

Using Guided Design Instruction to Motivate BME Sophomore Students to Learn Multidisciplinary Engineering Skills

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Abstract

Biomedical Engineering (BME) students at the University of Wisconsin-Madison participate in team-based design throughout the curriculum for six sequential semesters. Student teams work on hands-on, client-based, real-world biomedical design problems solicited from healthcare professionals, local industry, community members, and life sciences and clinical faculty. Through the design process, the students learn a variety of professional skills on topics including engineering notebooks, written and oral reports, engineering ethics, intellectual property, FDA approval, and animal/human subjects testing. The students also have the opportunity to learn as they are needed, various technical skills including computer-aided design, finite element analysis, machining/fabrication, electronics and electrical measurement and design, LabVIEW, MATLAB and microcontroller programming, mechanical testing, and basic laboratory techniques related to biomaterials and tissue engineering. As our student population has grown, we have had an increasing challenge to informally and effectively teach our students these cutting-edge skills that will enable them to be better engineers. In addition, our BME Student Advisory Committee (BSAC) has expressed interest in having more formal, directed training in a guided fashion early in the curriculum.

In order to effectively teach these important professional, technical, and life-long skills, we developed a new sophomore-level lecture/laboratory course, BME 201, “Biomedical Engineering Fundamentals and Design.” We offered it for the first time in Spring 2012, and it has been taught twice so far. The weekly lecture focuses directly on professional skills, and introduces students to the department’s five areas of study (bioinstrumentation, biomedical imaging, biomechanics, biomaterials/cellular/tissue engineering, and healthcare systems) through lectures by faculty in those areas. These lectures were recorded during the first offering so that the videos can be viewed outside of class, and the lecture time can be repurposed for a more blended learning experience in future offerings thus creating weekly modules.

The weekly laboratory period focuses on directly training the students in technical skills, such as those listed above that were previously offered on an *ad hoc* basis, in order train students to solve a multidisciplinary guided design project using these skills in teams. The laboratories were designed and are taught in conjunction with BME faculty instructors by undergraduate BME student assistants (SAs), allowing them to gain valuable teaching experience while giving our sophomore students an opportunity to learn from and interact with their peers. The guided design project requires the student teams to incorporate the knowledge and hands-on skills they learn during the semester to design and fabricate a bioreactor to measure the mechanical properties of soft biomaterials that they synthesize in our tissue engineering teaching lab. Throughout the project, the students maintain design notebooks, prepare product design specifications, create and present oral presentations, and communicate their design and results by preparing a technical report.

As this is the only course where all sophomore BME students are together, we have had the unique opportunity to teach them in an open forum led by their upperclassmen peers. Through

this multidisciplinary, blended, hands-on approach, early in the curriculum, students have obtained the skills they need to be successful in their future projects, to make informed decisions about their BME area of study and careers, and to enable them to become better engineers.

Introduction

The Biomedical Engineering (BME) Department at the University of Wisconsin-Madison developed a rigorous six-semester, team-based design curriculum for our undergraduates to solve real-world, client-based design problems when the department was founded in 1999 as shown in Figure 1.^{1,2} Teams of four or five students work on up to 41 different, real-world design projects every semester. This design sequence breaks down class boundaries, forms mentored relationships, actively involves each student in the evolution of the design courses and in the department, and engages the students in active learning.³⁻⁶ However, our Biomedical Student Advisory Committee (BSAC), as well as alumni and industry partners, have indicated a need for more direct technical design skill training and direct academic and career advising early in the curriculum to enhance student creativity and resourcefulness on subsequent team-based design projects and help them make informed decisions regarding academic and career choices. There are other BME departments in the country who offer multiple semesters of design and/or peer mentorship, however the students in BME at the University of Wisconsin-Madison are expected to build a physical prototype at the end of the semester for each of the six semesters of design.

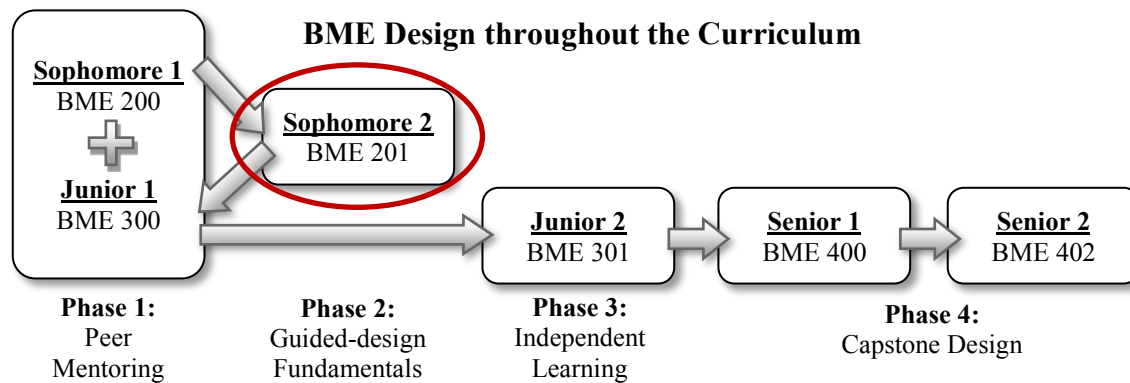


Figure 1: The BME design course sequence throughout the curriculum where each semester students work in teams of four or five on client-based design projects. During Phase 1, the junior students are teamed with and mentor the sophomore students; in Phase 2, historically the sophomore students worked on real-world problems independently. Beginning in 2012, we changed this course into the BME Fundamentals and Design course discussed in this paper. In Phase 3, the juniors start on a more complex project that they typically carry forward into Phase 4: senior year and capstone design.

The goals of each course are as follows:

BME 200 – First-semester sophomores are mentored and in part advised by first-semester juniors in teams of four-five on a real-world design project achievable in one semester. This model promotes peer-to-peer learning and enhances leadership qualities.

BME 201 – This course is the focus of this paper. Historically this course consisted of sophomore-only teams solving real-world problems.

BME 300 – First-semester juniors have the opportunity to teach the sophomores on their teams the design process. They also serve as mentors advising the younger students on curriculum issues and this serves as peer-to-peer mentoring.

BME 301 – Second-semester juniors start a more difficult design project that could lead toward their senior capstone design course. The intent is to instill in them the confidence to complete the design process on their own.

BME 400 – First-semester seniors complete and implement a more complicated design. They perform extensive research to fully develop and test their design. They also begin to work toward filing a patent and preparing a publication.

BME 402 – Final-semester seniors test, evaluate and improve their device and produce final documentation. All students complete an outreach requirement typically by giving a talk or organizing a hands-on activity in a K-12 classroom. They also write a technical paper in a journal format and if applicable, file for a patent and/or submit their paper to a journal.

All design courses require the following deliverables as well as the final design of a physical prototype:

1. Each student keeps an engineering notebook.
2. Each team submits a weekly progress report to their advisor and client by email.
3. Each team does a mid-semester PowerPoint presentation and a written report.
4. Each team produces an end-of-semester final report.
5. Each team maintains a website.
6. Each team does an end-of-semester public poster presentation.
7. Each student does a self and peer performance evaluation.

Over the last decade, the BME design students have solved a number of biomedical challenges, helping numerous companies, physicians, faculty, and patients.^{3,4} However BME students spend considerable time developing the necessary technical skills (such as SolidWorks, basic electronic circuits, microcontroller design, laboratory techniques, and others), as they are needed in order to solve these real-world problems. Over the years, we have provided workshops in the various skills areas so that groups of students who need to know a particular skill to complete their projects could acquire these skills in a just-in-time (JiT) learning mode. However, some seniors are still acquiring particular necessary skills even after taking five semesters of design. This learning curve sometimes hinders progress on developing these valuable designs and performing subsequent testing. These sessions have also become inadequate, as the student enrollment has grown. To effectively instruct this larger group of students, we decided that a new strategy was needed early in the curriculum.

Therefore our goal was to have a significant impact on our undergraduates' future by strengthening their core BME design expertise through implementing a new sophomore-level course called "*Biomedical Engineering Fundamentals and Design*." This course provides students with cutting edge hands-on technical and professional design skills for solving multidisciplinary biomedical design challenges. Following this course, we expect that our students will be more productive through their remaining four semesters of real-world, client-based design. This course consists of two parts, the lecture – a blended learning experience using video lectures and in-class problem solving overviewing the design process, introduction to technical content and advising; the laboratory – hands-on modules geared toward teaching multidisciplinary BME technical and professional skills; and the guided-design group project that assimilates all the other components of the course and independent research. The project implemented was the design of a bioreactor to perform simulated stress analysis on soft tissue constructs including developing a sensor-based computer acquisition and analysis system and performing relevant finite element computer modeling and biomaterial development. This new course, described herein will not only help support our growing student body, but will directly result in a more complete and rapid succession from the design specification to the prototype as our students solve biomedical engineering problems.

BME 201 Course Implementation

In the Spring 2012 semester we held the first offering of BME 201: *Biomedical Engineering Fundamentals and Design* (with 74 students followed by 82 students in the second offering). This course replaced our previously required second-semester sophomore design course. The course was implemented using the expertise of two instructors and 13 biomedical engineering Student Assistants (SAs) with experience in various technical skills needed for the course. The format of the course consisted of three components, lecture, laboratory, and a design project.

A. Lecture

The 50-minute lecture each week covered professional design skills and an overview of biomedical engineering. Expert speakers (including members of the BME faculty) were invited to talk about their areas of expertise. To accompany the BME track lectures, students with co-op, industry, or research experiences in these areas were also invited to act as an expert panel alongside the faculty speakers and course instructors. The topics taught in the lecture are shown in Appendix I.

The lectures in Spring 2012 were video captured and were used in spring 2013 as supplemental lectures. The lecture time for the second offering was utilized to preface the laboratory portion of the course in a blended fashion including problem solving and traditional lectures. This model allowed the labs to cover each design skill in greater depth.

B. Lab

The two-hour labs each week developed a diversity of hands-on skills that led to the completion by each student team of a multidisciplinary, guided design project—a physical prototype of a medical device. The topics taught in the lab are shown in Appendix I. Laboratory topics were

developed through interactions with our student advisor committee (BSAC) and student surveys, as well from our external advisory board's input. The skills that students indicated they utilized the most in past design projects and on internships and co-ops were made a priority and developed into guided exercises.

Students were required to review materials for each laboratory exercise before attending the lab period. They were provided with a laboratory manual as a required reading, consisting of a guide and future resources for each technical skill. For more advanced skills, such as SolidWorks, the students were required to review selected online materials and tutorials before the lab period. Students were tested on these materials through online quizzes before coming to lab.

C. Design Project

One of the aims of the course is to integrate the various skills acquired in the lab portion of the course into an open-ended guided design project thus combining the professional and technical design skills taught in the course. The students were divided in groups of 6-8 students, and all the student groups worked to solve the same design problem. We devised a multidisciplinary project that utilized all the skills taught in lab covering to some extent all five BME tracks: 1. Medical Instrumentation, 2. Medical Imaging, 3. Biomechanics, 4. Biomaterials/ Cellular/ Tissue Engineering, and 5. Health Care Systems. The project was to design a physical bioreactor to perform stress analysis on soft tissue using alginate samples fabricated by the students to mimic tissue. Appendix II provides an overview of the design project.

IV. BME 201 ABET Student Outcome Assessment

The Biomedical Engineering Department's Assessment Committee directly measures student performance by annually evaluating and quantifying student work from the previous year's design courses. A rubric based on our ABET Student Outcomes⁷ is used for directly measuring sophomore-, junior-, and senior-level performance.⁸ Thus we are able to track the performance of a graduating class through the curriculum and assess curricular changes such as in BME 201.

The Design Faculty acts as the Assessment Committee each Fall semester, a committee most recently consisting of 13 members. The committee randomly selects and reviews end-of-semester design reports and peer evaluations from several design (5–9) teams at each class level from the previous year – evaluating performance indicators for each Student Outcome, and evaluating the assessment process itself. At least two faculty members review each team's work with each reviewing at least three teams. Performance indicators are used to score each of the 12 student outcomes on a scale of 1–5 based on an established rubric for expected senior level achievement, yet all teams (regardless of level) are evaluated to this standard where seniors are said to have achieved a given student outcome with a score of four or higher. Through this process, the committee helps identify challenges and provides annual recommendations to the department's faculty.

Preliminary results after two years of assessment with the new BME 201: Biomedical Engineering Fundamentals and Design in place are shown in Figure 2, which indicate that on average, overall outcomes for the juniors with this course as background are higher than those

without. Juniors having had BME 201 were noted to have scored especially higher on outcomes related to using engineering tools, math, statistics, and those related to designing systems and solving biomedical problems. We acknowledge that Assessment Committee was aware that the most recent Junior class had the new BME 201, however, the Assessment Committee first calibrates scores by all reviewing the same senior team, and all teams (regardless of level) are scored to the same expectations. As such, the committee members are also asked to ignore the student team's level, thus bias is minimized. The number of students who took the new offering of BME 201 in 2012 and 2013 was 74 and 82 respectively. In the Figure caption of the assessment plot, n represents the number of teams assessed at each level. We will continue to use the Assessment Committee to directly assess the impact of the new BME 201 course.

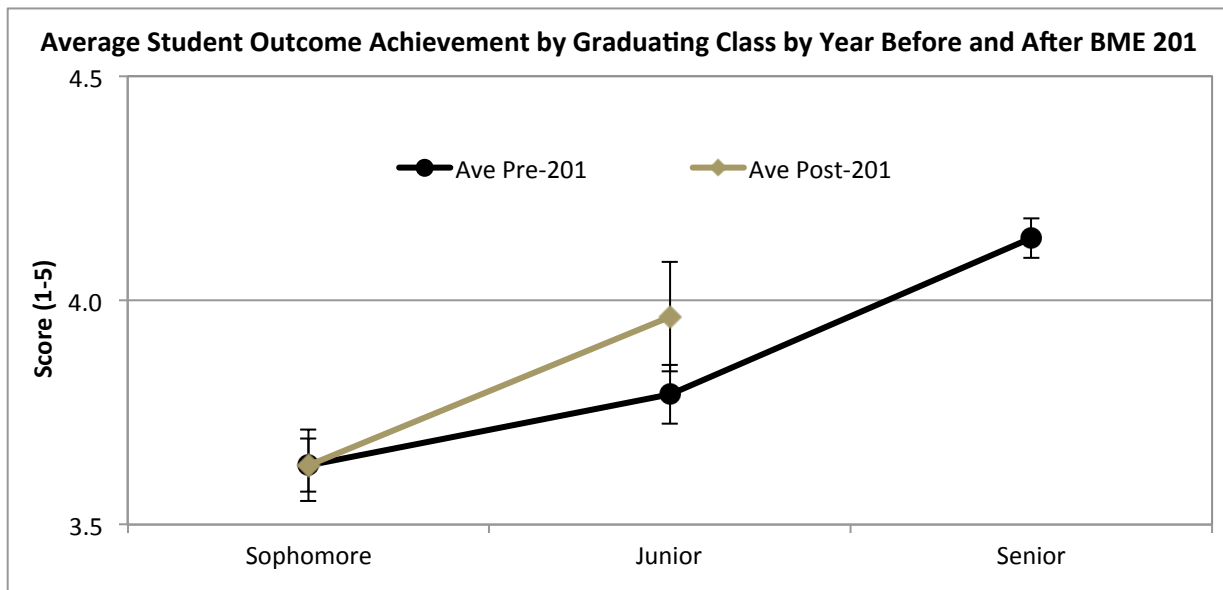


Figure 2: Assessment committee scores of ABET student outcome performance in the design curriculum following each graduating class through the curriculum and normalizing sophomore year performance. (●) Class of 2010–2013 average performance of all student outcomes having a traditional client-based design course for BME 201 (junior teams $n=16$ teams) (◆) Class of 2014 having had BME 201: Biomedical Engineering Fundamentals and Design (junior teams $n=5$).

V. Conclusion and Future Work

BME 201 is a required course for all sophomore students in BME. The goal of this course is to provide more direct technical design skill training and direct academic and career advising early in the curriculum. This should enhance student creativity and resourcefulness on future team-based design projects and help students to make informed decisions regarding academic and career choices. We have received positive response from the BME 201 students and from the BSAC for this course as it was offered in Spring 2012 and 2013. With the help of the SAs we have developed a course handbook for future BME 201 students, the contents of which are provided in Appendix III. We have received feedback from the BSAC and other students for course improvements. We plan to address these in the upcoming semester as described below.

Course improvement

We plan to further develop and improve upon this course as follows:

1. Increase the diversity of the blended learning experience using video lectures, in-class problem solving and advising
2. Improve and develop new hands-on laboratory modules geared toward teaching multidisciplinary BME technical and professional skills
3. Develop new guided-design multidisciplinary group projects
4. Implement an electronic lab notebook to speed content delivery, organization, and grading
5. Include new course content related to entrepreneurship and strengthen modules on engineering ethics

These five objectives will impact all the incoming sophomore students in the BME program.

We plan to implement the following five goals in the next BME 201 offering in the Spring 2014 semester.

1. Blended learning experience

During BME 201 in Spring 2012 we invited speakers to give lectures related to engineering design and the different study areas in BME. The lecture topics are listed in the Homework section of Appendix I. We recorded these lectures and made them available to BME 201 students in Spring 2013 as a blended learning exercise. Consequently, we used the lecture time for more design-related instruction and problem-solving. Based on the feedback we received from the students in that semester, we intend to re-record some of the lectures and add more lectures to help provide more information on topics related to engineering design and BME. In Spring 2014, we plan to use most/all of the lecture time for problem solving.

In 2013, we experimented with the Collaboratory for Enhanced Learning (WisCEL) facility in the College of Engineering library. This facility offers technology-enhanced, collaboration-friendly learning spaces for effective teaching and learning. Aspects of the blended instruction is inspired from one of the core course Bioinstrumentation taught in our department.⁹ We used the WisCEL facility for few of the BME 201 lectures to teach SolidWorks, LabVIEW, MATLAB and have the students work in teams on the design project. The WisCEL facility worked very well as all the students had computer access to learn these engineering tools. We plan to hold every BME 201 “lecture” (problem-solving session) in the WisCEL facility to maximize instructional value.

2. Hands-on laboratory modules

The laboratory section of the course was geared towards multidisciplinary hands-on learning experiences. In order to prepare BME students with technical skills in different areas of BME we taught a variety of introductory labs as shown in the Lab section of Appendix I. To better prepare the students for these diverse technical skills we developed online prelab quizzes on Moodle for students to take before they came to the lab. This ensured that the students had an opportunity to review the material in advance.

Additionally, we have found that the two-hour time period for these labs was inadequate; and have since increased the lab times to three hours and therefore the instructional content of all the labs. Also, based on our experiences, we plan to update specific labs as new technology becomes available (and/or less expensive), such as modifying the microcontroller lab to incorporate Arduino microcontrollers, instead of the current PIC microcontrollers. We hope this will expedite the students' learning experiences and encourage them to start programming the microcontroller without needing a detailed understanding of the microcontroller architecture, which is currently expected from them.

3. Guided-design group project

The BME 201 students work on a guided-design project that attempts to incorporate all the technical and professional skills they have learned in the course. The guided-design project process allows them to appreciate how the different areas of BME integrate with each other. In Spring 2012 and 2013, we had the students design and build a bioreactor system to test the mechanical properties of a biomaterial (alginate gel) that they synthesized. The students were required to develop a 3D model and perform finite element modeling of their bioreactor chamber in SolidWorks, and use the mill and lathe in the College of Engineering Student Shop to fabricate it. They performed stress tests on the alginate gels prepared in the tissue engineering labs and obtained the force/displacement data on computer by constructing a microcontroller-based electronic system. They further performed statistical analysis using MATLAB for the various experimental conditions and then compared the results of their testing under physiological conditions to data they obtained using the MTS machine. The students compiled a detailed report of their design process and presented it to the student lab group.

Since we have used the bioreactor design project for two consecutive years, for the Spring 2014 offering of the course, we plan to develop a different guided-design project with the similar goal of integrating different areas in BME. Ultimately, we will have three-to-four unique guided-design projects. Since our sophomores are mentored by the juniors in their first semester in the program (by combining students in BME 200 and 300 into teams), the diversity of projects will reduce the probability of content being passed down. Additionally, since we utilize juniors and seniors as student assistants, new design projects will afford them new learning opportunities.

4. Electronic Lab Notebook Implementation

We developed a BME 201 course textbook/laboratory notebook, which was written by the student assistants and instructors during Spring–Fall, 2012 and made available to the students in Spring 2013. The textbook contains all the labs, instructional materials and the lab notebook for the course. The lab notebook is an essential part of this course as the students are expected to take notes on their lab exercises and the design project. The lab notebook also accounts for a part of their final grade. In Spring 2014, we plan to implement an electronic lab notebook through LabArchives. We plan to incorporate the BME 201 textbook into the electronic lab notebook, where they can take notes for their lab exercises. The electronic notebook will also be used for maintaining a record for their design projects. The instructors and the student assistants will have access to these electronic lab notebooks for grading purposes and for providing continuous

feedback to the students. Hence the students will not be required to submit any paper copy for their lab assignments.

Laboratory notebooks are an essential part of design, and with LabArchives, course content and the notebook are tied together with built-in grading tools. Together with Moodle, the online notebooks will drastically reduce grading time and thus facilitate increased enrollment and dynamic changes to course content. There is no instructional cost associated with LabArchives; students pay \$5-\$10 per semester for access to the course notebook (which is less expensive than the \$20 print copy of the notebook required for the course). The students can also download an offline copy of their final notebook to keep as a reference. We evaluated LabArchives for possible use in all of our BME design courses in the Fall 2013 semester.¹⁰

5. Entrepreneurship and ethics

Often there exists a disconnect between engineering a solution to a problem and making that design idea marketable, then translating that idea into a product. Along with the extensive toolbox of hands-on skills present in BME 201, we wish to implement an entrepreneurship module toward the end of the semester that will prepare the sophomore students to translate their ideas into marketable products in subsequent semesters. We plan to work with the Institutes for Discovery Entrepreneurship Center to develop this module. Finally, we wish to strengthen our ethics module so our students continue incorporating appropriate ethical considerations into their design early in the curriculum, as well as practicing responsible research habits.

Over the last two years we have collected course evaluations and surveys from the BME 201 students. We have also received valuable feedback from BSAC to assess BME 201. A major outcome of this course is its impact on the student's progress in subsequent semesters of BME Design. As part of our department's assessment process we will continue evaluating the impact of this course on senior attainment of our ABET outcomes.

Final Remarks

Within the course, the new content and online laboratory notebooks will significantly facilitate assessment. It will also provide a permanent searchable archive of all materials for both the student and the instructors (not achievable with paper notebooks and assignments). We have received a grant through the College of Engineering Educational Innovation initiative at the University of Wisconsin-Madison to implement the above five goals.

We believe that BME 201 is a unique course and provides students with a broader perspective of the different areas in BME than they have had in the past, in addition to valuable hands-on technical and professional skills. We would like to form partnerships with other departments on campus interested in developing similar courses for their curricula.

Acknowledgements: We would like to thank the entire BME design faculty, our Biomedical Engineering Student Advisory Committee and the following undergraduate students: Zachary Balsiger, Gabriel Bautista, Eamon Bernardoni, Alenna Beroza, Matthew Bollom, Isabel Callan, Robert Carson, Caleb Durante, Joelene Enge, Jack Goss, Vanessa Grosskopf, Kelly Hanneken,

Kelsie Harris, Yuan He, Jeff Hlinka, Danielle Horn, Brandon Jonen, Hallie Kreitlow, Clair Kurzynski, Bradley Lindevig, Russell Little, Amanda MacAllister, Maria Maza, Abhishek Mehrotra, Jacob Meyer, Alyssa Mitchell, Mike Nonte, Samantha Paulsen, Sarah Reichert, Olivia Rice, Andrea Schuster, Nicholas Shiley, Amy Slawson, Rebecca Stoebe, Zach Vargas, Kelsey Vesperat, Don Weier, Bradley Wendorff, as well as all other BME undergraduate students who have helped and are helping with the course.

Part of the BME 201 course improvement project is being supported by the College of Engineering Educational Innovation Initiative at the University of Wisconsin-Madison from July 1, 2013 - June 30, 2014. Points of view in this document are those of the authors.

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Appendix I: Syllabus for the Spring 2013 semester

BME 201: Biomedical Engineering Fundamentals and Design

Spring 2013

Students will learn fundamentals of biomedical engineering and design techniques. Through a combination of labs, lectures, and a guided design projects, students will have the skills and knowledge to enable them to be successful in future design courses.

Lecture

Engineering Hall 2317
Fridays, 12:05 - 12:55 PM

Lab

Engineering Centers Building 2005 & 2043

Section 301:	Tuesday	7:45 - 9:45 AM
Section 302:	Tuesday	11:00 AM - 1:00 PM
Section 303:	Wednesday	2:25 - 4:25 PM
Section 304:	Thursday	7:45 - 9:45 AM
Section 305:	Thursday	11:00 AM - 1:00 PM
Section 306:	Friday	1:20 - 3:20 PM

Course Websites

Moodle Courses <https://courses.moodle.wisc.edu/prod/course/view.php?id=625>
Piazza <https://piazza.com/wisc/spring2013/bme201/home>

Learning Objectives

Students will learn the broad fundamentals of biomedical engineering and also the design process including such topics as ethical behavior, particularly with respect to human and animal subjects, intellectual property considerations, global biomedical engineering, codes and standards, and FDA regulations. The students will receive hands-on training on machining, wet-lab techniques, computer-aided modeling and simulation, basic electrical and electronics circuit design and computer programming.

Lecture

The 50 minute lecture each week will provide an introduction to lab topics or provide time for teams to work on their design project.

For lectures associated with lab material, please watch the mini lecture posted on Moodle Courses prior to lecture. Problems will given during these lectures to enable you to better understand the lab material prior to lab. Since the material covered in these lectures are directly related to the lab material, watching these mini lectures and participating in the problem sets will be excellent preparation for the pre-lab quizzes.

For lectures associated with the design project, teams will be given time to meet and work on their design project. Instructors will be available for consultation.

Lab

The two-hour labs each week develop a diversity of hands-on skills that will lead to the completion of a multidisciplinary, guided design project – a physical prototype of a medical device by each student team.

Prior to each lab, read through the notes and lab in your course handbook. Complete the associated pre-lab quiz. These pre-lab quizzes are configured to allow for multiple attempts with the highest grade stored in the grade book. However, these quizzes will not provide you with the correct answer if you get a question wrong. Pre-lab quizzes will open one week before lab and close at the start of lab.

Homework

The weekly homework assignment consists of watching lecture videos from a previous offering of the course. These videos are linked from the Moodle Courses homepage. A short reflection on the video is due at noon the following Monday.

Required Materials

The required BME 201 Course Handbook will be sold by the UW Chapter of the Biomedical Engineering Society (BMES) during the first lecture for \$20.00. There are no other required textbooks. Videos, slides, and written materials will be provided on Moodle Courses.

Printing access (such as through your CAE account) will also be needed for some supplemental materials to your handbook such as Lab 2 and notes about the design project.

Course Handbook

The BME 201 Course Handbook contains notes about design project topics, the lab materials, and starting space for your design notebook. The handbook contains a few blank pages for the design project, but it will not be sufficient. Rather than making you purchase blank pages you might not use, a blank PDF of the notebook page will be posted on Moodle Courses. Print this document as needed and add it to the end of your notebook.

Since this handbook is considered an engineering notebook, follow proper documentation procedures. Always write your entries in pen and don't allow anyone else to write in your notebook. More detailed notes regarding notebooks can be found starting on page 5 of the course handbook. This will also be discussed during the first lab period.

At the end of the semester, your handbook will be submitted for grading. It will be returned to you for future reference.

Piazza

This semester, we will be using Piazza for class discussion and distributing class-related information. The system is highly catered to getting you help fast and efficiently from classmates, the SAs, and instructors. Rather than emailing questions to the teaching staff, please post your questions on Piazza.

Teaching Staff

This course is taught with the assistance of undergraduate student assistants (SAs). The SAs have

been selected because of their knowledge and experience and are available to help you during lab and with your design project. If you have questions during the semester, please talk to an SA during lab or post a question on Piazza.

If you are interested in serving as an SA for a future offering of the course, please apply during the fall semester.

Grading Policy

Lecture attendance	10%
Laboratory notebook (course handbook)	60%
Laboratory experiments and quizzes	15%
Design Project	15%

Tentative Grading Scale

A:	93% and above
AB:	88% – 92%
B:	80% – 87%
BC:	70% – 79%
C:	60% – 69%
D:	50% – 59%
F:	below 50%

Tentative Course Schedule

Date	Lab	Lecture	Design Project	Homework
Jan 22	Introduction to Lab & Shop Quizzes	Introduction to BME 201 & Electronics Part I	Pick teams	“Principle and Practice of Design”
Jan 27	Electronics Part I	Electronics Part II	Literature review	“Introduction to the PDS, FDA, and Standards & Codes”
Feb 3	Electronics Part II	LabVIEW Part I*	PDS	“Introduction to Healthcare Systems Track”
Feb 10	LabVIEW Part I	LabVIEW Part II*	Electronics, LabVIEW, & Microcontrollers	“Introduction to Biomechanics”
Feb 17	LabVIEW Part II	Microcontrollers Part I		“Introduction to Biomaterials & Tissue Engineering”
Feb 24	Microcontrollers Part I	Microcontrollers Part II		“Introduction to Medical Instrumentation”
Mar 3	Microcontrollers Part II	BME Class/Career Advising Day ^b	SolidWorks	“Introduction to Biomedical Imaging”
Mar 10	3D Modeling and Stress Analysis I	3D Modeling and Stress Analysis*		“Impact of Engineering Solutions in a Global and Societal Context”
Mar 17	3D Modeling and Stress Analysis II	Design Project*	Fabrication	“Ethical Problem Solving”
Mar 24	Spring Break			
Mar 31	Biomaterials and Tissue Engineering	Tong Distinguished Entrepreneur Lecture ^b	Fabrication	“Human Subjects in Research & Institutional Review Boards”
Apr 7	Cell Culture and Hydrogels	MATLAB I*	Testing & Analysis	
Apr 14	Design Project	MATLAB II*		
Apr 21	Design Project	Design Project	Presentation & Paper	Human and Animal Subjects Certification
Apr 28	Design Project	Attend Design Presentations		
May 5	Design Project Presentations	No lecture	Design Project deliverables due May 10, 2013 at 5:00PM	

* Lecture will be held in Wendt 410 (4th floor),

^b Lecture will be held in 1610 Engineering Hall

Appendix II: BME 201 Design Project

BME 201 Design Project Overview

Design and fabricate a simple bioreactor to measure the mechanical properties (ultimate strength and Young's modulus) of a common biomaterial known as alginate.

Overview

Tissue engineering is a rapidly expanding field, which results in the creation of novel biomaterials from year to year. It is important to meticulously study every property of these biomaterials to explain in detail how they interact, function, and support portions of the body. Some of the main biomaterial properties to determine are the mechanical properties; for example if cells are encapsulated in an alginate gel, how much mechanical stress in the body could it endure before rupturing and exposing its contents? These types of questions can be answered by replicating the in-vivo environment with a simple bioreactor and applying a known force until the alginate sample ruptures. Biomedical engineers need to be equipped with the knowledge of basic electronics, programming, and fabrication in order to perform experiments and answer such questions related to biomaterials testing. Simple bioreactors in combination with force sensors can be applied to many fields such as measuring the structural stiffness of bone samples or the tensile strength of tendons.

General Specifications

- Height of the alginate sample to be tested in the bioreactor is 10 mm.
- Diameter of the alginate sample to be tested in the bioreactor is 15.6 mm.
- Alginate sample needs to be completely immersed in the Phosphate Buffer Saline (PBS).
- Outer diameter of the bioreactor has to be less than 3.8 cm (1.5 inch).
- The bioreactor needs to have two holes, one for input and one for output in order to allow PBS to flow through the simple bioreactor. Diameter of the holes will be provided later.
- The max force to be measured is 0.907 kg (2 lbs).
- Material of choice for the bioreactor is polycarbonate.
- Force and displacement will be measured.
- Force will be measured using a force-sensing resistor. Displacement will be measured with a digital calipers with RS232 output. Both sensors will be provided to you, but system implementation and programming will be your responsibility.
- The force and displacement data needs to be acquired on the computer using a microcontroller.

Appendix III: BME 201 Course Handbook

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