121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #10344

Promoting Active Learning in Biomedical Engineering Classes through Blended Instruction

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Promoting Active Learning in Biomedical Engineering Classes through Blended Instruction

Abstract

In 2013 we implemented blended teaching in one of the core biomedical engineering classes Bioinstrumentation (BME 310) in the Biomedical Engineering Department at the University of Wisconsin-Madison. BME 310 is a required sophomore level first course in bioinstrumentation covering clinical and research measurements.

Each chapter in the textbook is explained through a list of Learning Objectives (LOs), which contains a summary of the concepts, relationships, and skills presented in this course. For each of the LOs we prepared a power point slide with an online video, which is about 1 to 4 min long. The students are required to view the video and take an online quiz with automated grading before they come to the lecture class. In the lecture class, we conduct 10 min in-class quizzes based on the material taught in the previous video and class. We have a 30 min in-class problem solving session with 7 students at each round table in a big classroom. The instructor and lab teaching assistants walk around and answer student questions in class. The instructor gives a 10 min lecture at the end of the class discussing the solutions to problems solved during lecture time. The solutions to these problems are posted on the course webpage.

We assessed the traditional and blended teaching style for BME 310 with regards to the student engagement with the course inside and outside the classroom, and observed students' increased time involvement with the course.

One of our challenges was the adequate space needed for blended instruction for 88 students. We wanted the students to sit in groups around a table, so they could work together and share ideas. However, this requires more space than for traditional classroom instruction, which we received through our college of engineering. In 2014 we implemented further changes.

I. Introduction

Course Information

Bioinstrumentation (BME 310) is a required sophomore level course in the Biomedical Engineering Department, University of Wisconsin-Madison, which teaches the fundamentals of clinical and research measurements. The course covers the following topics: designing medical instruments, displacement sensors, temperature and optical sensors, amplifiers and signal processing, cell, nerve, and muscle potentials, electrocardiogram, electrode polarization, surface electrodes, electrocardiograph, power line interference, blood pressure sensors, heart sound sensors, blood flowmeters, impedance plethysmography, respiratory pressure and flow, respiratory gas concentration, blood-gas sensors, noninvasive blood-gas sensors, clinical laboratory measurements, radiography, MRI, and ultrasonic imaging,.

Appendix I shows the course outline. The purpose of the course is to prepare students for choices of either graduate school, medical school or employment by learning and accomplishing goals in the following areas: using vocabulary of the field by reading the text and from on-line lectures; analyzing systems by solving in-class problems; designing systems by performing in-class design themselves; searching for new information such as articles and patents using the web; presenting information by writing a paper.

Students learn best when course expectations are clear. We provide them with a course outline, on-line lectures, on-line quizzes, in-class problems, in-class quizzes, and a list of instructional or learning objectives to guide their learning. Students are expected to read the assigned instructional objectives prior to class in order to be prepared to discuss them during class. Quizzes are open book to encourage learning by problem solving rather than by rote, as problem-solving skills are essential for graduate work or in industry. Further each student writes a research paper on a topic not well presented in the text, and is provided feedback to improve their presentation skills. This teaches them to research relevant information on web, in books, periodicals and patents, to organize it and to present it in a meaningful way. The above method of instruction prepares students for lifelong learning. Students will know how to find information, critically select it, and present it. This course was taught in the traditional style from 2001 to 2012. We implemented the blended teaching style for this course for the first time in spring 2013 and the second time in spring 2014.

II. Traditional Teaching for BME 310

Traditional education emphasizes lectures and instructions directly given by the instructor. Therefore, it has been categorized into instructor-centered style.[1] Listening in class is playing an important role in learning and managing new knowledge.[2] The instructor introduces the topic, principles, equations and application models through lectures in class. This style also gives students practice through homework and test whether they manage and control knowledge through exams.[3]

Traditional teaching of BME 310 in the Biomedical Engineering Department at the University of Wisconsin-Madison consisted of 25 lectures by the instructor, 25 homework assignments, three in-class hour exams, 13 labs and one research paper to be written by the students. Typically one homework assignment consisting of two problems was assigned per lecture. The 25 homework assignments needed to be completed out of class individually. The students sought mentoring from the TAs and the instructor through office hours. However we observed minimal student interaction with the TAs and instructor during office hours, due to lack of time, overlap of schedules and such. This sometimes caused frustration to the students with their inability to get necessary mentoring to understand the concepts and to solve the homework problems. The three 50 min in-class exams were conducted during normal lecture times. Historically Exam I focused on Chapters 1, 2 and 7, Exam II on Chapters 8, 9 and 10 and Exam III on Chapters 3, 4, 5 and 6.

Some of the other major universities teach Biomedical Instrumentation differently. At one of the universities the course has three different sections focusing on Signals & Systems, Molecules & Cells and Applied Physical Laboratory. The students can choose corresponding sections according to their requirements. Each section usually has take-home assignments, in-class problems, labs, paper and presentation.[4] Usually Biomedical Instrumentation courses have lecture and laboratory. One of the other universities focuses on both theoretical and practical concepts of instrumentation and highlights laboratory skills as well as homework, presentation and final exam.[5] While, another university evaluates the ability and skill of students by laboratory report, final design report and specific writing tasks, three prelims and the final design report.[6]

III. Blended Teaching for BME 310

Blended Teaching Style

Blended teaching takes advantage of the current instructional and multimedia technologies, the goal is to accommodate different learning styles of students. The frequent uses of Internet, digital media and web-based communication yield the blended teaching style platform. Currently, the main use of blended learning usually combines modern technologies with traditional teaching style.[7] Advanced technologies incorporated with blended teaching are a significant factor to satisfy students and to achieve success in blended learning courses.[8,9]

Both instructor and students can benefit from blended teaching. The instructor improves design ability according to the students' requirements. In addition, blended learning allows the instructor to integrate and rearrange existing course sources instead of replacing them.[10] Blended teaching now is an increasingly popular format of teaching.[11] It is becoming more and more widely used in engineering fields such as control engineering.[12]

Blended teaching forms a new relationship between instructors and students. Blended teaching helps develop the self-learning abilities of students, communication and collaboration abilities between different students. The students involved in blended teaching tend to take more initiative and are likely to control and manage the study pace and time by themselves compared to the students in traditional teaching styles. The students in blended teaching seem to adopt knowledge and new things with higher efficiency than students involved in traditional teaching styles. Blended teaching gives students a variety of ways to demonstrate their knowledge and encourages them to become lifelong learners.[13] The data/survey in one engineering course showed that students accept blended learning quite well, and their academic achievements were also better than expected.[14] Blended teaching offers a variety of choices for instructors to choose from, which makes the teaching style more flexible and easily accepted by different levels of students. The blended learning process consists of online content, collaboration and assessment.[15] In blended teaching, instructor/lecturer and students communicate more than in the traditional style and students can understand material better based on use of "computer-based qualitative and quantitative assessment modules".[16] The motivation and engagement of students is a significant factor for the academic success of blended-learning.[17] Also the students' satisfactions come from the support from the instructor and technologies used in the course system.[5]

Blended Teaching for BME 310 at University of Wisconsin-Madison

In spring 2013 we implemented the blended teaching style for BME 310 for the first time. Each chapter in the textbook was explained through a list of Learning Objectives (LOs), which contains a summary of the concepts, relationships, and skills presented in this course. Appendix II shows example of these LOs for chapter 1. The LOs provide students with a guide for learning the material in the chapter. For each of the LOs we prepared a power point slide with an online video, which is about 1 to 4 min long as shown in figure 1. Before coming to the lecture, students watch about 10 or more online videos related to the LOs as shown in the syllabus in Appendix I. These videos introduce the basic concepts and material of the course. At the end of the each video the students take an online quiz that is automatically graded. The students can view the videos multiple times and take these quizzes at their own pace, which facilitates their learning process.

In 2013 at the beginning of each class students took a 10 min quiz consisting of 2 problems/questions based on the material discussed in the previous lectures. These quizzes reinforced the material learned and facilitated continuous learning, as compared to learning just for exams. After the 10 min quiz, they had a 30 min in-class problem solving session. We "flipped" our traditional classroom space, thus typically a group of six to seven students sat around a round table in a big classroom and solved 6 to 7 problems/questions together. The instructor and the four TAs walked around each of these round tables and answered questions for individual students. The students got to interact with other students around their table and solved the problems collectively and this greatly facilitated their peer-to-peer learning process. In addition to this they interacted with the instructor and TAs on an individual basis. The collaborative peer-to-peer communication and individual interactions with the instructors and the TAs greatly enhanced their learning process. The instructor gave a 10 min lecture and discussion at the end of the class discussing the solutions to problems solved during class time. The solutions to these problems were posted on the course webpage after each class. Also, to measure students' knowledge and learning abilities, other assessments besides the pre-quiz and class-quiz such as research paper writing and lab experience were also required. Research paper writing developed the students' ability to learn and find information that is not readily available and select information that is important and reject information that is not. We implemented aspects of the blended instruction for BME310 into one of the core courses BME201: Biomedical Engineering Fundamentals and Design in our department.[18]

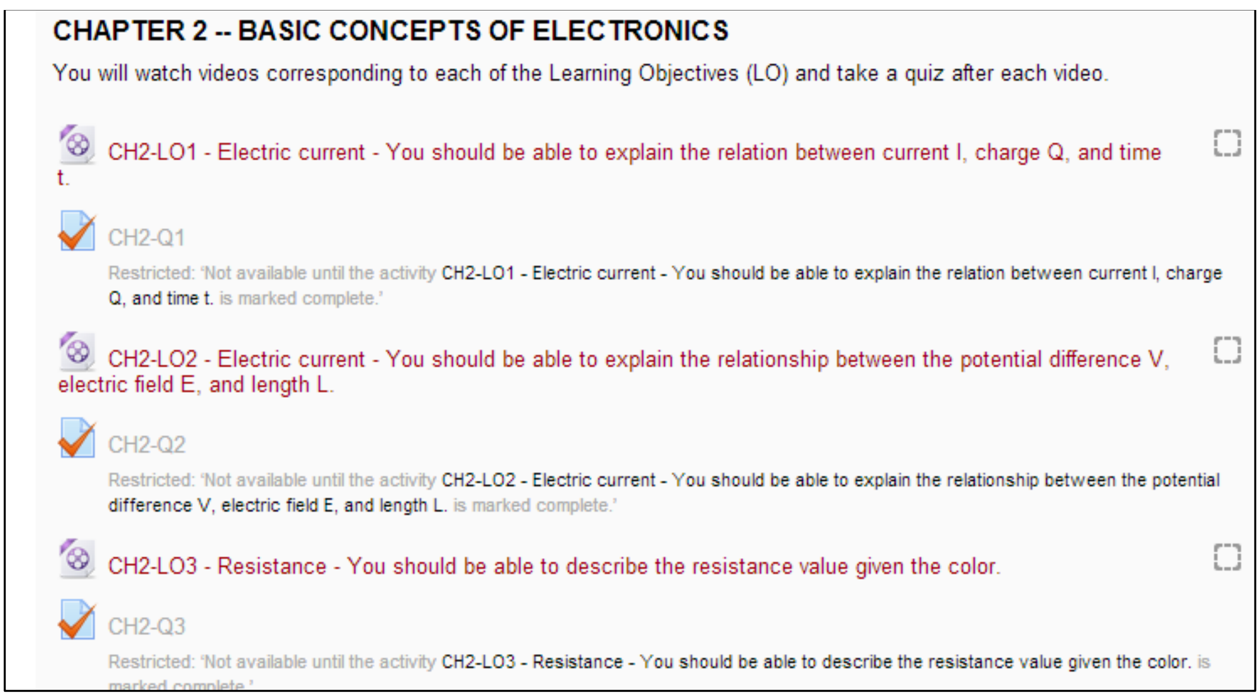

Figure 1 - On our website course (Moodle) we provide power point slides with voiceover with online videos, which are each about 1 to 4 min long.

Grading Policy

Our online grading policy consists of: On-line pre-class quizzes must be completed 1 h before class, 10% (each counts 1.0, normalized to 10% at end of semester); 10 min open book in-class quizzes 50% (lowest 4 times will not count) (each counts 2.0 summed to 50% at end of semester); laboratory performance and reports, 30% (pre-lab quiz 10%, bench exam 1: 15%, bench exam 2: 15%, reports 60%); paper, 10%. We asked the students to work individually on pre-class quizzes, open book in-class quizzes, lab reports, and paper. The students are supposed to work and study together on all other aspects of the course that are not graded.

IV. Technology used

We used the HD Everio camera to make the videos on medical or lab instruments and Everio MediaBrowser 3 to download the video from the Everio camera. We used Camtasia Studio 8 to make the instructor's voice over for the PowerPoint or captured figures on the screen and used Camtasia Studio 8 to edit the videos we needed. All the videos were posted on the course webpage using Moodle. The link is provided for Camtasia Studio official Site to learn how to create the instructional videos.[19] Other camera or media could also finish making video and other images and the video editing tool could also edit the videos as well as make the instructor's voice over.

V. Assessments for Traditional and Blended Teaching for BME 310

Traditional Teaching Style for BME 310

We evaluated the traditional and blended teaching for BME 310 based on the amount of time students spent on learning, interacting with other students, TAs and instructor for the course, and the grade distribution over the last four years.. The features in Moodle kept a log of the time students spent answering the pre lecture quizzes for each chapter. Figure 1 shows number of prelecture quizzes students need to finish for each chapter before they came to the lecture, and the corresponding average total time taken to finish them. Each chapter had more than 15 prelecture quizzes and the students spent on average more than 15 min to watch the videos (as they are each 1 to 4 min long). Also, they spent 30 min or more to take each of these quizzes. The students spent on average more time per quiz to answer quizzes for chapter 2, 3, 7, 8 and 10. The standard deviation of the time taken to answer quizzes for chapter 2, 3 and 8 is higher as compared to the other chapters. This information helps us to identify the most challenging concepts in the course for the students and accordingly develop strategies to better teach them.

Overall we developed 262 prelecture quizzes for 10 chapters of the course textbook. In order to determine the average total time taken for the prelecture quizzes shown in figure 2, we randomly chose 10 quizzes from each chapter for all the 88 students and took an average of the time taken to finish them. Thus out of the 262 prelecture quizzes, 100 quizzes were selected randomly for our analysis.

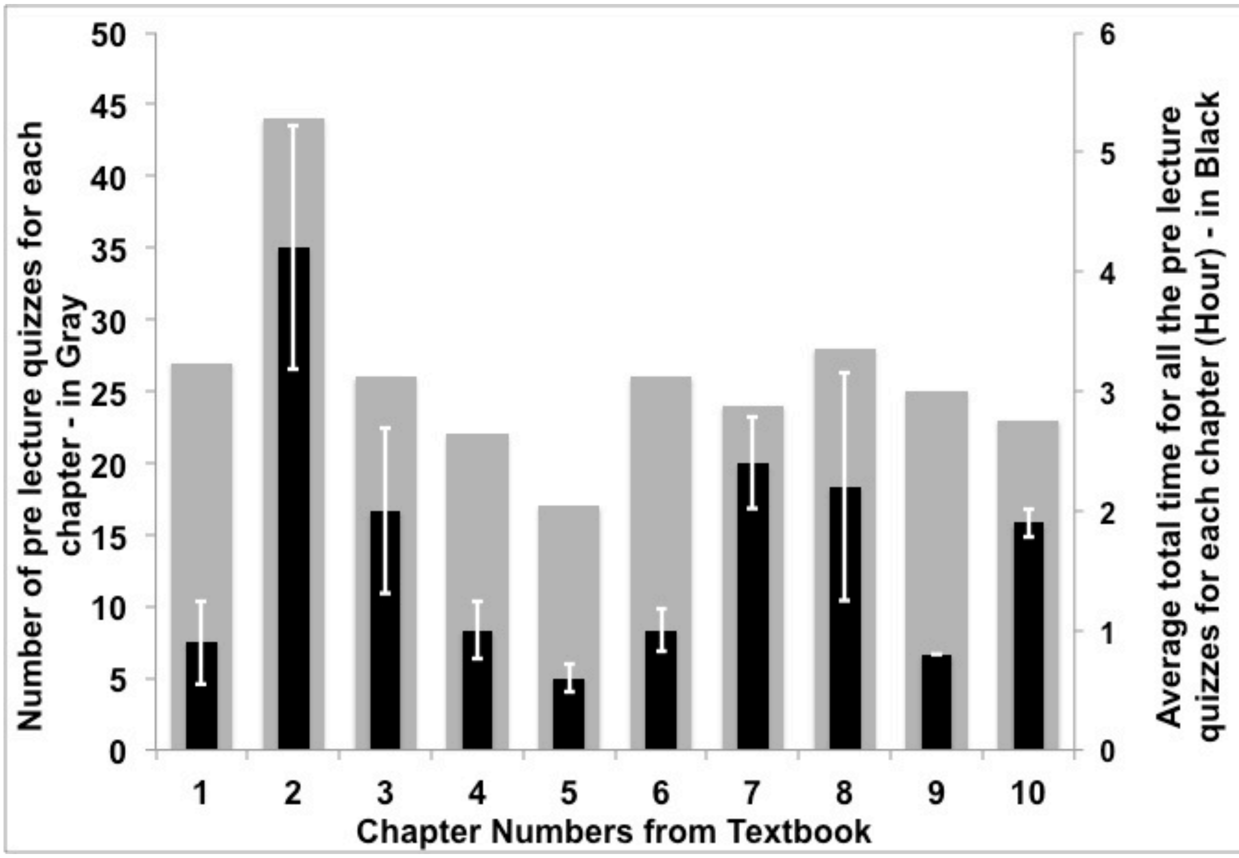

Figure 2. The number of prelecture quizzes students needed to finish for each chapter is shown in gray. The average total time taken to finish all the prelecture quizzes for each of the ten chapters is shown in black.

Table 1. shows the blended teaching as compared to the traditional teaching in terms of students' engagement. There was overall increase in student time engagement in the course. There was more time interaction between students and with the TAs and the instructor during in-class group problem solving

Table 1. Comparison of Blended vs Traditional Teaching Style in terms of overall students time engagement in the course.

Blended Teaching Style	Time (hr)	Traditional Teaching Style	Time (hr)
In-class 28 lecture quizzes 10 min each	4.7	3 individual midterm in-class exams, 50 min each	2.5
In-class 28 lecture group practice problem solving, 40 min each	18.7	Q&A during 25 lectures max (5-10 min)	4.2
Online videos for each learning objective/prelecture quiz	13.1	In-class lectures 40-45 min	18.8
Online prelecture quizzes	16.5	25 homework assignment (expected ~40 min per homework)	16.7
Student total time engagement	**53**	**Student total time engagement**	**42.2**

Figure 3 shows the grade distribution of the BME 310 course from 2009 to 2013. In spring 2013 blending learning was implemented in the class for the first time. Most of the teaching style was changed in 2013 except the research paper writing and lab portion of the course. As a result of this new implementation, one of the most important outcomes was the increased students' engagement inside and outside of the class.

The overall increase of grade A in 2013 as compared to other years could be a possible sign of student engagement. Since the grading scheme pre-2013 included hour exams are not implemented in the blended instruction for this course. It is unclear if the increased number of A's was due to a lack of summative assessment of learning rather than success of the blended learning techniques. Thus, more data from future classes are needed to confirm this conclusion. The in-class group activity and online videos greatly facilitate the learning/teaching process. The students are generally more prepared to learn when they come to the classroom, thus regular quizzing encourages time-on-task. We believe these pre-class online quizzes using the Moodle method and in-class 10 min quizzes will increase their time-on-task and learning.

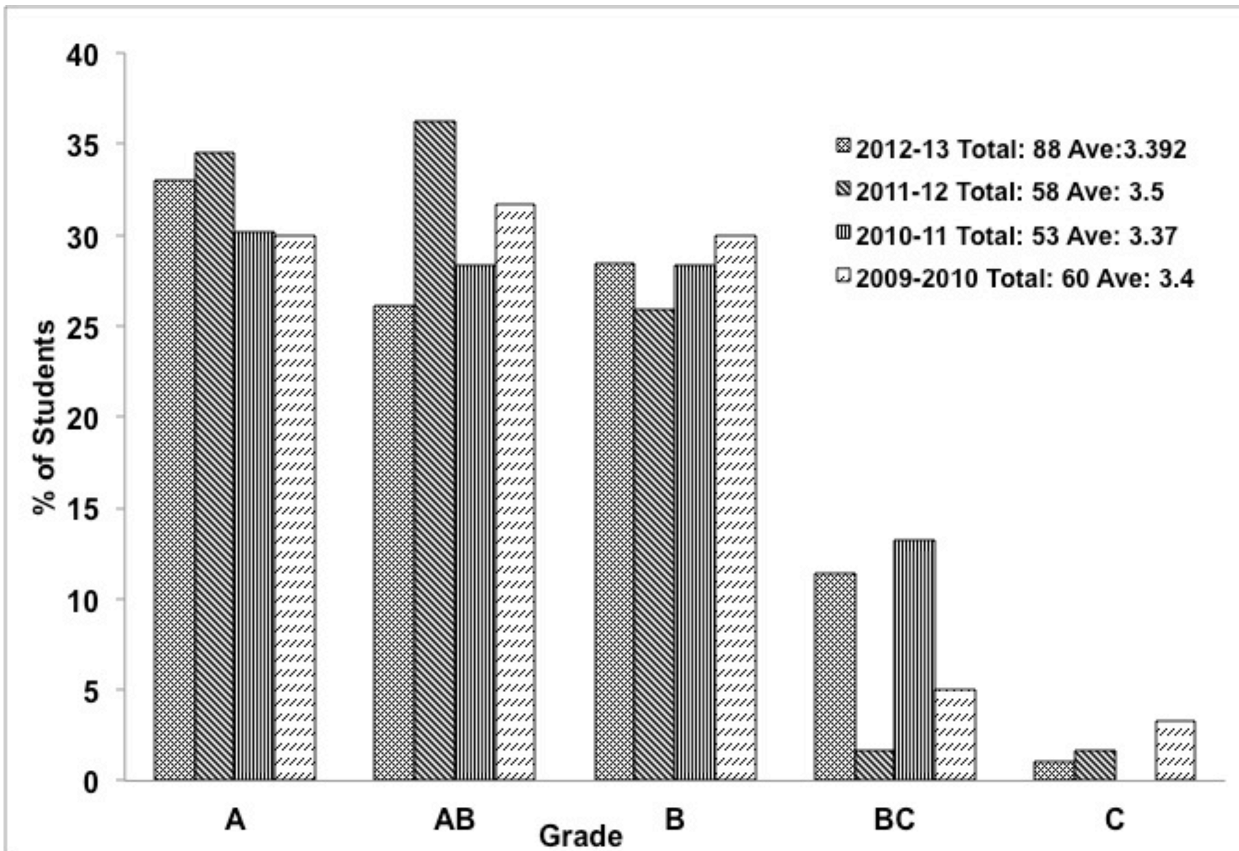

Figure 3. Grade distribution of BME 310 from 2009 to 2013.

As an informal assessment we conducted a survey during the early part of the semester. We asked the following question: "*List changes to BME310 that will help improve your learning the most*:" We received 26 responses. The students had suggestions to move the in-class quizzes to the beginning of the next class, posting detailed answers for the quizzes, the amount of time it takes for answering online quizzes using Moodle. The students had suggestions for improving the lab part of the course. We addressed some of these concerns during 2013 semester and are currently incorporating more changes during the spring 2014 semester.

VI. Challenges and Future Work

One of our challenges is the adequate space needed for blended learning instruction for 88 students. We want the students to sit in groups around a table, so they can work together and share ideas. However, this requires more space than traditional classroom instruction, which we have received through our college of engineering. In 2014 we obtained a room with multiple hexagonal tables for 6 students each.

One of our barriers to blended teaching is the pathological fear that our students' performance will worsen if we do not lecture to them.[20] Capable students underperform because of ineffective time-on-task. Capable students such as brilliant students or students with good prerequisite background prefer some flexibility and challenging problems for in-class quizzes. The answers/solutions of the quizzes provide the main idea or some hint, which is fine for them. But for most students, they prefer some normal and average level problems for in-class quizzes. Also most students want all detailed answers/solutions.

In 2014, based on the time-on-task, we divided students into fixed number groups of 6. We wanted students to sit in groups, and share ideas. Each student was responsible to solve one different specific problem and then explain it to the other 5. TAs helped them where necessary, thus everyone contributed to the learning. The instructor did not lecture and solutions to in-class problems were not posted until after the quiz. This encouraged the students to stay in the class and work on the problems where they were helped by the instructor and TAs. We hope to encourage students to prepare better before class and enhance their explanation and communication skill. In addition, we will also add self/peer evaluations at the end of semester to assist with the assessment process.

Acknowledgments

We would like to thank all the TAs who helped with the implementation of blended instruction for BME 310. Part of the BME 310 course improvement project is supported by the 2013 Engineering Beyond Boundaries, College of Engineering Educational Innovation Initiative project number PRJ63MT at the University of Wisconsin-Madison. Points of view in this document are those of the authors.

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Appendix I

BME/ECE 310 Bioinstrumentation – Spring 2013

Text: J. G. Webster (ed.), *Bioinstrumentation*, New York: John Wiley & Sons, 2004. (On reserve at Wendt Library)

Date	Topic	Text pages, Learning Objective (LO)	Lab experiment for the week
1/23	Chapter 2, Electronics	27–40, CH2-LO1–LO11	
1/28		41–54, CH2-LO12–LO21	1 Basic circuits and PSPICE
1/30		55–67, CH2-LO22–LO32	
2/4		68–87 , CH2-LO33–LO51	2 Filters and PSPICE
2/6	Chapter 1, Measurement systems	1–12 Send your paper topic CH1-LO1-LO16	
2/11		13–25 CH1-LO17-LO-27	3 Amplifiers and PSPICE
2/13	Chapter 7, Nervous system	228–237 CH7-LO1-LO10	
2/18		238–247CH7-LO11-LO16	4 Digital Signal Proc-LabView
2/20	CH7-LO17-LO24	248-259 Send your references	
2/25	Chapter 8, Heart and circulation	262–274 CH8-LO1-LO14	5 ECG #1Signal Processing
2/27		275–288 CH8-LO15-LO23	
3/4		289–301CH8-LO24-LO28	Individual bench exam 1
3/6	Chapter 9, Lung, kidney, bone	303–313 Send your outline CH9-LO1-LO8	
3/11		314–324 CH9-LO9-LO15	6 ECG #2
3/13		325–336 CH9-LO16-LO24	
3/18	Chapter 10, Body	339–350 CH10-LO1-LO11	7 Pressure Sensor and Blood Pressure Measurement
3/20	Send your draft	351–362 CH10-LO12-LO18	
4/1		363–374 CH10-LO19-LO23	8 Pulse Ox and US Flowmeter
4/3	Chapter 3, Molecules	91–103 CH3-LO1-LO8	
4/8		104–116 CH3-LO9-LO19	9 Spirometer
4/10		117–128 CH3-LO20-LO26	
4/15	Chapter 4, Biomaterials	129–141 CH4-LO1-LO9	10 Temperature
4/17	Send your final paper	142–154 CH4-LO10-LO16	

4/22		155–167 CH4-LO17-LO22	11 Electrodes
4/24	Chapter 5, Hematology	170–178 CH5-LO1-LO10	
4/29		179–188 CH5-LO11-LO17	Review Lab for individual bench exam (optional)
5/1	Chapter 6, Cellular measurement	190–202 CH6-LO1-LO11	
5/6		203–215 CH6-LO12-LO22	Individual bench exam 2
5/8		216–227 CH6-LO23-LO26	

Example topics for the paper.

3-D cellular topography
Ambulatory monitoring
Anesthesia measurements
Anorectal manometry
Arryhthmia analysis
Arterial compliance
Arterial pulse wave velocity
Arterial tonometry measurement of blood pressure
Artificial heart
Artifical heart valve
Audiometry
Automatic external defibrillator (AED)
Autoradiography
Bioelectrical impedance analysis
Bioelectrodes
Bioelectromagnetics
Biomagnetism
Biospace Life Support Systems
Biotelemetry
Blood clotting
Blood collection
Blood rheology
Bone density measurement
Brain pacemakers
Calorimetry of human metabolism
Cardiac pacemakers
CD
Cell adhesion
Cell pore size
Chromatography
Circuit for Coulter cell counter
CO_2 electrodes
Cochlear implant
Colorimetry
Computational blurring
Contact angle
Cortical stimulation for brain mapping
CT
CPAP
Cutaneous blood flow
Cystic fibrosis sweat test
Hot flash sensor
Hot-film velocity
Hydrodynamic focusing
Impedance plethysmography
Inductance plethysmography
Infrared telemetry
Intracranial pressure
Intra-ocular pressure
Intraventricular electrogram mapping
Judicial electrocution
Laparascopic surgery
Laser-Doppler flowmetry
Laser trapping
Lie detector instrumentation
Light scattering
Linear variable differential transformer
Lung sounds
Measuring ECG through two electrodes
Measuring glucose through the skin using spectrophotometry
Metal Artifact Reduction in CT Scans
Microbial detection systems
Microdialysis
Microelectrodes
Microfluidic cell sorting
Motion capture systems
Microwave vs. other ablation
MRI
MRI force sensors such as fiberoptic
MRI imaging data classification
Myoelectric Prosthetics
Neonatal monitoring
Neural signal as man-machine interface
Neuromuscular electrical stimulation
Nonmetallic temperature sensors
Obstetrics measurements
Ocular fundus reflectometry
Overshunting in hydrocephalus
Peñás method of blood pressure measurement
PET
Piezoelectric sensors
Pneumotachometers

Dc-coupled ECG amplifier
Dermatology measurements
Diffusion tensor imaging (DTI
DNA sequencing
Dry electrodes
DSC
Dual photon confocal microscopy
Echocardiography
Electroporation
Ellipsometry
Electroencephalography
EMG
Endoscopes
EOG
ERG
Esophageal manometry
Evoked potentials
Evaporative water loss
Exercise stress testing
Eye movement measurement
Female sterilization by ablation
Fetal monitoring
Fluorescent speckle microscopy (FSM)
Fluorescent tagging
Foot force distribution
Force-sensitive resistors (FSRs)
Forehead temperature sensors
FT-IR
FTIR-ATR
Gamma camera
Glucose sensors
Pulmonology measurements
Radiation detection for chromatography
Radiolabeling
Radiology measurements
Radiotherapy Rapidarc system
Receiver operating curve
Rehabilitation measurements
Renal denervation
RFID for patient safety
SEM
SFM
Shotgun optical mapping
Sieve electrodes for connecting nerve to electronics
Skin impedance vs time after electrode application
Skin potential motion artifact
Sleep lab instrumentation
Somatosensory evoked potentials
SPECT
Spinal cord stimulation
STM
Strain gages
Superconductivity
TEM
TIRF
Tissue temperature during ablation
Transcranial magnetic stimulation (TMS)
Tympanometry
Ultrasound imaging
Urinary flow measurement
X-ray detectors

Appendix II

Example of the BME310 Instructional and Learning Objectives for Chapter 1

The following list of instructional and learning objectives (IOs, LOs) contains a summary of the concepts, relationships, and skills presented in this course. These IOs, LOs should provide you with a guide for learning the material in the chapter indicated by the first number in each group. In open-book quizzes/examinations during this course you should be able to:

BME310 Instructional Objectives

IO1. Explain the specification values for an electrocardiograph.
IO2. Explain results when dynamic range is exceeded.
IO3. Distinguish accuracy and precision.
IO4. Calculate mean, standard deviation, standard deviation of the mean.
IO5. Calculate Poisson probability.
IO6. Calculate sample size to achieve estimations with 95% confidence.
IO7. Calculate prevalence, sensitivity, specificity, positive predictive value, negative predictive value.

BME310 Learning Objectives

LO1. Biomedical engineers work in a variety of fields - You should be able to distinguish the fields of biomedical engineering application.
LO2. Biomedical engineers work in different disciplines - You should be able to explain and distinguish the relationship between each discipline and its examples.
LO3. Biomedical engineers workplace environment - You should be able to describe the biomedical engineers workplace environment.
LO4. The Scientific Method - You should be able to describe the scientific method.
LO5. Clinical diagnoses - You should be able to describe the basic method and principle for clinical diagnoses.
LO6. Feedback in Measurement Systems - You should be able to understand the method and principle of the feedback in measurement systems and application.
LO7. Clinician's function - You should be able to describe the function of the clinician.
LO8. Common medical measurands - You should be able to describe the basic knowledge of the common medical measurands and value range.
LO9. Sensor specifications for blood pressure sensors - You should be able to describe the sensor specifications determined by a committee composed of individuals from academia, industry, hospitals, and government.
LO10. Hysteresis loop - You should be able to describe the principle of the mechanical hysteresis loop.