

Course Title: BIOEN 403 – Bioengineering Capstone Research Project

Instructor: Each student registers with an individual Bioengineering faculty advisor, and may be co-advised by others active in biomedical research. Writing progress, in-class presentations, and individual issues will be supervised by dedicated capstone instructors.

Credits: ([2]-, 4 total).

UW General Catalog Course Description: Independent senior research project.

Prerequisite: BIOEN 401

Course Description:

BIOEN 403 places seniors in Bioengineering faculty laboratories to conduct individual research projects. Students may initiate projects or choose projects suggested by the faculty host. Each project must apply engineering principles and be sufficiently novel that its successful completion would merit publication in a science or engineering journal. A senior project may be part of a larger project, but its goals and relationship to the larger project should be well defined.

Students are encouraged to participate in research group activities as early as practical in the undergraduate career. During this preparatory phase and during the registered quarters, students are members of a laboratory group, attending group meetings and sharing lab maintenance duties in addition to planning and executing the senior project. In larger lab groups, seniors are typically assigned a graduate student or post-doctoral fellow as mentor.

Each student will choose a host lab before starting BIOEN 401 in spring of the junior year, and must select a project topic early in BIOEN 401. The BIOEN 403 project proposal is developed during BIOEN 401. A review early in BIOEN 401 confirms that each project will meet criteria for engineering research, based on the ABET learning objectives. The completed project plan will be reviewed again by the Bioengineering Student Affairs Committee during the spring or summer quarter.

Students register for 4 credits of BIOEN 403, divided between two consecutive quarters with two credits per quarter. Students may receive credit for research during the summer and autumn quarters, or autumn and winter quarters. The course is hyphenated, meaning that the grade for both quarters of BIOEN 403 is determined upon completion of the course, project, and journal-style paper. Details of capstone grading are provided in the appendix.

The research project should be completed before spring quarter, to avoid concurrent due dates for the research project report and required team design project report in BIOEN 405. Therefore, the project length should be chosen such that all aspects of the project -- planning, equipment acquisition, and training, fabrication, experimentation, analysis and reporting -- can be completed by the end of the second quarter, with the student working in lab 12-15 hours per week.

Prerequisites by Topic:

Bioengineering Capstone Principles (BIOEN 401), biology, chemistry/biochemistry, probability and statistics for scientists and engineers.

Textbooks: None

Course Objectives:

BIOEN 403 promotes the transition from student to research engineer by assigning professional responsibilities. To gain the necessary experience, each student will:

- work and communicate in a research group
- design and conduct bioengineering experiments with educational support and advice
- observe and practice the detailed tasks needed to plan and conduct Bioengineering projects and to maintain a research lab
- write and receive feedback on a thesis-style report.

Topics Covered:

Design, conduct, and documentation of experiments. Composition of research progress reports. Specialized topics and techniques as necessary.

Class Schedule:

Students work in lab on a schedule agreed between each advisor and student (12-15 hours/week). All students registered for BIOEN 402 (individual capstone design project) and BIOEN 403 convene one hour per week to discuss their progress, technical issues, and course requirements.

Computer Use:

Requires on-line access to search literature and to communicate via email. Requires computer-based data analysis, report generation, and overhead slide preparation. May require numerical simulations, signal and image processing, and advanced programming depending on the individual research projects.

Laboratory Projects:

Students conduct cutting-edge research projects in biomedical research laboratories under the mentorship of UW faculty or outside biomedical experts. Projects may be proposed by the students or advisors, according to the interests of both. Topics of past senior projects have included: macrophage labeling and tracking, characterization of specific chemical inhibitors for a plasma membrane transporter, study of the effect of pulsatile flow on catch-bond mediated adhesion of bacteria, and investigation of metabolic changes in induced pluripotent stem cells during cardiomyocyte differentiation.

Course Requirements, Outcomes and Assessment:

BIOEN 403 comprises a bioengineering research project, in which students must engage in activities that teach and assess certain engineering capabilities. For a senior research project to qualify for engineering credit, the Department of Bioengineering considers it sufficient that the student can demonstrate achievement of the learning outcomes listed below.

Learning outcomes:

- (b) An ability to design and conduct experiments, and to analyze and interpret data
- (e) An ability to identify, formulate, and solve engineering problems
- (g) An ability to communicate effectively
- (i) Recognition of the need for, and an ability to engage in, life-long learning

The BIOEN 403 project must provide students with experience in applying advanced mathematics and engineering to solve biological or biomedical problems.

The project proposal should state how the engineering research project will provide each student experience with the application of advanced mathematics and engineering to solve biological or biomedical problems. The advanced mathematics should emphasize statistics and, if possible, differential equations.

Students' acquisition of the learning outcomes listed above is assessed based on their research project reports and by direct observation by the faculty advisors. The attached grading rubric should be used as a guide when assessing the learning objectives and assigning course grades.

Relationship of Course to Departmental Objectives:

The Department of Bioengineering has a goal of preparing its undergraduates to achieve a specific set of career objectives, which are listed below. Although not all of our students will pursue all of these objectives, every student should gain the educational foundation to do so. BIOEN 403 contributes to this foundation by requiring students to complete an engineering research project, in which they apply the bioengineering fundamentals they have learned, and learn advanced topics and techniques, in a manner consistent with graduate and professional training in medicine and biology. The projects are typically part of externally funded programs, and therefore address immediate or long-term issues that are of considerable importance to human health. Students are responsible for their own progress, but must also communicate their progress and results to advisors, collaborators, and peers, who may encompass a broad range of academic and professional backgrounds. Fulfillment of their project allows students to gain key professional and research skills, including project management, communication, and teamwork, that they will need to obtain employment in bioengineering-related fields. As such, this experience will give students many tools needed to reach the program educational objectives of the Bioengineering undergraduate program:

- Earn advanced degrees and/or obtain employment in bioengineering-related fields, such as medicine, device development, or biotechnology.

- Advance their careers by obtaining appropriate educational and professional qualifications.
- Serve their profession and community.
- Contribute to responsible development of new technical knowledge.
- Take leadership roles in addressing domestic or global bioengineering-related issues.

Grading Summary

BIOEN 403 is a hyphenated course, meaning that no letter/number grade is assigned until both quarters and the final paper are complete. The first quarter receives an N grade, which is replaced when the final numerical grade is assigned.

BIOEN 403 is graded on the following aspects:

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| • Quality and quantity of work in lab | 40% |
| • In-class contribution | 10% |
| • Final project report | 50% |

Quality and quantity of work in lab – 40%

The capstone advisor(s) have the flexibility to judge – as objectively as possible – the performance of the student on a day-to-day basis. This judgment should consider progress on the project itself, as well as the student's ability to function effectively as a member of a research lab group. Specific items to be considered include planning, record keeping, adherence to safety guidelines, following experimental procedures and good lab practice, communication with advisors and group members, follow-through on agreements, and time spent on the project or in lab.

Table 1 provides a rubric for evaluating a student's performance on the practical aspects of conducting the project.

Progress Reports

At the end of the first quarter, the primary adviser should provide a performance review and hypothetical numerical grade for the "Quality and quantity" portion of the course evaluation. When the numerical grade is calculated for the final quarter, the "Quality and quantity" portion should be consistent with the performance reviews reports from the previous quarters. This policy is intended to increase students' motivation to improve when necessary, and to give them a more accurate prediction of their final capstone grade.

In-class contribution – 10%

BIOEN 403 students are required to submit draft of their capstone paper during the first and last quarters of the project. The drafts should be submitted to the BIOEN 402/403 classroom instructors for feedback and to count toward the grade. Students are expected to participate in the weekly classroom meetings, and a presentation to the class is required during the second quarter of the project. In addition, students should meet with their primary advisors at least quarterly and share a summary of their performance review with the capstone instructors; the summary will count toward the "In-class contribution" portion of the course grade. The classroom instructors will report a score for the in-class contribution to the capstone advisors for inclusion in the final course grade.

BIOEN 403 SYLLABUS FOR 2015 - 16

Table 1. **Project** grading rubric. Each BS BIOE graduate will conduct a research project that shows his/her ability to...

ABET Outcome	Capability	4 Exemplary	3 Proficient	2 Apprentice	1 Novice	Score
b	Design and conduct experiments as well as analyze and interpret data: Utilize BioE skills to test experimental hypotheses developed in BIOEN 401; correctly analyze results; compile/interpret results in a permanent record such as lab notebook or written reports. Conduct experiments consistent with relevant standards.	Appropriate analytical methods were selected and correctly implemented. Quality laboratory conduct was followed, including experimentation consistent with all relevant standards, and compilation of results in a professional manner in a lab notebook or written reports.	Analytical methods were appropriate and correctly implemented. Basic laboratory conduct was followed including adherence to relevant experimental standards and maintenance of a lab notebook, detailed notes or written reports.	Analytical methods were appropriate, but implementation may be questionable. Basic laboratory conduct was followed including lab notebook or detailed notes and reports. Student may need reminding to consider and follow experimental guidelines and standards.	Analytical tools applied were inappropriate and/or not implemented correctly. Basic laboratory conduct was only partially followed (including neglecting experimental standards, infrequent reports or inadequate details in lab notebook).	
e	Identify, formulate, and solve BioE problems: Recognize need in medical or bioscience community; evaluate its relative and absolute importance; cast need as engineering research challenge; perform experiments that address the need.	Medical or scientific need is clearly understood; current costs (health, economic, social, etc.) were used to justify project. Project provides the desired knowledge or discovery.	Medical or scientific need is understood; current costs (health, economic, social, etc.) were considered; problem was cast as engineering challenge. Research meets experimental goals.	Medical or scientific need is understood; current costs were considered; research design may be inappropriate for challenge.	Student did not show understanding of need for project, the project did not satisfy the stated needs.	
g	Communicate effectively: Maintain active, effective communication with lab members and advisors. Scheduling and form of communication depends on the lab group and agreements with the advisor.	Student maintained frequent, productive communication with lab members and advisor. Provided high-quality written reports or group presentations. Could be counted on to communicate professionally with outside collaborators.	Student maintained adequate, communication with lab members and advisor. Provided written reports on time and was prepared for group meetings. Could be counted on to communicate effectively with outside collaborators.	Student maintained intermittent, communication when required. Written reports were submitted eventually, and participation in group meetings was minimal. Advisor needs to oversee communication with collaborators.	Student seldom responds to email, Attendance at group meetings was minimal. Advisor reluctant to let student communicate with collaborators.	
I	Recognize the need for, and have the ability to engage in, life-long learning: Shows an ability to keep up with continuous progress in the field during project. See note (1) below.	Current literature is monitored. Key advances relevant to the project were identified and considered as motivation for changes in the project. Student welcomes opportunities to attend conferences, if available.	Literature is monitored, and key advances relevant to the project were identified but impact on project was not recognized.	Student reads relevant current literature when its existence is pointed out. Student is not interested in interpersonal communication as means to advance knowledge.	Either ability or motivation to engage with current literature is lacking.	

Apply math (Program Criterion)	Apply mathematics (including statistics) and engineering to solve biological or biomedical problems. Preparation should emphasize statistical analysis, when appropriate to support conclusions.	Masters appropriate mathematical techniques or extended math capabilities appropriate for undergraduate curriculum; addresses each hypothesis posed in experimental design; performs statistical analysis using appropriate methods, large sample sizes and thorough control experiments.	Correctly applies undergraduate-level engineering mathematics in theoretical analysis; addresses hypotheses posed in experimental design; performs statistical analysis to assess statistical significance of conclusions, with appropriate methods, adequate sample sizes and some control experiments.	Applies basic mathematics to theoretical analysis; performs statistical analysis to assess statistical significance of conclusions, but may use inappropriate methods, analysis may be insufficient or has errors	Incorrectly applies engineering mathematics; does not quantitatively address hypotheses posed in experimental design.	
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(1) Assessing **recognition of the need for life-long learning** is similar to assessing students' understanding of scientific and technological progress and potential. Students should be able to relate: A brief history of their technical field, starting from a point that predates their advisors' entry into the field; Recent and ongoing advances in the field, especially those that change the goals, methods, and analysis of their projects; A set of new skills or knowledge that must be learned before the next major step in this project or research can be taken; How the education of others outside this institution might change after the results of their project (or the advisor's larger research effort) are publicized.

Suggested criteria for assessing a student's ability to engage in life-long learning are: An ability to gain access to available academic resources – including texts, specialized periodicals, and technical databases – after the student has graduated; An ability to seek out and communicate with persons who possess knowledge that cannot be learned effectively from impersonal means; An ability to assimilate newly acquired knowledge into one's existing understanding of technology; An ability to assess which endeavors are worthy of pursuit, in order to apply time and energy effectively.

The BIOEN 403 Research Paper – 50%

The final report is to be prepared in the form of an engineering research paper following the manuscript format for one of the journals relevant to the field. The document should be in 12-point Times, Cambria, or equivalent font, 1.5- or double-spaced, with 1" margins. The recommended length is 10-15 pages, not including figures or appendices. It is not necessary for the paper to have the same appearance (columns, type face, figure placement) as would appear in the final published version of the paper.

At a minimum, the paper should include the following sections:

Title page

Abstract

Introduction

Methods and Materials (including adherence to relevant experimental standards and guidelines, such as IACUC and BSL-2)

Results

Discussion (may be combined with Results)

Acknowledgements

References

Appendix with the following information:

Costs (equipment, services and supplies) in a spreadsheet or table,

Description of any significant changes from the initial research plan

Experimental/design decisions made by the student during the course of the project, as a measure of the level of independence exercised by the student.

- Additional figures, data, programs, CAD files, etc., that do not fit in the paper may be made available in electronic form made available on a web site as supplemental information.
- A statistical evaluation of the results must be included in the appropriate section.
- All writing is to be in formal technical English, using EndNote or equivalent for references (with appropriate in-text citations).

Final Report Submission

The report is to be submitted to the primary advisor and any co-advisor(s) in whichever form (paper or electronic) the adviser requests. The official due date is the last day of classes during the second quarter of BIOEN 403. The report should also be submitted to the academic counselor as a PDF or Word document.

Final Report Grading

The final paper is to be graded by the primary advisor, with input or guidance by any co-advisers, as appropriate. Grading for the paper will be based on the criteria in Table 2. Full credit for each item is 4 points, and the cumulative grade will be the average of the scores for the listed criteria. Items that are omitted entirely should receive zero.

Bioengineering Senior Project Rubric

Student: _____ Advisor: _____ Academic Year: _____

Project Title: _____

Table 2. BIOEN 403 Report grading rubric. The report grade is the average of scores from the five criteria below.						
ABET Outcome	Capability	4 Exemplary	3 Proficient	2 Apprentice	1 Novice	Score
b	Design and conduct experiments as well as analyze and interpret data: Utilize BioE skills to test experimental hypotheses or prototypes from design plans developed in BIOEN 401; correctly analyze results.	Analysis is complete, correct and conclusions are consistent with results. Appropriate analytical methods are selected and correctly implemented. Experimental design considers all appropriate and required standards and guidelines.	Analysis is complete but contains 1 or 2 minor errors. Analytical methods are appropriate and correctly implemented. Experimental design considers appropriate standards and guidelines.	Analysis is satisfactory, but contains 1 or more conceptual and/or procedural errors. Analytical methods are appropriate and correctly implemented. Some relevant standards and guidelines are mentioned but may be incomplete.	Analysis contains major conceptual and/or procedural errors. Analytical tools applied are inappropriate and/or not implemented correctly. Lack of description of how experiments are consistent with relevant standards and guidelines.	
e	Identify, formulate, and solve BioE problems: Recognize need in medical or bioscience community; evaluate its relative and absolute importance; cast need as engineering research challenge; perform experiments that address the need.	Medical or scientific need is clearly explained; current costs (health, economic, social, etc.) are used to justify project; problem is cast as engineering challenge; report shows that the research provided the desired knowledge or discovery.	Medical or scientific need is clearly stated; current costs (health, economic, social, etc.) are mentioned; problem is cast as engineering challenge; report shows that research met experimental goals.	Medical or scientific need is clearly stated; some current costs are mentioned; engineering design may be inappropriate for challenge; successful or not, the report explains the experimental outcomes.	Need is not clear, problem is not addressable by engineering solutions, and/or the report does not explain the impact of the experimental outcomes.	
g	Communicate effectively: Prepare detailed written report that addresses engineering, economic, and societal issues as shown in report outline.	Written report is virtually error-free, logically presents project, is well organized and easy to read, and contains high quality data/graphics.	Report is logically presented, well organized, easy to read, contains high quality data & graphics, with few minor grammatical or rhetorical errors.	Report is generally well written but contains some grammatical, rhetorical and/or organizational errors; project is not well explained and not fully discussed.	Does not present project clearly, is poorly organized and/or contains major grammatical and/or rhetorical errors.	
i	Recognize the need for, and have the ability to engage in, life-long learning: Show/describe the continuous progress in the field prior to and during project.	Current and seminal literature is discussed in relation to the project; key advances relevant to the project are identified. Proper referencing shows that the literature was thoroughly searched and analyzed.	The number and quality of citations indicates a thorough literature search. Literature is discussed in relation to the project. Sources are cited throughout paper where needed.	The current literature is mentioned/listed, indicating an adequate literature search. Information sources are cited throughout paper where required.	Number and brevity of citations indicates only a minimal literature search. Statements are made without citing information source.	

Bioengineering Senior Project Rubric

Student: _____ Advisor: _____ Academic Year: _____

Project Title: _____

Apply Math (Program Criterion)	Apply mathematics (including statistics) and engineering to solve biological or biomedical problems. Demonstration of preparation should emphasize statistical analysis, when appropriate to support conclusions.	Provides a theoretical analysis using appropriate engineering mathematics; addresses all hypotheses posed in experimental design; supports conclusions with thorough statistical analysis using appropriate methods, large sample sizes and thorough control experiments.	Provides a theoretical analysis using appropriate engineering mathematics; addresses hypotheses posed in experimental design; includes statistical analysis and explains why that test is correct, with appropriate methods, adequate sample sizes and some control experiments; uses statistics to support conclusions.	Explains theory using basic engineering mathematics; includes statistical analysis to assess statistical significance of conclusions, but included analysis may be insufficient of contain errors	Incorrectly applies engineering mathematics in theoretical analysis; does not quantitatively address hypotheses posed in experimental design; mentions statistical evaluation without evaluating the data.	
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