially under the GloGerm™ and GermBLING™ brands, respectively.[21] Mastering the glove-removal technique was not required for safe completion of the lab; however, we used this exercise to teach students about mammalian cell culture, a different facet of tissue engineering in which removing gloves properly is important in controlling the spread of bloodborne pathogens.[19] By learning this safety technique, participants were exposed to the real-life safety skills that a tissue engineer uses on a daily basis.

LABORATORY ACTIVITIES

Before beginning the activity, participants were given 5-10 minutes to read through the laboratory background and procedures. Also, students were asked to form groups of 2-5 participants and pick a team name. In the laboratory activity, participants performed a colorimetric assay that measured the soluble amount of glycosaminoglycans (GAGs), a major component of cartilage.[22] The handout explained that when the dye and GAGs react, the color of the solution changes from blue to a purple or pink color (see Figure 2).[17] The students were asked to use this reaction to determine the concentrations of two unknown solutions and were given six standard solutions of known concentrations to create a calibration curve.

Materials

This laboratory requires the use of 500 μL capacity pipettes and 20 μL capacity pipettes. One of each pipette is required for a group of 2-5 students. This laboratory also requires the use of one plate reader (or cuvette reader, see Variations section) and a balance. The directions below assume that a balance, pipettes, and plate reader or cuvette reader are already present in the laboratory. Additional materials and estimated prices for a group of three students are shown below:

- *Pipette tips*
  - *Approximately two 500 μL capacity tips and five 20 μL capacity tips for each student*
  - *Example products: VWR 83007-376 and VWR 14217-708*
  - *Estimated cost: $0.23 per student*
- *Microcentrifuge tubes to hold standard and unknown solutions*
  - *Eight 1.5 mL tubes per group*
  - *Example product: VWR 14231-062*
  - *Estimated cost: $0.19 per student*
- *Reservoirs to hold reagent and water*
  - *Two reservoirs per group*
  - *Example product: VWR 89094-676*
  - *Estimated cost: $0.36 per student*
- *1,9-dimethylmethylene blue (DMB) reagent (0.04 mM 1,9-dimethylmethylene blue dye, 0.04 M glycine, 0.04 M NaCl, and 0.01 M HCl in water. Mix with a stir bar overnight.)*
  - *Approximately 10 mL per group*
  - *Example products: Sigma 341088, Sigma G8898, VWR MK758106, Sigma 258148*
  - *Estimated cost: $0.75 for 500 mL, less than $0.01 per student*
- *Chondroitin sulfate*
  - *Approximately 0.5 mL of each standard or unknown in one microcentrifuge tube for a group.*
  - *Example product: Sigma C4384*
  - *Estimated cost: $0.15 for 1 mg, less than $0.01 per student*
- *Optically transparent 96-well plates and a plate reader*
  - *One plate per group*

In particular, we found that including YouTube videos of traumatic joint injuries captured the participants' attention.

  - *Example product: VWR 15705-066*
  - *Estimated cost: $0.95 per student*
- *Gloves*
  - *Approximately two pairs for each student*
  - *Example product: VWR 40101*
  - *Estimated cost: $0.75 per student*

The cost of the laboratory is estimated to be about $2.50 per student. To initially purchase all reagents and materials, the cost is expected to be $615 or less. All materials were purchased separately and assembled.

Before the laboratory activity

Volunteers prepared the DMB reagent and the chondroitin sulfate standard and unknown solutions for all participants. Any chondroitin sulfate concentrations in the linear range may be used for standard solutions, but we found that chondroitin sulfate concentrations of 0, 2.5, 5, 10, 20, and 40 μg/mL worked well for a calibration curve. A stock solution of chondroitin sulfate was made by dissolving chondroitin sulfate in water, and the standards were made by serial dilution. We also chose one unknown concentration within the calibration curve (*e.g.*, 20 μg/mL) and one unknown concentration outside of the curve (*e.g.*, 60 μg/mL) for the participants to analyze. The unknown solution whose concentration lay outside of the standard curve was used to spark discussion at the end of the activity. Before the activity, a graduate student tested the assay to ensure all solutions were made properly.

During the laboratory activity

After reviewing the laboratory handout, participants formed groups of 2-5 people. The volunteers gave a short tutorial on using a micropipette and had each group member practice her technique using water. We found that it was important to teach the participants how to pipette properly because pipetting error was a significant source of variation in the results. All groups were given the following experimental procedure:

1) *Add 20 μL of each GAG standard (samples A-F) to a 96-well plate in duplicate or triplicate. Mark the location of your samples on your plate map. Do the same with your unknown samples.*
2) *Add 250 μL of DMB reagent to each well. Be careful to not bring liquid from one well into another well.*
3) *Measure the absorbance of each sample at 525 nm in the plate reader immediately after adding the reagent to the samples.*

4) *Record the data in the plate map or print your results.*

Volunteers and participants discussed the number of replicates and how to set up the plate maps. Participants were encouraged to split the work equally but decided amongst themselves how to distribute the work. Volunteers guided the participants through the activity and were available to answer any questions. The student groups filled out plate maps, added samples to the appropriate wells, and then added the DMB reagent. Next, a volunteer led the group to the plate reader, and the volunteer took the absorbance data with the machine. The volunteer explained how the machine works while the data was being collected. The students were provided with a printout of the data, which consisted of absorbance values for each well.

TABLE 3

Unknown concentrations estimated by participants compared to typical graduate student results and actual values.

	Participant Values (μg/mL)	Graduate Student Values (μg/mL)			Actual Values (μg/mL)
		Average	Standard Deviation	Replicates	
Unknown 1	6, 14, 16, 17.5,19, 22, 26.5	21	1.9	3	20
Unknown 2	1, 32, 45, 49, 60, 77, 100	61	4.8	3	60

Variations

This activity could easily be completed with the use of a cuvette reader instead of a plate reader. Larger volumes can be used, and fewer replicates and samples can be analyzed. In addition, if a laboratory cannot accommodate a large number of participants, laboratory access can be staggered, and participants not conducting the laboratory activity can work on the calculations section of the handout. Finally, this laboratory activity can be adjusted to be appropriate for undergraduate students by: increasing the difficulty of the calculations, having students make their own standard solutions, and providing less guidance than provided to high school students.

CALCULATIONS AND DISCUSSION

The calculations section of the handout, which introduces material balances, can be performed before or after the laboratory activity. In the calculations section, the handout described how the standard solutions were made.[17] The participants were asked to calculate the concentration of the 40 μg/mL solution by performing a material balance. The remaining concentrations of the standard solutions were calculated based on a simple dilution series. To simplify the calculations, all unit conversions were provided for the participants. Originally, a material balance was used to calculate the concentration of each standard solution; however, we discovered that students found too many calculations to be frustrating and that one calculation still taught participants how to perform a material balance.

Students completed the discussion section of the handout after the laboratory activity. Participants were asked what shape their standard curve was and what the concentrations of the unknown samples were. Scaffolding provided by the volunteers indicated that the students should plot the absorbance readings vs. the known concentrations of the standard solutions, draw a best-fit line through these points, and use the standard curve to determine the concentrations of the unknown samples. Table 3 shows the range of values participants estimated for the unknown samples. Compared to a typical graduate student, participants often had a larger variance in data, which was largely due to pipetting errors. For participants who had particularly poor data, it was necessary to implement additional scaffolding such as suggestions to remove an outlying data point. These discussions also presented a learning opportunity when the student was not familiar with the concept of an outlier. During the group discussion of the results, the values obtained by each group and the actual values were written on a white board. We used this as a starting point to discuss what to do with the unknown concentration that was outside of the standard curve. Volunteers explained that because the curve may not remain linear, values outside of a standard curve often are not trusted. Participants were encouraged to think of methods to improve their data, including the use of additional standard solutions or diluting the unknown sample.

Discussion questions also included asking the participants to comment on how much variation occurred in their data and potential sources of variation. Participants were asked to comment on the accuracy of their estimates and what could be done to improve their results. Finally, participants were asked to think of other measurements that would be important to perform when developing a fully functional cartilage replacement.

POST-SURVEY

We distributed a post-survey to the participants at the end of the activity. To assess whether students' knowledge about engineering changed as a result of participating in the activity, the post-survey included the same statements as the pre-survey. The post-survey also included statements addressing the panel discussion, the hands-on laboratory, and the data analysis and calculations (see Table 4). Additional statements assessed the students' perceptions of the session. In 2011, we

TABLE 4
Post-survey results show the satisfaction with the activity and indicate areas for improvement.

Question	Average	Standard Deviation	Number of Responses
I enjoyed the panel discussion during this session.	4.3	0.8	66
I enjoyed the hands-on lab component of this session.	4.6	0.6	66
I enjoyed the data analysis and calculations component of this session.	3.2	1.0	65
The lab instructors were helpful in increasing my understanding of the material.	4.3	0.8	66
The lab instructors increased my interest in the material presented.	4.0	0.9	66
In the future, I am more likely to take classes related to tissue engineering because of this session.	3.2	0.9	46
In the future, I am more likely to take classes related to chemical engineering because of this session.	4.0	0.9	47
I would recommend this session to a friend.	4.0	0.7	66
Overall, I enjoyed participating in this session.	4.4	0.6	66

added two statements related to students' interest in taking classes related to chemical engineering or tissue engineering. The post-survey also contained four open-ended questions that allowed the students to articulate their feelings about the session, what they learned, and suggestions for improvement. Both the pre- and post-surveys provided valuable feedback to continuously improve the activity each year.

LESSONS LEARNED AND IMPROVEMENTS FOR THE FUTURE

Results from the pre- and post-surveys are shown in Tables 2 and 4. Data were collected in 2010, 2011, and 2012 with two sessions being held per year. The average and standard deviation were calculated by pooling data from all years. It should be noted that in 2011, three questions were added to the surveys, which were, "I think chemical engineering is a profession where you get the opportunity to help people," "In the future, I am more likely to take classes related to tissue engineering because of this session," and "In the future, I am more likely to take classes related to chemical engineering because of this session." Because those questions were only asked in 2011 and 2012, the number of respondents was lower for those survey questions.

Table 2 directly compares the results from the pre- and post-surveys. The activity appeared to achieve the goal of educating students about what chemical engineers do because students increased their agreement with the statement "I understand what chemical engineers do." A similar result was seen in response to the statement "I think chemical engineering is a profession where you get the opportunity to help people." The responses to these two statements suggest that the activity achieved its goal of increasing student awareness about chemical engineering and the opportunities to help people as a chemical engineer. We believe these are important results because women are more attracted to professions where there is social impact.[3,5]

After the activity, interest in chemical engineering appeared to increase, with 30% strongly agreeing with the statement "I am interested in chemical engineering." We also note that students seemed to form stronger opinions after the activity; their responses shifted away from neutral or agree to disagree or strongly agree. A very similar result was achieved with the statement "I see chemical engineering as a desirable career option." One potential explanation for the shift is that the activity provided students with the information they needed to make stronger opinions about the profession. After the activity, many students may have learned that they really enjoyed chemical engineering whereas others may have learned that chemical engineering was not as suitable for them as they previously thought. After the activity, stronger opinions also appeared to form about the statement "I am interested in tissue engineering."

Table 4 shows additional post-survey results that provide insight into how participants feel about different aspects of the activity. Participants indicated that the data analysis and calculations were the least enjoyable part of the activity. This dislike was also reflected in the written responses to the question "What did you like least about this session?" Many participants listed the calculations or graphing as their least favorite aspect. Future efforts will be made to make the calculations portion more engaging for the students. One potential alternative is to physically demonstrate how the standard is made and to ask questions and do calculations along the way. Another potential improvement is to add an open-ended design element to the laboratory and focus less on the calculations. For example, based on their results and information given to them in the handout, students could be asked to brainstorm different implant designs.

Participants also gave low responses to the statements about taking classes in chemical and tissue engineering. Students may genuinely have felt that they had no interest in taking more classes in the subject. Students also may have been thinking about high school classes, however, and it is unlikely that their high schools offer the opportunity to take engineering classes. In the future, we plan to specifically describe what classes students can take in high school to help them learn more skills a chemical or tissue engineer might need. We expect this will improve the responses to these statements.

Not surprisingly, students responded positively to the statement "I enjoyed the hands-on laboratory component of this session." Their enjoyment was reflected in the participants' written responses to the question "What did you like most about the session?" Many participants listed the laboratory in their response.

We found that participants generally liked the panel discussion. Many students actively participated and asked questions. The panel was included in the participants' written response about what they liked most about the session. Based on the survey results, we recommend that if alterations are made to the activity, the panel discussion should remain a part of the activity.

The survey also indicated that the participants felt the instructors were helpful. Given that the volunteers provided a significant amount of scaffolding to the students, this result is not surprising. The individual interactions provided more personal opportunities for students to ask questions about the material, about chemical engineering, or about college in general. We plan to ensure this interaction remains a major portion of the lab in the future. The survey also indicated that the students generally enjoyed participating in the session.

In conclusion, the survey data indicate that the goal of educating participants about the chemical engineering profession was met. Participants left the activity knowing more about chemical engineering and that chemical engineers help people. This knowledge appeared to help them form stronger opinions about their career interests. Participants generally liked the activity, especially the hands-on portion in the laboratory. Thus, this activity was helpful in providing female students the information necessary for them to make educated career choices.

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