BIOEN 402 SYLLABUS FOR 2015-16

Course Title: BIOEN 402 – Bioengineering Capstone Design Project

Instructors: C. M. Neils, A. C. Taylor, D. G. Hendricks and Bioengineering faculty. Each student registers with an individual Bioengineering faculty advisor. Instructors supervise writing progress, student presentations, and individual issues that may arise.

Credits: 10 total, divided among 2-4 consecutive quarters, with 2-6 credits per quarter.

UW General Catalog Course Description: Independent senior design project. Prerequisite: BIOEN 401.

Course Description:
The Department of Bioengineering offers two options for completing a senior capstone project. Students who choose the BIOEN 401-402 sequence conduct an individual design project. Students who choose the BIOEN 401-403-404-405 sequence conduct an individual research project and a team design project. The number of total credits in each sequence is equal.

BIOEN 402 places seniors in Bioengineering faculty laboratories to conduct individual design projects related to real medical problems. Students may initiate projects or choose projects suggested by the faculty host. A senior project may be part of a larger project, but it must have definable design goals and be sufficiently novel that its successful completion would merit publication in a science or engineering journal. The design content should be consistent with the ASEE white paper, *Design versus Research: ABET Requirements for Design*.[1]

During the project, seniors 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.

Students register for 10 credits, divided among 2-4 sequential quarters with 2-6 credits per quarter. Autumn quarter typically includes planning, equipment acquisition, and training, winter quarter includes fabrication and/or experimentation, and spring quarter emphasizes analysis and reporting. This schedule is flexible to accommodate students' progress and graduation plans. The grade for all quarters of BIOEN 402 is determined upon completion of the course, the project, and a formal report. Details of capstone grading are provided in the appendix.

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 402 project proposal is developed during BIOEN 401, and the nature of the project and plan to fulfill the design requirements are examined by the BIOEN 401 teaching team. Review in BIOEN 401 confirms that each project will be a culminating Bioengineering design experience, recommending changes as necessary.

Additional details about the capstone procedures may be found in the capstone help file: http://depts.washington.edu/bioe/academic-programs/undergraduate/capstone-help-file/

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

Textbooks: None

Course Objectives:

Allow students to observe and practice the detailed tasks needed to plan and conduct Bioengineering projects and to maintain an R & D lab. Provide independent bioengineering design experience with educational support and advice. Promote the transition from student to engineer by assigning professional responsibilities. Provide experience working in a group. Provide practice writing and revising a thesis.

Topics Covered (mainly by experience in your lab groups):

Design of experiments, tools, and devices. Engineering and experimental standards. Statistical basis for the design and analysis of experiments. Composition of design project reports. Podium and poster presentations. Specialized topics and techniques as appropriate. Intellectual property, regulatory issues, and R & D funding.

Class Schedule:

Students work in lab on a schedule agreed between each advisor and student (8-24 hours/week). All students convene one hour per week to discuss their progress and course requirements.

Course Outcomes and Assessment:

Students' success in BIOEN 402 depends on their ability to perform the tasks described below, and to synthesize these tasks into a coherent effort. Individual students are assessed by their senior project advisor(s), with contributions from the course instructors; details are provided in the "Grading summary" section below. In addition, the course itself is assessed annually by a committee of faculty who review the outcomes data from advisors.

All BIOEN 402 students are expected to present their work to the BIOEN 402/403 class during the autumn, winter or spring quarter. This presentation will contribute to the participation score.

All BIOEN 402 students are encouraged to give a **public presentation**, i.e. one to which the university community is invited. The Mary Gates Symposium is a good opportunity, and participation in the annual Bioengineering Capstone Design Symposium is expected. Students are also encouraged to prepare a poster for review and feedback from the advisor and instructors.

Students are graded on their ability to engage in the following eight activities, as demonstrated by their final report and their performance in lab and quantified in the attached grading rubrics. Letters refer to ABET student learning outcomes, which apply to all students and projects. The bulleted items are BioE-specific program criteria; we seek to teach all of these topics to our students and give them experience with each of these, but given the real-world relevance and wide variety of project topics, any given Capstone project will emphasize some subset of the topics listed.

[b] Design and conduct experiments as well as analyze and interpret data

[c] Design a system, component, or process to meet desired needs.

[e] Identify, formulate, and solve Bioengineering problems.

[g] Communicate effectively.

[i] Recognize the need for, and ability to engage in, life-long learning.

[j] Demonstrate knowledge of contemporary issues.

- Apply mathematics (including statistics), science, and engineering to solve bio/biomedical engineering problems.
- Analyze, model, design, and realize bio/biomedical engineering devices, systems, components, or processes.

Relationship of course to Departmental Objectives:

This course allows students to apply the Bioengineering fundamentals they have learned, and to learn advanced topics and techniques, in a manner consistent with graduate and professional training in medicine and biology. The student 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 may encounter problems that require knowledge from any or all of their prior courses or that may require them to master concepts that they have not previously explored. Students must communicate their progress to their advisors, collaborators, and peers, who may encompass a broad range of academic and professional backgrounds.

The Department of Bioengineering has a goal of preparing our 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 402 contributes to this foundation by requiring students to manage a real-world research and design project independently, while working as part of a larger group in a workplace setting. They develop lab citizenship skills, technical expertise, and engineering design knowledge. Together, this experience in project management, working in a team in a lab setting, and communicating their ideas to their peers and supervisors prepares them for long-term leadership roles. Students also gain key professional and research skills that they will need to obtain near-term employment in bioengineering-related fields. Students help develop new knowledge for their lab and, in many cases, use this knowledge in grant applications, publications, patents, etc. As such, the BIOEN 402 capstone experience gives 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.

References:

(1) Gassert, J., Enderle, J.D., Lerner, A., Richerson, S. and Katona, P., Design versus Research; ABET Requirements for Design and Why Research Cannot Substitute for Design, *Proceedings of the ASEE Annual Conference and Exposition,* June 18-21, 2006, Chicago, Illinois, Session 2006-1139. Accessed September 14, 2009, http://soa.asee.org/paper/conference/paper-view.cfm?id=1341 Also available via http://depts.washington.edu/bioe/about/about_accreditation.html#design.

Grading Summary

BIOEN 402 is a hyphenated course, meaning that no letter/number grade is assigned until the last course of the sequence is complete. Earlier quarters receive an N grade, which are back-filled upon assignment of the final numerical grade.

BIOEN 402 is graded on the following items:

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

Progress Reports

At the end of each of the first two quarters, 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 402 students are required to submit drafts of their capstone reports during each of the first two 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 last two quarters of the project. In addition, students should meet with their advisors at least quarterly. The results of this report and an estimate of the grade for "Quality and quantity of work in lab" should be reported to the BIOEN 402/403 classroom instructors. The classroom instructors will report a score for in-class contribution to the capstone advisors for inclusion in the course grade.

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 design project.

Table 1. Each BS BIOE graduate will conduct a design **project** that shows his/her ability to…

ABET Outcome	Ability	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; compile/interpret results in a permanent record such as lab notebook or written reports.	Appropriate analytical methods were selected and correctly implemented. Quality laboratory conduct was followed including: results compiled in a professional manner in lab notebook or written reports.	Analytical methods were appropriate and correctly implemented. Basic laboratory conduct was followed including 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.	Analytical tools applied were inappropriate and/or not implemented correctly. Basic laboratory conduct was only partially followed (inadequate details in lab notebook or infrequent reports).	
c	**Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability:** Apply design plans developed in BIOEN 401; incorporate realistic constraints, including engineering standards, into engineering design process; modify and improve based on experimental results.	Realistic design constraints, including appropriate engineering and experimental standards, were considered thoroughly during the design process. Design adaptations based on acquired results were considered to better adapt the design to the desired needs. More than one option was considered and tested and the best option was utilized.	Multiple realistic constraints (including any relevant engineering standards) were identified and incorporated into the design process. Design adaptations based on acquired results were considered to better adapt the design to the desired needs. At least one option was considered and tested.	Some realistic constraints were integrated into the design process but some may be missing. A design adaptation based on acquired results was considered to better adapt the design to the desired needs. One option was considered but not tested.	Failure to identify and/or incorporate relevant realistic constraints into design process. Original design followed without considering modifications.	
e	**Identify, formulate, and solve BioE problems: Recognize need in medical or bioscience community; evaluate its relative and absolute importance; cast need as engineering challenge; demonstrate device or process that addresses the problem.**	Medical or scientific need is clearly understood; current costs (health, economic, social, etc.) were used to justify project; device or process was shown to be an effective solution, or student clearly understood the outcome of efficacy testing.	Medical or scientific need is understood; current costs (health, economic, social, etc.) were considered; problem was cast as engineering challenge; device or process was shown to be an effective solution, or student at least understood the effectiveness of the attempted solutions.	Medical or scientific need is understood; current costs were considered; engineering design may be inappropriate for challenge; demonstrated some understanding of the effectiveness (or lack thereof) of attempted solution.	Student did not show understanding of need for project, problem was not addressable by engineering solutions, and/or the student did not understand clearly why the attempted solution 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 are 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 are identified but impact on project is 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.	
j	**Demonstrate knowledge of contemporary issues** surrounding the design, such as regulatory matters including current relevant standards, and environmental, social, legal, ethical, geopolitical consequences.	Considers a number of important E, S, L, E, G topics; identifies and discusses current standards related to project; evaluates strengths & weaknesses of each category, including present and future ramifications.	Identifies a number of important E, S, L, E, G considerations; identifies current relevant standards; includes limited discussion of the strengths & weaknesses of each category, including present ramifications.	Identifies only a few of the obvious R, E, S, L, E, G considerations with shallow discussion of the ramifications.	Lists R, E, S, L, E, G considerations with no discussion of the ramifications.	
Apply math (Program Criterion)	**Apply mathematics (including statistics) and engineering to solve bio/biomedical engineering problems.** Preparation on this topic via Capstone 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.	

(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.

BIOEN 402 Project Report – 50%

The final report should take the form of a thesis with the content shown in the outline below; the order of contents is a guide and may be modified to fit the particular project. Recommended format is 12-point Cambria or an similar font, 1.5-line spaced, with 1-inch margins. The recommended length is 25-40 pages, not including references and appendices. All writing is to be in formal technical English, using EndNote or equivalent for references (with appropriate in-text citations).

Title

Abstract (~250 words)

Introduction, 17 pages

- Concise definition of the project, 1 page
- Significance (medical and/or scientific), 1-2 pages
- Social, Ethical, Regulatory and Economic Issues, 1-2 pages
- Identification/Discussion of engineering standards related to design project, <1 page
- Technical Background
    - -Theory, 2 pages
    - -Review of Literature (>30 relevant references concisely narrated), 5 pages
- Previous relevant work in the advisor's laboratory, 2 pages
- Outstanding technical issues at the outset of the project, 2 pages

Design of Tools, Devices, and Experiments, 8 pages

- Overview of design and research plan as proposed in BIOEN 401, 1 page
- Overview of revised design process (if significantly different from proposal), 1 page
- Materials and Methods, 1 page
- Costs (e.g., equipment, services and supplies purchased for the project), 1 page including an Excel-style table
- Details of design process, 3-4 pages, including:
    - - Discussion of realistic constraints (including those imposed by related engineering standards as well as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability) considered during engineering design process
    - - Table of design specifications
    - - Statistical basis for design of experiments

Results, 22 pages

- Final timeline (using MS Project Gantt chart or equivalent), 1 page
- Data, including a chronological narrative, tables, figures, and statistical analysis, 15 pages
- Design (and experimental, if relevant) decisions made by the student during the course of the project, including a discussion of design iterations, 1 page
- Analysis and Conclusions, 4 pages
- Suggestions for future work, 1 page

Acknowledgements

- Recognition of all others who gave significant guidance, technical assistance or financial support in the performance of the project, 1 paragraph

References

- At least 30, as noted above

Appendices (optional)

- Additional figures, data, programs, CAD files, etc., in electronic form made available on a web site

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 quarter in which the 10th credit of BIOEN 402 is taken. The report should also be submitted to the academic counselor and Capstone instructors as a PDF or Word document, usually via Catalyst Collect It.

Final Report Grading

The final report is to be graded by the primary advisor. Grading of the report should 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 first seven criteria presented in the table (and the eighth criterion if appropriate to project). Items that are relevant but are omitted entirely should receive a zero. The grade should be submitted by the advisor with whom the student is officially registered, who might not be the primary advisor in cases where the primary advisor is not core or adjunct BioE faculty.

Table 2. **Report** grading rubric

ABET Outcome	Ability	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; provide interpretation of results.	Analysis is complete, correct and conclusions are consistent with results. Appropriate analytical methods are selected and correctly implemented.	Analysis is complete but contains 1 or 2 minor errors. Analytical methods are appropriate and correctly implemented.	Analysis is satisfactory, but contains 1 or more conceptual and/or procedural errors. Analytical methods are appropriate and correctly implemented.	Analysis contains major conceptual and/or procedural errors. Analytical tools applied are inappropriate and/or not implemented correctly.	
c	**Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability:** Describe how the design plans developed in BIOEN 401 were applied, how design constraints and engineering standards were incorporated into the design process, and how the design was modified and improved based on experimental results.	The report describes how the design incorporated multiple realistic constraints and was adapted to meet desired outcome, based on acquired results. When appropriate for the project, report describes relevant engineering standards incorporated into the design process. Describes multiple options, test results, and choice of final option.	Report describes how the design incorporated multiple realistic constraints, including appropriate engineering standards, and how the design was adapted to meet the desired outcome, based on acquired results. Describes at least one option, test results, and choice of final option.	Report describes how the design incorporated some realistic constraints but other relevant constraints were not considered. Report describes how the design was adapted to meet desired outcome. One option is considered but not tested.	Report does not describe the consideration of realistic constraints during the design process. Report does not discuss any consideration of design modifications.	
e	**Identify, formulate, and solve BioE problems**: Recognize need in medical or bioscience community; evaluate its relative and absolute importance; cast need as engineering challenge; demonstrate device or process that addresses the problem.	Medical or scientific need is clearly explained; current costs (health, economic, social, etc.) are used to justify project; problem is cast as engineering challenge; device or process is shown to be an effective solution.	Medical or scientific need is clearly stated; current costs (health, economic, social, etc.) are mentioned; problem is cast as engineering challenge; device or process is shown to be an effective solution.	Medical or scientific need is clearly stated; some current costs are mentioned; engineering design may be inappropriate for challenge; device or process is implemented but is only partially effective.	Need is not clear, problem is not addressable by engineering solutions, and/or the project does not satisfy the stated needs.	

e	**Identify, formulate, and solve BioE problems**: Recognize need in medical or bioscience community; evaluate its relative and absolute importance; cast need as engineering challenge; demonstrate device or process that addresses the problem.	Medical or scientific need is clearly explained; current costs (health, economic, social, etc.) are used to justify project; problem is cast as engineering challenge; device or process is shown to be an effective solution.	Medical or scientific need is clearly stated; current costs (health, economic, social, etc.) are mentioned; problem is cast as engineering challenge; device or process is shown to be an effective solution.	Medical or scientific need is clearly stated; some current costs are mentioned; engineering design may be inappropriate for challenge; device or process is implemented but is only partially effective.	Need is not clear, problem is not addressable by engineering solutions, and/or the project does not satisfy the stated needs.	
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. See note (1) below.	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.	
j	**Demonstrate knowledge of contemporary issues** surrounding the design, such as regulatory matters including standards, and environmental, social, legal, ethical, geopolitical consequences.	Considers a number of important E, S, L, E, G topics; identifies and discusses current standards related to project; evaluates strengths & weaknesses of each category, including present and future ramifications.	Identifies a number of important E, S, L, E, G considerations; report identifies relevant current engineering standards; includes limited discussion of the strengths & weaknesses of each category, including present ramifications.	Identifies only a few of the obvious E, S, L, E, G considerations with shallow discussion of the ramifications.	Lists E, S, L, E, G considerations with no discussion of the ramifications.	
Apply Math (Program Criterion)	**Apply mathematics (including statistics) and engineering to solve bio/biomedical engineering problems.** Preparation on this topic via Capstone 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.	