Work in Progress: Lab-bench-marking: How are we using lab courses in BME curricula?

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Introduction

Biomedical engineers work at the interface of numerous engineering and science disciplines to manipulate and create biological systems for a wide variety of applications. While biomedical engineering primarily focused on medical device design in the 1950-1960s, biomedical engineers today now work across a variety of application areas, ranging from prosthetics to tissue engineering to bioinformatics [1]. As the field continues to evolve, undergraduate biomedical engineering programs have also continued to grow and evolve. To support the needs of the growing field, biomedical engineering (BME) curricula were established as broad and interdisciplinary, integrating knowledge from both basic sciences and engineering disciplines. This training prepares graduates for a wide variety of careers in medicine, government, and industry. The first BME programs were accredited by ABET in the early 1970s [2] and at present there are 139 programs accredited, with new programs accredited each year [3].

In an effort to define the core content of a BME undergraduate curriculum, the VaNTH curriculum project identified key content and topics in BME curricula [4]. Efforts to analyze credit hour requirements across engineering programs have been conducted in other disciplines [5] and repeated throughout the years in BME programs to assess coverage of curriculum topics and to assess program tracks [6]. However, while the VaNTH project, ABET, and BMES provide guidelines on curriculum topics, no guidelines or requirements are given for laboratory courses. Further, the costs of implementing lab courses, breadth of application areas, and varying faculty expertise on experimental techniques leads to a wide range of laboratory offerings across BME programs. A variety of BME laboratory courses, activities, assessments, and best practices have been described in the literature [7-12], but to our knowledge there is not a current benchmarking study available to assess the landscape of laboratory courses in BME undergraduate programs. Towards this goal, we reviewed lab credit requirements for BME programs and surveyed BME instructors about their laboratory and project-based courses, including on techniques taught and methods of assessment. Preliminary data from the review of lab credit requirements and instructor survey will be presented.

Methods

A combination of an instructor survey and website data mining were used in the present study to evaluate the current use of laboratory courses in BME undergraduate programs.

Survey Design. The research team created a survey to collect lab credit requirements for BME programs and information directly from BME instructors about their laboratory and project-based courses (including senior design). Survey participants were asked to provide information on each laboratory course that they currently teach. Participants were asked course structure, credit hours, techniques taught, and methods of assessment. Participants were given the option to upload a course syllabus.

Survey Data Collection. Survey data were collected under institution IRB approval. Survey questions reported are listed in Appendix 1. The survey was advertised through information cards passed out to attendees at the Biomedical Engineering Society (BMES) annual meeting in

the fall of 2019 and through emails to the American Society for Engineering Education (ASEE) Biomedical Engineering Division (BED) listserv as well as LinkedIn. In the recruitment message, participants were notified that by participating in the survey they would be entered in a raffle for a $200 Amazon gift card. In all, 19 different institutions participated in the survey. Lab instructors, the majority non-tenure track faculty, directly responded and gave feedback on the courses they taught. The majority of respondents taught at large, ABET accredited programs across the country.

Program Data Collection. In addition to data collected from the survey participants, data mining of program webpages was conducted to extract missing information on overall curriculum requirements for lab courses offered, both within and outside of the department. US News and World Report was used as a baseline to establish the first top 20 undergraduate biomedical and bioengineering programs that were researched. The ABET accredited program search tool and College Choice was used to look into the next 20 top accredited programs bringing the total to 40. Data mining was conducted by searching university course catalogs and course syllabus maps from the registrar offices and the department websites. All courses that incorporated lab sections required for graduation were included in the research, and the total number of labs and course credit hours were recorded. Lab courses were distinguished as either BME labs, offered directly through the BME department, or general STEM labs (i.e. physics, chemistry, biology, etc.) to account for all required labs, including senior design. The number of credit hours/points was recorded per course to quantify and clarify differing credit formatting via different universities. Both BME and non-BME course numbers and credits were averaged for each university to substantiate the amount of BME labs and the total amount of labs required for the program. In order to account for the differences between university credit hours and academic calendar systems, programs were compared by the percent of BME lab credit hours of the total curriculum.

Results

The average number of required BME lab courses was 2.98 +/- 1.67 across all 40 universities studied, with an average required BME lab credit hours of 6.64 +/- 5.32. This represented an average of 5.18% +/- 3.18% of the total credit hours needed for graduation from these schools. Of all programs, six universities only required one laboratory course, and the highest number of required lab courses was eight. Multiple, mainly larger, universities offer a wide array of technical labs as electives and track coursework. Survey respondents were asked to report topics and techniques taught across their curriculum. Major areas that emerged were in anatomy and physiology, design, circuits and systems, biomechanics, and cell and molecular biology courses. In addition, many labs integrate in topics related to statistics and experimental design, design process, and technical communication skills. Results are summarized in Table 1.

Instructors were asked to give the grading schema for their lab course and those results are summarized in this paper. Lab reports are the largest portion of lab grades but remain largely varied in percentages of grades among universities and courses. Lab reports consisted of an average 51±20% of the grade, with most entries between 40-45% and an outlier of 90% of the grade. Pre-quizzes were also popular in BME lab courses with 23% of respondents citing pre-lab quizzes worth an average 14±4%

Table 1. Topics and techniques reported by BME lab instructors.	
Topics	**Techniques**
Statistics/Experimental design	Statistical tests (ANOVA, t-tests, etc.) and visualizations
Anatomy & Physiology	BIOPAC use, filtering, sampling, and data processing
Design process	Computer-aided design and modeling
Circuits & Systems	Circuit design, LabView, signal processing
Biomechanics	Material testing, 3D printing, computer-aided design, gait analysis, electromyography
Technical communication	Technical writing, record keeping, regulatory documentation
Cell & molecular biology	Cell culture, molecular analysis, data analysis, microscopy

of the grade, but with low variations between courses and all within the range of 10-20%. Not all courses reported lab notebooks, but those who did often also emphasized written communication in their lab learning outcomes and had lab notebooks account for 13±.075% of the overall grade. Participation was on the lower end of the grade percentage for those who responded, with many courses associating it with reports and notebooks. There was low variability as many courses attributed 5-12% of the grade to it, with an outlier maximum of 20%. There were many unique assessment items that were only mentioned once but showed the diversity of assessment methods possible in lab settings: Technical Reports (Design History Files, memos, quality reports, etc.), written exams, project, oral presentation, and posters.

Discussion

The main limitation of the present study is the number of survey participants. With 139 ABET accredited biomedical engineering programs, our current sample of 22 courses is small. A second limitation the research team encountered in the survey data collection phase was that some participants lacked a wider knowledge of their curriculum (e.g., how many total lab credit hours were included in the core curriculum). In future data collection efforts, the research team will work to collect program-level data separately to mitigate this limitation, which will serve a second benefit of shorter surveys which will potentially increase participation rates for the survey data collection. The research team plans to continue data collection, particularly to better understand lab techniques taught, and assessments implemented in biomedical engineering undergraduate labs.

Further, we propose that regular efforts to assess aspects of biomedical engineering curricula will be beneficial to the larger biomedical engineering education community and may promote future collaborations and sharing of educational materials. In the future, the research team seeks to establish such data collection and distribution to benefit the community and foster sharing of educational resources and best practices in biomedical engineering programs. These data and resources could be widely shared through BMES, ASEE BED, and the Biomedical Engineering Educator Conference (BEEC).

Acknowledgments

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References

[1] J. Bronzino, "Biomedical engineering: a historical perspective," in *Introduction to Biomedical Engineering*, ed: Elsevier, 2005, pp. 1-29.

[2] R. A. Linsenmeier, "What makes a biomedical engineer?," *IEEE Engineering in Medicine and Biology Magazine,* vol. 22, pp. 32-38, 2003.

[3] ABET, "ABET-Accredited Program search," 2019.

[4] R. A. Linsenmeier, T. R. Harris, and S. A. Olds, "The VaNTH bioengineering curriculum project," in *Proceedings of the Second Joint 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society][Engineering in Medicine and Biology*, 2002, pp. 2644-2645.

[5] D. G. Williamson and K. Fridley, "A Survey of Credit Hour Requirements in BS Civil, Electrical, and Mechanical Engineering ABET Accredited Programs," in *ASEE Annual Conference & Exposition*, 2017.

[6] J. R. Amos and G. R. Dupont, "Work in Progress: Are We on Track with Tracks?," in *ASEE Annual Conference & Exposition*, 2018.

[7] K. Jensen and P. Jensen, "Board 6: Work in Progress: Alternative Lab Reports for Biomedical Engineering," in *ASEE Annual Conference & Exposition*, 2019.

[8] J. Cezeaux, "Integration of Diverse Laboratory Experiences throughout the Biomedical Engineering Curriculum" in *ASEE Annual Conference & Exposition*, 2006.

[9] T. Allen, "Integrative Design and Experimental Analysis: A Yearlong Laboratory Course in Biomedical Engineering", in *ASEE Annual Conference & Exposition*, 2007.

[10] E. K. Bucholz, "Creating New Labs for an Existing Required Biomedical Engineering Imag-ing Course," in *ASEE Annual Conference & Exposition*, 2018.

[11] C. Zapanta, W. Ruder, J. Newberg, P. Glass, D. Minhas, E. G. Osuna, *et al.*, "An integrated undergraduate biomedical engineering laboratory course," in *ASEE Annual Conference & Exposition*, 2009.

[12] E. J. Perreault, M. Litt, and A. Saterbak, "Educational methods and best practices in BME laboratories," *Annals of biomedical engineering,* vol. 34, pp. 209-216, 2006.

Appendix 1. Survey questions reported.

Curriculum

Please indicate your department:

Is your undergraduate program ABET accredited?

- Yes
- No
- Not sure

How many total credit hours of lab courses are required for your undergraduate program (including senior design)?

How many lab courses does your department offer for undergraduate students (including senior design)?

What is your current position?

- Tenure track faculty
- Non-tenure track faculty
- Other (please specify)

Please indicate your institution:

What is your current rank?

- Assistant
- Associate
- Full
- Other (please specify):

Lab Course (for each course)

Please answer the next page of the survey for each lab or project course separately, so that we can capture how different types of courses are taught. You will be prompted at the bottom of the page to enter information for an additional course or to complete the survey.

What is the title of your course?

How are students assessed in your course and how are these assessments weighted (% of final grade)? (Examples of assessments: lab documentation, participation, lab practical, reports, prototype, etc.)

What topics are covered in your course instruction (examples: statistics, technical writing, etc.)?

What techniques are covered in your course (example: microscopy, mechanical testing, etc.)?

How many credit hours is your course (per semester if it is a sequence)?

Is your course offered

- Over one semester
- Over two semesters
- Less than one semester
- Other (please specify)

Is there any other information you would like to share about your course?

Please upload your course syllabus.