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BOARD # 21: Work in Progress: A Revised Biomedical Engineering Program: Building Student Engagement and Competency through Design, Aligned Courses, and Flexibility.

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WIP: A Revised Biomedical Engineering Program: Building Student Engagement and Competency through Design, Aligned Courses, and Flexibility.

Overview

This work-in-progress paper describes the curriculum revision in the Biomedical Engineering (BME) program at the University of Miami, a mid-sized, private university. This revision aims to increase student competency by emphasizing industry-relevant skills, while increasing student engagement through improved flexibility and engagement with real-world problems.

Original Curriculum

The original BME curriculum includes a set of core courses (see Table 1) and four tracks – Biomaterials and Tissue, Electrical, Mechanical, and Pre-med. Each track provides depth in one area of biomedical engineering (see Table 2). Students were required to complete one track to graduate. The original curriculum had been unchanged from the inception of the department in the 1990s, except for the addition of the Biomaterials and Tissue concentration in the 2012-13 academic year.

Table 1. Core Courses in Original Curriculum (Bold = taught by BME department)

CORE - MATHEMATICS AND SCIENCE		**CORE - ENGINEERING**	
Calculus I	5	Introduction to Engineering I	3
Calculus II	4	**Introduction to Engineering II (BME)**	2
Ordinary Differential Equations	3	**Matlab for Biomedical Engineers**	3
Mathematical Analysis in BME	3	**Foundations of Medical Imaging**	3
Biomedical Statistics	3	**Biomaterials**	3
General Biology	4	**Fundamentals of Biomechanics**	3
General Biology Laboratory	1	**Biomedical Design**	3
Medical Systems Physiology	3	**Senior Project I**	2
Human Physiology Laboratory	1	**Senior Project II**	1
Principles of Chemistry	4	**Biomedical Measurements**	4
Principles of Chemistry Laboratory	1	**Biomedical Transport Phenomena**	3
Physics I (Classical Mechanics)	3	**Biomedical Signal Analysis**	3
Physics II (Fluids, optics, thermal phenom.)	3	**Biomedical Instrumentation**	3
Physics III (Electromagnetism)	3	**Regulatory Control of Biomedical Devices**	3
Physics II Lab	1	ECE 201 Electrical Circuit Theory	3
Physics III Lab	1		
TOTAL COMMON CREDITS	**43**	**TOTAL COMMON CREDITS**	**42**

Table 2. Course for each Biomedical Engineering Track (Bold = taught by BME department)

Biomaterials and Tissue Track		**Mechanical**	
Cell Engineering	3	Mechanics of Solids	3
Cell Engineering Lab	1	Dynamics	3
Organic Chemistry I	4	Electrical Circuits Lab	1
Organic Chemistry I Lab	1	**Physiological Fluid Mechanics**	3
Tissue Engineering Lab	1	**Computer-Aided Design for BME**	1
Principles of Cellular and Tissue Eng.	3	**Tissue Mechanics**	3
Advanced Biomaterials	3	**Tech. Elective**	3
Tech. Elective	3	**Tech. Elective**	3
Tech. Elective	3	**Tech. Elective Lab**	1
TOTAL CREDITS	**22**	**TOTAL CREDITS**	**21**

Electrical		**Pre-Med**	
Electrical Circuits Lab	1	Organic Chemistry I	4
Electronics I	3	Organic Chemistry I Lab	1
Logic Design	3	Organic Chemistry II	4
Digital Design Laboratory	1	Organic Chemistry II Lab	2
LabView Applications for BME	1	Evolution & Biodiversity	4
Microcomputer-Based Medical Inst.	3	Evolution & Biodiversity Lab	1
Medical Electronic Systems Lab	2	Biochemistry for Biomedical Sciences	4
Tech. Elective	3	**Cell Engineering Lab**	1
Tech. Elective	3	**Tech. Elective**	3
Tech. Elective Lab	1	**Tech. Elective Lab**	1
TOTAL CREDITS	**21**	**TOTAL CREDITS**	**25**

Motivations for Change

The Biomaterials and Tissue track has become the most popular track with Electrical and Mechanical tracks each having an average of 4 students per year – less than 20% of all students. In parallel, BME programs have shifted away from concentration-based curricula. Comparing programs of similar ranking (peer) as well as several highly ranked and established programs (aspirational) showed that four out of six peers and five out of eight aspirational programs have removed tracks or requirements beyond their core courses. See Appendix A for details.

Further, input from our main stakeholders – students, graduates, faculty, and Industrial Advisory Board (IAB) – indicated that a change in our program was desired. This information was gathered via exit interviews, one-on-one conversations, and group discussions (student town halls, and meetings with our IAB, faculty retreats, etc.). From these discussions, several themes for improvement emerged:

- ***Stronger and intentional course interconnectivity***: In the original curriculum, students from different tracks took courses at varying times, making it hard to link topics across courses. Separating lecture-based and lab courses magnified this issue, as students could take labs before learning the relevant lecture material. Additionally, 1-credit skill-focused courses like CAD for BMEs and LabVIEW were often used to fill credit gaps in the final year of the program instead earlier when they would have been more useful.
- ***Focus on learning and using technical skills***: All stakeholders expressed a desire to have more technical skills upon graduation. Specifically, solid modeling (SolidWorks), technical programming (Matlab), and numerical simulation (COMSOL, or SolidWorks). There was a sense that the original curriculum did a good job introducing and reinforcing communication and teamwork skills, and that any revisions should keep this.
- ***Flexibility***: Students and faculty found the tracked system inflexible. Changing tracks often required extra courses or substitutions, and the rigidity limited students' ability to focus on topics outside the tracks. Additionally, there was a concern that the core courses overemphasized electrical and instrumentation topics (five courses: circuit theory, medical imaging, instrumentation, signal analysis, measurements).
- ***Work on "real world" problems***: Our students consistently stated that they want to impact the world directly and as such they want to work on "real world" problems. In the original curriculum, this occurred primarily through the Biomedical Design and Senior Design courses. Unfortunately, these came in the final semesters of the program.

Revised curriculum:
A curriculum revision committee with subcommittees representing each track created a revised curriculum that eliminates tracks, introduces new core classes, while increasing the number of technical electives (see Table 3). These changes were approved in the Spring 2023 and the first cohort of students in this curriculum started in Fall 2023. The major changes are:

- ***Design throughout the curriculum***: There are now design experiences in all years. In the first-year students are introduced to design through Global Challenges, Introduction to BME and Entrepreneurship classes. The second and third year have design and project sequences that expose them to need finding and concept generation with emphasis on building and testing with simulations and physical prototypes. These courses also introduce SolidWorks to all students.
- ***Labs and technical skills folded into core courses***: Instead of standalone labs, courses incorporate lab sessions into the lecture classes (e.g. Medical Systems and Human Physiology Lab now is Human Systems Physiology with Lab). Courses also emphasize assignments that require technical tools and skills (Matlab, SolidWorks, COMSOL, etc.).
- ***Increase technical electives and advising***: Students must complete 15 credits of technical electives from approved engineering, science, and math courses selected by the BME faculty. Each student is assigned a BME faculty mentor and an academic advisor. They meet with their mentor each semester to discuss career paths and course selection, while advisors ensure graduation requirements are met. Students interested in medical school are given specific guidance to meet the requirements for medical school.

Table 3. Revised core curriculum. New/Revised courses in bold

CORE - MATHEMATICS AND SCIENCE		**CORE - ENGINEERING**	
Calculus I for Engineers	5	**Innovation and Entrepreneurship**	3
Calculus II	4	**Global Challenges in Engineering**	3
Differential Equations	3	Introduction to Biomedical Engineering	2
Mathematical Analysis in BME	3	Matlab for Biomedical Engineers	3
Biomedical Statistics	3	**Biomedical Design I**	1
General Biology	4	**Biomedical Project I**	2
General Biology Laboratory	1	**Biomedical Design II**	1
Human Systems Physiology with lab	4	**Biomedical Project II**	2
Principles of Chemistry	4	Biomaterials	3
Principles of Chemistry Laboratory	1	**Living Systems Engineering**	3
Physics I for the Sciences	4	**Biomedical Instrumentation I**	4
Physics II for the Sciences	4	**Biomedical Instrumentation II**	3
Physics I Lab	1	**Applied Biotransport**	3
TOTAL COMMON CREDITS	**41**	Biomedical Signal Analysis	3
		Fundamentals of Biomechanics	3
		Capstone Project I	3
		Capstone Project II	3
		Regulatory Control of Biomedical Devices	3
		TOTAL COMMON CREDITS	**48**

Future work:
We are currently collecting survey data from the students. Data from Fall 2024 indicates that they like the exposure to design, but that the topics between 1st and 2nd year design courses are repetitive. We will assess student achievement using exit surveys and analysis of artifacts from student capstone projects from the 2025 and 2026 graduating classes (old curriculum) and 2027 and 2028 classes (new curriculum). These items will be compared against ABET criteria. This is an observational study. The University of Miami IRB has determined that this study is exempt from review.

Appendix A: Summary of Concentrations Available at Other Universities

Comparisons based on data available on the internet in Fall 2022

Table 1. Universities with no specific requirements for electives beyond core curriculum

University	Concentrations
Boston University*	Offers plain BME degree with 8 elective courses Electives divided into "BME electives", "Engineering electives", "Professional electives", and "Design electives"
Georgia Tech	Core curriculum with 4 BME "depth" electives; any courses on the list of depth electives may be selected; there are no restrictions for breadth either: these allow students the flexibility to complete a minor, do pre-med courses, get a certificate, etc.
Northwestern University*	26 core courses, 5 basic engineering courses, 11 courses BME core, 4 BME electives and 2 technical electives. Electives are selected from a list.
Rice University*	Bioengineering core courses (21 courses/labs) and bioengineering tech electives (3 courses)
University of Florida	Removed specialization tracks in 2017. 9 credits of BME electives and 6 credits of free electives
University of Pennsylvania*	3 "free electives", 2 "technical electives", 1 advanced BME elective, 1 engineering elective
Stanford University	Three relevant majors: bioengineering, biomechanical engineering, biomedical computation; 27 credits of core and 12 credits of "depth electives" (no restrictions)
Vanderbilt University*	4 BME electives, 3 technical electives (science, engineering, or math), 2 open electives. Courses subdivided into groups, but students don't have to choose courses within these groups
Columbia University	30 credits core, 21 credits (7 courses) of technical electives. At least 5 of 7 technical electives must be from an engineering department (but NOT Applied Physics/Math, CS, IEN, or Materials Science program), 3000 level or higher (with some noted exceptions). At least 2 of 7 MUST be BME courses. Several tracks with course sequences are suggested: Cell and Tissue Eng, Biomechanics, Biosignals and Biomedical Imaging, Neural Engineering, Genomics and Systems Biology, Quantitative Biology, Bioinductive and Biomimetic Materials, Biomaterials, Biomems and Nanotechnology, Robotics and Control of Biological Systems, PreMed/PreHealth

* indicates aspirational peer

Table 2. Universities with some rules/standards for electives

University	**Concentrations**
Case Western Reserve*	8 courses within a "specialty track": Devices and Instrumentation, Biomaterials, Biomechanics, Biomedical Computing and Analysis
Duke University*	"Elective Course Sequences": Biomedical imaging and instrumentation, Biomechanics, Electrobiology, Biomolecular and tissue engineering; 1 core class per sequence, 3 advanced electives (at least 2 in same area core)
Johns Hopkins University	18 credits basic sciences, 20 credits math, 18 credits humanities and social sciences, 30 credits of "biomedical core knowledge", 6 credits of design, 3 credits computer programming, 13 credits free electives (for pre-med courses, minors, etc.), and 21 credits of a "focus area". Focus areas include: biomedical data science, biomedical imaging and instrumentation, computational medicine, genomics and systems biology, immunoengineering, neuroengineering, translational cell and tissue
University of North Carolina, Chapel Hill/NC State	Three "gateway electives" to meet the pre-requisites for four "specialty electives" from no more than two specialization areas
University of Rochester*	Four courses in a "focus area" concentrations: biomechanics, biosignals and biosystems, cell and tissue engineering, medical optics

* indicates aspirational peer