First-year interest groups and 1st semester BME design class exposure to improve engineering student outcomes

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Introduction

First year Biomedical Engineering (BME) students at The University of Texas at Austin have the option of joining a First-year Interest Group (FIG). FIGs can increase student interest and retention in the major by allowing groups of 15-20 students to attend a weekly seminar and their first engineering classes together. [1] BME 303L *Introduction to BME Engineering Design* is a required course for first year BME students; students who join a FIG facilitated by the BME advising office enroll in BME 303L together during their first semester (fall) on campus. Approximately 80% of fall semester BME 303L enrollment is FIG students, while the other 20% are not part of a BME FIG. The same course taught by the same instructor is also offered during the following spring semester, and spring enrollment is exclusively made up of first year students who did not participate in a fall FIG. While FIGs have been shown to increase retention[1] and we have observed a positive impact on attitudes toward engineering, we have not yet been able to correlate these successes to engineering student outcomes as defined by the Accreditation Board for Engineering and Technology (ABET). In order to better understand if the FIG success is correlated to engineering student outcomes, the authors surveyed all first year BME students at the end of the fall 2017 semester to measure their own perception of teamwork, communication skills, lifelong learning, and ability to use engineering tools. This paper presents initial results of the survey comparing engineering student outcome perceptions from students who just completed a FIG and BME 303L in the fall semester, and students who did not participate in FIG and are enrolled in BME 303L in the spring semester. These data will be used to optimize advising and curriculum for first year students and improve engineering outcomes for all students. Future surveys are planned for sophomore and junior years as well.

1. Methods

The authors measured student outcomes among both the fall 2017 and spring 2018 BME 303L groups with identical electronic surveys via Qualtrics. The survey included five sections with a total of 44 questions: 43 questions were Likert-scale, and the last was an open-ended text box format. Section 1 of the survey was informed consent per IRB requirements. Since one of the authors is the instructor of the first-year design class, and the other author is a facilitator of 3 of 5 BME FIGs, the informed consent page was very specific with students that they would in no way be penalized, nor would their relationship with the authors or the university be affected, should they refuse to participate in the study. See **Appendix A** for a copy of the survey.

1.1 Teamwork measurement

Section 2 of the survey measured the students' perception of their teamwork ability, which is related directly to ABET Student Outcome d: an ability to function on multi-disciplinary teams. This included 9 Likert-scale questions adapted from Tseng et al. (2009) in measuring the relationship between collaboration factors and teamwork satisfaction. [2] This section of the survey asked the students to rate their level of agreement on 5 points from Strongly Disagree to Strongly Agree with nine statements of important teamwork factors. These included solving problems, interactions with teammates, and producing quality work.

1.2 Communication measurement

Section 3 of the survey measured the students' scientific communication self-efficacy, which is related to ABET Student outcome g: an ability to communicate effectively. This included 15 Likert-scale questions adapted from a validated self-efficacy in scientific communication measurement developed by Anderson et al. (2016).[3] This section asked the students to rate their security in their ability to accomplish 15 specific scientific-communication related tasks on a 5 point scale from Very Insecure to Very Confident. These tasks included writing a first draft, using correct grammar, giving scientific presentations, and asking questions in front of an audience or lab group.

1.3 Lifelong learning measurement

Section 4 measured students' interests in engaging in lifelong learning, related to ABET Student Outcome i: recognition of the need for, and an ability to engage in, life-long learning. This included 14 Likert-scale questions adapted from Kirby et al. (2010). [4] Questions asked the students to rate their level of agreement on 5 points from Strongly Disagree to Strongly Agree with 15 statements measuring preferences in lifelong learning. Factors measured include dealing with unexpected problems, uncertainty, self-directed learning, locating information, and taking responsibility for learning.

1.4 Ability to use engineering tools measurement

Section 5 measured students' ability to use engineering tools solve biomedical engineering problems, related to ABET Student Outcome k: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. This included 6 Likert-scale questions created by the authors designed from the expected learning outcomes of introduction to engineering courses. Questions asked the students to rate their level of agreement on 5 points from Strongly Disagree to Strongly Agree with 6 ability statements related to approaching engineering problems, creating visual presentations with data, communicating results, and analyzing data. A sixth question was an open-ended essay format that asked students to evaluate a data set and describe the process they would use to solve a specific biomedical engineering problem, however the responses to this question were not analyzed for the present work.

1.5 Student grades

Student grades were compared between all students (not only those who participated in the survey) enrolled in BME 303L in the fall of 2017 and enrolled in BME 303L in the spring of 2017 to determine if there was any correlation between self-reported efficacy on the surveys and actual student performance as measured by grades. Spring 2018 students were surveyed, but spring 2017 grades were used as a representative sample of students were not enrolled in a FIG and taking BME 303L in the spring.

1.6 Statistical analysis

The Likert scale questions were analyzed using ANOVA with post-hoc Tuket HSD testing where appropriate. A p-value of less than 0.05 was considered significant. Data are presented as mean ± standard deviation.

2. Results

Survey participation rates among the BME 303L students varied. Students enrolled in BME 303L and a BME FIG in fall 2017 participated at a rate of 41.1% (37/90). Students enrolled in BME 303L but not a BME FIG in fall 2017 participated at a rate of 9.1% (2/22). And students enrolled in BME 303L in spring 2018 (did not participate in a BME FIG) participated at a rate of 43.8% (21/48). Because participation among the non-FIG BME 303L students from fall 2017 was so low, this data was removed from the results sections presented here, as the participation was too low to allow for meaningful analysis and comparison. **See Figure 1**.

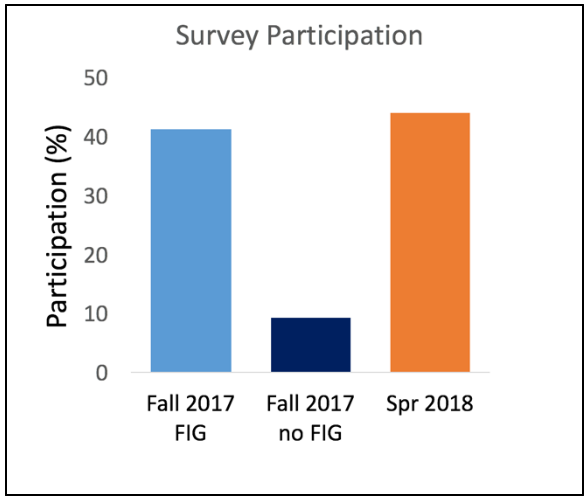

Figure 1. Survey Participation

1.1 Teamwork results

There were no statistically significant differences for any of the 9 questions about teamwork between the fall 2017 class and spring 2018 class.

1.2 Communication results

Of the 15 questions regarding communication ability, only one statement, "Excel in giving scientific presentations (i.e., you usually receive high praise for your presentations from your mentor or the audience)," was significantly different between fall 2017 and spring 2018 groups. The mean rating on a scale of 1 (Very Insecure) to 5 (Very Confident) for BME 303L students in fall 2017 was 2.27 ± 1.02. The mean for BME 303L students enrolled in spring 2018 was 3.1 ± 1.26. **See Figure 2**.

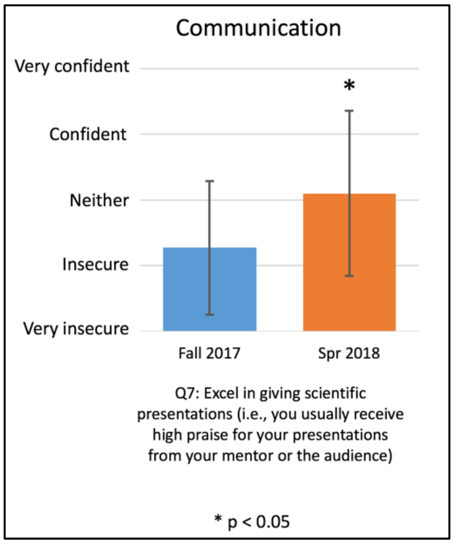

Figure 2. Communication measurement results

1.3 Lifelong learning results

One prompt ("I prefer to have others plan my learning") from the lifelong learning portion of the survey showed a significant difference between fall 2017 and spring 2018 groups. The mean rating on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree) for BME 303L students in fall 2017 was a 3.41 ± 1.12. The mean for BME 303L students enrolled in spring 2018 was a 2.67 ± 0.86. **See Figure 3**.

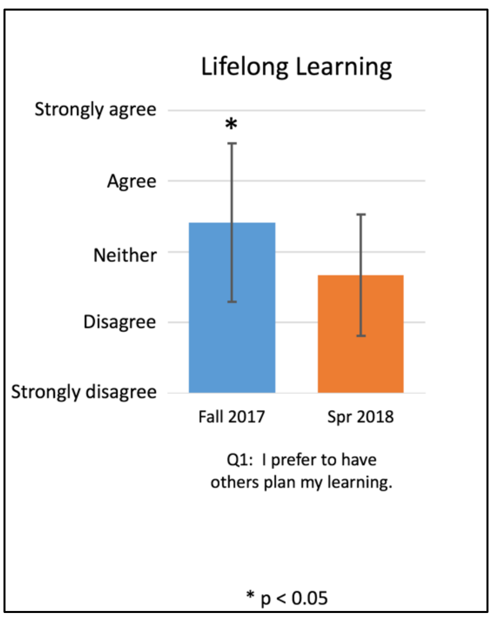

Figure 3. Lifelong learning measurement results

1.4 Engineering tools ability

All of the questions in which the students self-evaluated their ability to solve engineering problems showed statistically significant difference, with the fall 2017 class more likely to disagree with statements affirming ability to solve engineering problems. For all questions, the ratings were on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree). **See Appendix A for the list of questions. See Figure 4.**

Q1: fall 2017 = 2.24 ± 0.93; spring 2018 = 3.48 ± 1.03
Q2: fall 2017 = 1.97 ± 0.73; spring 2018 = 2.86 ± 1.01
Q3: fall 2017 = 1.87 ± 0.71; spring 2018 = 3.10 ± 1.25
Q4: fall 2017 = 2.32 ± 0.85; spring 2018 = 3.05 ± 1.40
Q5: fall 2017 = 2.22 ± 0.85; spring 2018 = 3.10 ± 1.34

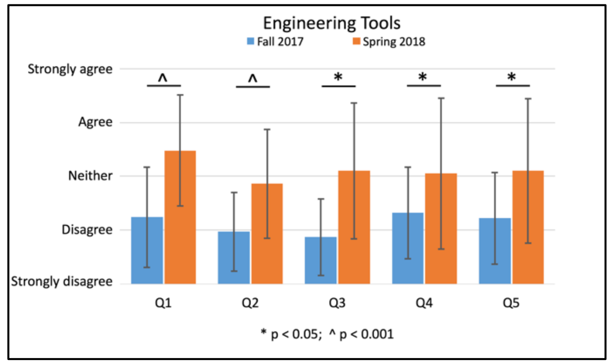

Figure 4. Engineering tools ability results

1.5 Student grades

There was no significant difference in the average grade between fall 2017 FIG students (93.9 ± 5.3%), fall 2017 non-FIG students (93.9 ± 3.4%) or spring 2017 students (92.8 ± 4.7%). **See Figure 5.**

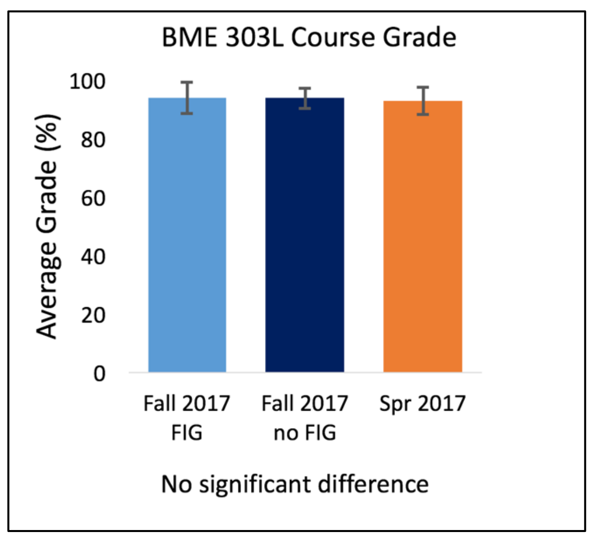

Figure 5. BME 303L course grades

3. Discussion

The authors first observed the significantly lower participation rate among BME students who were enrolled in BME 303L in fall 2017 and also chose not to join a BME FIG. This may indicate a lowered interest in engaging with the department among this cohort of students. Students selected the option to join a FIG in summer orientation advising before their first fall semester at the university. Therefore, these students' choice to not join a FIG precluded their decision to decline participating in this survey.

There were no significant differences between students who had completed BME 303L in the fall of 2017 and students who were enrolled in BME 303L in the spring of 2018 for the teamwork portion of the survey. For all 9 questions, both the fall 2017 and spring 2018 groups had an average less than 2.0 (disagree) for their self-efficacy ratings for teamwork. Improving teamwork ability and mindset are a key student outcome for BME 303L, as students worked in teams on various projects throughout the semester. These data indicate that the students' experience with teamwork in BME 303L had little effect on their perception of self-efficacy toward teamwork. Additional classroom training in teamwork skills and attitudes may be needed to achieve the desired teamwork outcomes in BME 303L.

The scientific communication self-efficacy results indicated that students who took BME 303L in the fall had similar confidence levels of their ability to communicate as students who are enrolled in BME 303L in the spring. One question showed a statistically significant difference between the fall 2017 and spring 2018 students in which students were asked about their perceived ability to give scientific presentations. Students enrolled in the spring BME 303L were more likely to agree with the statement "Excel in giving scientific presentations (i.e., you usually receive high praise for your presentations from your mentor or the audience)" than students who just completed BME 303L in the fall 2017. While scientific writing is a learning outcome for BME 303L, giving a scientific presentation is not. Without further analysis of the curricular differences between the two cohorts of students, it is unknown whether the spring 2018 students are exposed to more opportunities to give scientific presentations than the fall 2017 students. One limitation of the measurement scale used in this survey is that it was developed by researchers at the UT M.D. Anderson Cancer Center for graduate students in biomedical sciences. Although the scale is intended for science communication and was adapted slightly by the authors for undergraduate-level questions, it may not be a valid measure of first year undergraduate communication tasks.

There was also little difference in student attitudes toward lifelong learning. Only one question from this section of the survey was significantly different between fall 2017 BME 303L students and spring 2018 BME 303L groups. Students who took BME 303L with a FIG in the fall were more likely to agree with the statement "I prefer to have others plan my learning" than did students who are taking BME 303L in the spring. This may indicate a higher level of learning independence among the students who declined to join a FIG; this would be consistent with their desire to not be joined with their peers in group seminars. A topic covered indirectly in the BME FIG seminars is the need for lifelong learning. This is frequently presented through student and faculty panels, wherein panelists are asked to share their experiences, strengths, and failures that led to their future successes. FIG seminar panels are designed based off of Stephens and Destin (2014) difference-education intervention module that can provide students with an identification with panelists. [6] When students understand that their background or other relatable factors matter, and they see other students like them persisting through similar challenges, they can often improve their mindset to persist as well. It is interesting that the FIG Fall 2017 groups appeared to have less interest in independent learning, despite the panels. Furthermore, in BME 303L, one of the major pedagogical metacognitive tasks that the instructor uses is to encourage students that they are responsible for their own learning. The results of this survey may represent a frustration with that approach on the part of the students.

The engineering tools section of the survey measured students' self-reported efficacy to solve engineering problems or analyze data. The authors hypothesized that the students who took BME 303L in fall 2017 would rate themselves much higher than students who were enrolled in BME 303L in the spring of 2018 because the spring students had not yet taken engineering classes in college. However, the results were the opposite of expectations, with students enrolled in spring 2018 BME 303L rating themselves more capable of solving engineering problems than students enrolled in BME 303L fall 2017. BME 303L focuses on engineering problem solving, including learning important tools including Excel, MATLAB, ImageJ, and LabVIEW. Students have an opportunity to solve hands-on engineering problems in their lab sections of BME 303L and have consistently learned well in BME 303L as demonstrated by their grades (figure 5). Therefore, it is surprising that these students would have rated themselves lower than students who have not been exposed to the material. One explanation may be that the exposure to introductory engineering material had a humbling effect on student attitudes and that they realized that they had much more to learn, whereas the students who have not taken

BME 303L have not encountered the full depth of engineering problem-solving and therefore are confident out of naivety.

Overall, the survey results indicate that, for the most part, students who had taken BME 303L in the fall 2017 and students enrolled in BME 303L in the spring have similar self-reported feelings toward teamwork, communication skills, and lifelong learning. However, in each instance where there were differences, students who had not been exposed to the training in these areas (spring BME 303L students) had a more desirable rating than those who had been exposed to it (fall BME 303L students). While these results seem counterintuitive, they may indicate a degree of false self-confidence in students who had not been exposed to the difficult material. They may also demonstrate a bias in the survey due to students wanting to "impress" their future instructor. Furthermore, the scales used throughout the survey measure self-efficacy, a psychological construct that indicates whether or not a person believes in their own ability to accomplish something—not necessarily their actual ability. [5] The timing of this survey employment at the end of the fall semester is a very stressful time for first year engineering students, and they may have a very low overall self-efficacy.

4. Future Work

Although this survey did not confirm low engagement directly due to a lack of participating in the survey, the authors consider it worth further investigation on whether or not students who join BME FIGs have a higher interest in engaging with their peers and the department activities in general, and how that may or may not correlate to their later success in the degree. The authors would also like to investigate whether or not the spring semester students have overestimated their abilities and are a possible example of the Dunning-Krueger effect. [7]

For each section of the survey, there are improvements that can be made to better capture BME student attitudes in both groups. A pre-test baseline measurement of self-efficacy before students begin coursework in the future could be informative. The teamwork portion of the survey may need to be written in a more specific way to better understand how students' attitudes were affected by their experiences in BME 303L. The authors suggest using a different scientific communication self-efficacy scale that is more specific for first year undergraduate students.

We find it worth investigating whether or not activities in the FIG are correlated to improvements in lifelong learning attitudes. Measuring this through a survey directly will be a challenge in future work. The authors are interested in measuring lifelong learning attitudes as students move through the program and will consider implementing this measurement in future surveys with sophomores and juniors.

The results of the survey also indicate that self-reported efficacy to solve engineering problems should not be measured apart from demonstrated ability to solve problems. We also suggest that if self-efficacy is an important factor in measuring students' perceptions of their ability, employing surveys at different times during the semester may level out variability from stressful periods during the semester.

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Appendix A

Page 1: Informed Consent

Consent for Participation in Research

Title: First-year interest groups and first-semester Biomedical Engineering design class exposure to improve engineering student outcomes

PAGE 1 of 5 - Informed Consent

Consent for Participation in Research

Title: First-year interest groups and first-semester Biomedical Engineering design class exposure to improve engineering student outcomes

Introduction
The purpose of this form is to provide you information that may affect your decision as to whether or not to participate in this research study. The person performing the research will answer any of your questions. Read the information below and ask any questions you might have before deciding whether or not to take part. If you decide to be involved in this study, this form will be used to record your consent.

Purpose of the Study
You have been asked to participate in a research study about improving students' positive attitudes toward engineering. The purpose of this study is to understand how participate in First-year interest groups and/or introductory design courses may impact students' perception of their ability to become an engineer.

What will you be asked to do?
If you agree to participate in this study, you will be asked for your consent to have your survey responses analyzed. Some evaluation information is protected under the Family Educational Rights and Privacy Act (FERPA), which protects the privacy of student educational records. Findings from this study will be included in research presentations or papers for publication. This study will take not take any of your time and will include approximately 140 study participants.

What are the risks involved in this study?
There are no foreseeable risks to participating in this study.

What are the possible benefits of this study?
There are no expected benefits to participating in this study.

Do you have to participate?
No, your participation is voluntary. You may decide not to participate at all or, if you start the study, you may withdraw at any time. Withdrawal or refusing to participate will not affect your relationship with The University of Texas at Austin (University) in any way.

If you would like to participate please select AGREE at the bottom of this consent form. If you do not wish to participate, please select DECLINE at the bottom of this consent form.

Will there be any compensation?
You will not receive any type of payment for participating in this study.

How will your privacy and confidentiality be protected if you participate in this research study?
Your privacy and the confidentiality of your data will be protected by storage on UT Box. Any identifying information will be removed and replaced with a unique identifier. UT Box has been approved by the University's Information Security Office for use with Confidential (formerly known as Category I) university data, including HIPAA data. Only researchers involved in the study will have access to this data.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to you will be protected to the extent permitted by law. Your research records will not be released without your consent unless required by law or a court order. The data resulting from your participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

If you choose to participate in this study, the researchers involved will access your survey responses only. Data will be maintained electronically on UT Box; destruction of the data after the standard records retention period will be through permanent electronic deletion of data files.

Whom to contact with questions about the study?
Prior, during or after your participation you can contact

the researchers Dan Puperi, PhD, at 512-232-6487 or send an email to danpuperi@utexas.edu, or Margo Cousins, MA, at 512-471-3049 or send an email to margocousins@utexas.edu, for any questions or if you feel that you have been harmed.

Whom to contact with questions concerning your rights as a research participant?
For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Participation
If you would like to participate please select AGREE at the bottom of this consent form.

Signature
You have been informed about this study's purpose, procedures, and possible benefits and risks. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time. You voluntarily agree to participate in this study. By selecting AGREE, you are signing this form and you are not waiving any of your legal rights.

Once you have selected AGREE or DECLINE above, please click the arrow below to save.
AGREE
DECLINE

Page 2: Teamwork

Likert scale 1-5:

Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)

1. I like working in collaborative groups
2. I like solving problems in group projects
3. Interacting with teammates can increase my motivation to learn
4. I have benefited from interacting with teammates
5. I have benefited from teammates' feedback
6. I enjoy the experience of collaborative learning
7. Teamwork promotes creativity
8. Working as a team produces better project quality that working as individuals.
9. I gain collaboration skills by working in groups.

Page 3: Communication

Likert scale 1-5:

Very insecure (1)	Insecure (2)	Neither confident nor insecure (3)	Confident (4)	Very confident (5)

1. Write a first draft by yourself of a manuscript intended for publication
2. Write using correct grammar
3. Manage any anxiety you may have about your writing ability
4. Use the expected scientific style when writing
5. Continue to revise a manuscript multiple times after receiving negative feedback from your mentor or reviewers
6. Need minimal help because my writing skills are strong enough
7. Excel in giving scientific presentations (i.e., you usually receive high praise for your presentations from your mentor or the audience)
8. Give a scientific talk to a lay audience (e.g., high school students, cancer patients)
9. Require little to no assistance with my speaking and presenting skills
10. Defend your point of view convincingly in a scientific discussion, in spite of a negative response from others
11. Speak using correct grammar without rehearsing
12. Manage worries you may have about your pronunciation, accent, vocabulary, grammar, or style of speaking
13. Ask a question or add a comment during a meeting or discussion in your own lab group
14. Ask a question in front of the audience after a presentation at a national scientific meeting
15. Use the expected scientific style when speaking

Page 4: Lifelong Learning

Likert scale 1-5:

Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)

1. I prefer to have others plan my learning.
2. I prefer problems for which there is only one solution.
3. I can deal with the unexpected and solve problems as they arise.

4. I feel uncomfortable under conditions of uncertainty.
5. I am able to impose meaning upon what others see as disorder.
6. I seldom think about my own learning and how to improve it.
7. I feel I am a self-directed learner.
8. I feel others are in a better position than I am to evaluate my success as a student.
9. I love learning for its own sake.
10. I try to relate academic learning to practical issues.
11. I often find it difficult to locate information when I need it.
12. When I approach new material, I try to relate it to what I already know.
13. It is my responsibility to make sense of what I learn at school.
14. When I learn something new I try to focus on the details rather than on the 'big picture'.

Page 5: Engineering Tools

Likert scale 1-5:

Strongly disagree (1)	**Disagree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Strongly agree (5)**

1. I know the general approach to solve biomedical engineering problems
2. I have access to tools that would help me solve engineering problems.
3. I am able to create visual representation of engineering data in order to analyze and communicate results
4. I am confident in my ability to solve engineering problems.
5. I am confident in my ability to analyze engineering data in order to make design decisions.

6. You are asked to evaluate the inflammation produced as a result of two different biomaterial implants. Given the following data set of inflammation with respect to time, briefly describe the process you would use to determine which material was more promising for use in an implantable device. Do not try to determine which is better from the data, only describe the process you would use to evaluate these data.

Time (sec)	**Material #1 inflammation marker**	**Material # 2 inflammation marker**
0	0.034	0.032
60	0.051	0.044
120	0.072	0.056
240	0.118	0.081
480	0.126	0.140
900	0.138	0.159
1800	0.150	0.142
3600	0.149	0.125
7200	0.143	0.101

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