

I. General program information

A. Program background information

1. **Title: B.S. in Biomedical Engineering**

2. **Mode: Lecture/Lab/Studio (primarily day)**

3. **Previous Program Review – ABET Evaluation Fall 2007**

The Biomedical Engineering (BME) Department was formed in July 2000 and was first eligible for ABET accreditation during the 2007-2008 accreditation cycle. It was awarded ABET accreditation to September 2014, with retroactive extension to October 2005. Program strengths include the faculty and its demonstrated dedication to developing a high quality and continuously improving program, as well as the highly motivated student body and its record of post-graduate placement in industry, graduate, and medical/dental school. An identified program weaknesses included lack of evidence in how course assessment data on specific ABET outcomes were integrated to indicate the degree to which all *program* outcomes (a-o) are achieved. The weakness was resolved by means of an action plan (formation of a sub-committee of the BME Undergraduate Curriculum Committee to perform gap analysis) and detailed documentation showing that a program-wide assessment had been developed and implemented.

4. **Student Evaluation, Advising, Monitoring**

The BME department provides individual advisement to every student during every semester in the program. Freshmen are required to attend an orientation course that familiarizes them with the curriculum, research and career opportunities and associated expectations, and the three specialization areas (biomechanics, biomaterials, and bioinstrumentation). Pre and post-course surveys are administered to freshmen to gather data on student placements, perceptions, and goals. These are reported at faculty meetings; if curricular adjustments are implied by these surveys, the Biomedical Undergraduate Curriculum Committee (BUCC) reviews in the context of program and course goals. As seniors, the BME students are asked to complete an Exit Survey to self-assess their skills and knowledge with respect to each ABET outcome. The survey also asks seniors to rate the effectiveness of the BME program in providing these skills/knowledge.

Student performance is evaluated within the context of course-embedded assessments using program-wide performance criteria. These course assessments are based on measureable criteria in a pass/fail system. The results (percentage of students meeting the program-wide criteria standards) are presented to the BME Undergraduate Curriculum Committee; the sub-committee performs a program wide-assessment and present recommendations as appropriate.

Surveys utilized by the BME undergraduate program that are not in-house include the NJIT Student Course Evaluations and the NJIT Survey of Student Satisfaction. The former provides course-specific and the latter program-wide feedback.

5. Significant Constituencies:

All BME shareholders have a student-centered focus:

- Students
 - a) Focused: Current Students and representatives (BMES and BME Student Senator)
 - b) Broader: Alumni of BME Program

Students understand the BME program objectives and the outcomes that ABET expects graduates to possess. Knowledge and understanding of these goals are emphasized throughout program from first design course (FED) to final capstone presentation; student advisement and engagement in forward planning allows students to address gaps in achievement of outcomes.
- Faculty
 - a) Focused: NJIT BME faculty
 - b) Broader: Representatives to Council of Chairs of BME, Academic Council of AIMBE, Education Committee of BMES

Curriculum differentiates ABET outcomes across program; instructors share responsibility of integrating appropriate outcomes in their courses and responding to recommendations based on course-embedded assessments.
- Employer
 - a) Focused: NJIT BME Industrial Advisory Board

BME program objectives allow advisory board to clearly understand program goals and give appropriate advice. Members review program on annual basis.

 - b) Broader: Representatives include employers/supervisors of BME alumni, employment officers in industry, graduate program administrators, and professional school admission officers
- MSCHE: BME fully adheres to continuous quality improvement cycle with formative reviews.

II. Program Mission and Goals

A. Program Mission and Goals

The mission of the Biomedical Engineering Department at NJIT is to: (1) educate undergraduate students for productive careers and lifelong learning, especially in the health-related areas of industry, the professions, and government service; (2) educate biomedical engineering graduate students for employment in industry, health professions, government, or academe; (3) emphasize preparation for leadership roles for all levels of students, both undergraduate and graduate; (4) engage in research to

support the advanced education of graduate students, maintain the intellectual vitality of the faculty, and expand the frontiers of knowledge in areas of importance to the state and nation; (5) publish and present the results of our intellectual activities, resulting from both research as well as teaching advances; (6) serve our profession through membership and leadership in national and international societies; and (7) serve our wider constituencies by offering our expertise to other health-related professionals, industries, and state and local communities.

This mission is correlated with the missions of NJIT and NCE as indicated in Table B-2-1 of the **Program Self Study for BME (2007)**.

III. Educational Objectives and Learning Outcomes

A. Educational Objectives

The overall educational objectives of the Bachelor of Science Biomedical Engineering Program fall into two categories (A and B) as outlined below.

Objective A) The BME program should prepare students for productive careers related broadly to biomedical engineering. It is anticipated that BME graduates will embark upon diverse career paths: **Obj-A-1)** We anticipate that a significant number of our graduates will serve the medical device / pharmaceutical / biotechnology industries. **Obj-A-2)** We also anticipate that many of our graduates will utilize their foundation from biomedical engineering education in a variety of related endeavors: for example, medicine, dentistry, law, business, government, and other engineering/scientific fields.

Objective B) While working within their selected career path, we expect that our alumni will demonstrate the following traits:**Obj-B-1)** BME alumni are integrators: We expect BME graduates to successfully and effectively integrate their fundamental knowledge of sciences, mathematics, liberal arts, and engineering analysis into actions that address and solve a wide range of problems, especially those related to medicine and biology. **Obj-B-2)** BME alumni are communicators/translators: We expect BME graduates to successfully and effectively utilize their multidisciplinary background to foster communication across professional and disciplinary boundaries. **Obj-B-3)** BME alumni continue their professional growth: We expect BME graduates to advance their skills through professional growth and development opportunities provided by participation in a professional society, continuing education, or graduate study in engineering or other professional fields. **Obj-B-4)** BME alumni are engaged in service: We expect BME graduates to engage themselves in service to their chosen professional societies as well as their local, national, or global communities.

B. Program Learning Goals/Outcomes

The Biomedical Engineering Program Learning Goals are consistent with accreditation criteria, as expressed by the ABET Program Outcomes (“a” through “o”) **outlined in the Program Self Study for BME (2007), Chapter 2**. We believe that student achievement of ABET program outcomes forms a solid basis of skills and knowledge that will subsequently allow them to attain the BME Program Objectives. In addition to fifteen ABET criteria, we incorporate two additional learning goals for our assessment of student engagement. Table 3-B maps the relationship between BME Program Level Learning Goals and Institutional Level Learning Goals.

Table 3-B

Institutional-level Goals	Specific BSBME Core Learning Goals
Research-based Inquiry	<p>(A) an ability to apply knowledge of mathematics, science, and engineering</p> <p>(B) an ability to design and conduct experiments, as well as to analyze and interpret data</p> <p>(C) an ability to 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</p> <p>(E) an ability to identify, formulate, and solve engineering problems</p> <p>(G) an ability to communicate effectively</p> <p>(K) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.</p> <p>(M) the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve problems at the interface of engineering and biology</p> <p>(N) an ability to make measurements on and interpret data from living systems</p> <p>(O) an ability to address problems associated with the interaction between living and non-living materials and systems</p> <p>(I) a recognition of the need for, and an ability to engage in life-long learning</p>
Ethical Conduct	(F) an understanding of professional and ethical responsibility
Economic Opportunity	<p>(H) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context</p> <p>C) an ability to 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</p> <p>(J) a knowledge of contemporary issues</p> <p>(M) the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve problems at the interface of engineering and biology</p> <p>(O) an ability to address problems associated with the interaction between living and non-living materials and systems</p>
Collaboration	<p>(D) an ability to function on multi-disciplinary teams</p> <p>(F) an understanding of professional and ethical responsibility</p> <p>(H) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context</p>
Engagement	<p>an ability to effectively engage in independent research experiences</p> <p>an ability to effectively engage in co-operative industrial learning experiences</p> <p>(I) a recognition of the need for, and an ability to engage in life-long learning</p>

The BME Program Goals are assessed by 5 sorts of measures relevant to ABET outcomes:

- Course-embedded assessment using program-wide performance criteria
- A standardized exam of basic engineering skills (BEST Exam)
- Surveys using student self-assessment that report on
 - Skills and knowledge at graduation
 - General satisfaction with academic programs among all students
- Student evaluations of their current courses (material and delivery)
- Student feedback sessions held regularly every semester

The Program goals relevant to student engagement and not aligned with the ABET criteria are assessed By the following measures:

- Surveys using student self-assessment that report on general satisfaction with academic programs among all students
- Student feedback sessions held regularly every semester
- Student participation in research
- Student participation in co-operative learning programs
- Student participation in professional societies
- Student feedback sessions held regularly every semester

Course-embedded assessment using program-wide performance criteria

A new method of assessment was developed and adopted by the BME Department during spring 2007. The key to the method of course-embedded assessment is to have clearly expressed Performance Criteria that are written broadly enough so they can be consistently applied throughout all courses to assess Program outcomes. The entire BME faculty was involved in writing and evaluating these Performance Criteria, in consultation with a model developed at Rose-Hulman Institute.

The goal of the Performance Criteria is to provide faculty with a consistent set of expectations that they can apply in their course, while at the same time knowing that other faculty are applying the expectations in respective courses (although the details will be course specific). This will lead to more consistent assessment between courses. The list of all performance criteria is presented in Table 3B-1. The full set of descriptions of all of the performance criteria is presented in the **Exhibits Section** of the **Self-Study**. Note that there are often two (or even three, occasionally) Performance Criteria for each Program Outcome; each criterion expresses a different aspect of the goal.

A sample Performance Criteria is presented on the next page in Table 3B-2. This criterion evaluates program goal C, a student's ability to handle constraints in a design process. The rubric queries several key aspects that the student should include in his work to demonstrate acceptable performance of this criterion – in this case, key aspects of how he/she should treat constraints. The kind of student work that will be examined to assess this criterion is also indicated. Finally, several examples of student work that would be considered passing are presented, as well as examples of work that is unacceptable.

Table 3B-1 List of Performance Criteria for the Biomedical Engineering Program Goals

<p>A-1) Possess a strong foundation in mathematics, science and engineering and demonstrate the ability to apply this knowledge to develop a solution to a given problem.</p>
<p>B-1) Demonstrate the ability to design and conduct experiments on a given problem.</p> <p>B-2) Demonstrate the ability to properly collect and analyze data, and clearly present the results.</p> <p>B-3) Demonstrate the ability to interpret the meaning of analyzed experimental results.</p>
<p>C-1) Demonstrate the ability to assess needs and propose a design solution that conceptually meets the needs/requirements for a given design effort.</p> <p>C-2) Demonstrate the ability to identify constraints for a given design project.</p> <p>C-3) Demonstrate the ability to test the proposed design solution to determine if it meets the required needs.</p>
<p>D-1) An ability to work with others and share responsibilities in a team setting.</p> <p>D-2) Ability to build consensus and solve problems through effective team interactions.</p>
<p>E-1) Synthesize information necessary to identify an engineering need and/or problem and formulate a potential engineering approach.</p> <p>E-2) Present a suitable solution and/or logical answer to an engineering problem.</p>
<p>F-1) Demonstrate understanding of modern ethical issues in the biomedical field.</p> <p>F-2) Demonstrate understanding of professional and ethical issues associated with human subjects and/or animal testing of biomedical devices and products.</p>
<p>G-1) Ability to present oral communication of technical information and/or experimental results to general audience in a professional manner.</p> <p>G-2) Ability to present written communication of technical information and/or experimental results.</p>
<p>H-1) Demonstrate the ability to assess how global social concerns, cultural trends, economics, and/or the environment affect a biomedical problem.</p> <p>H-2) Critically analyze a contemporary biomedical design solution and evaluate the potential impact on patient health, global economics and/or the environment of various cultures.</p>

<p>I-1) Recognize that biomedical engineers must continually update their knowledge and skills in this rapidly developing field.</p> <p>I-2) Demonstrate the ability to self educate.</p>
<p>J-1) Demonstrate broad and contemporary knowledge of an issue affecting biomedical engineering applications within one of the subfields -- biomaterials, tissue engineering, biomechanics, or biomedical instrumentation.</p> <p>J-2) Demonstrate broad and contemporary knowledge to evaluate important implications of a biomedical engineering application/solution.</p>
<p>K-1) Demonstrate the ability to use modern computational methods in engineering practice.</p> <p>K-2) Demonstrate the ability to use modern technology and/or instrumentation in engineering.</p> <p>K-3) Demonstrate the ability to apply high-level engineering software applications.</p>
<p>L-1) Demonstrate a strong background in biology and/or physiology with the ability to apply this knowledge to a given biomedical topic.</p> <p>L-2) Demonstrate the awareness of how biology and/or physiology are important to the development of an approach/application of a biomedical topic and/or problem.</p>
<p>M-1) Demonstrate the ability to model physiological or biological systems using math, science and engineering concepts to gain an advanced understanding of living systems.</p> <p>M-2) Demonstrate the ability to apply and interpret statistical analysis to a given set of biological or physiological data.</p>
<p>N-1) Demonstrate the ability to perform data collection during experiments using human subjects, animal tissues, and/or <i>in vitro</i> cells.</p> <p>N-2) Demonstrate the ability to analyze data collected from human subjects, animal tissues, and/or <i>in vivo</i> cells.</p>
<p>O-1) Demonstrate the ability to critically analyze an existing or proposed biomedical engineering device/material/system based on the assessment of known and potential interactions between a non-living material and living tissues.</p> <p>O-2) Describe safe and effective strategies that attempt to optimize the interactions between living tissues/systems and engineered devices, materials or procedures.</p>

Table 3B-2 Example of a BME Performance Criterion for Course-Embedded Goal Assessment

<p>BME Program Outcome</p>	<p>Program Outcome (C)</p> <p>An ability to 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</p>	
<p>Courses where outcome assessed</p>		
<p>Performance Criterion:</p> <p>C-2) Demonstrate the ability to identify constraints for a given design project.</p>		
<p><i>Rubric:</i> for a given problem, student work should:</p> <ul style="list-style-type: none"> • Describe the problem’s constraints • Identify how the constraints affect development of the design • Constraints should include consideration of issues from relevant fields (e.g., economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability, regulatory issues, testing with animals or human subjects, working with tissues) 	<p><i>Performance data assessed from:</i></p> <ul style="list-style-type: none"> • Laboratory Reports / Notebooks • Design Project documentation • Presentations 	
<p><i>Passing example</i></p> <ul style="list-style-type: none"> • The student work identifies at least two applicable constraints and discusses the challenges associated with approaching a design with those constraints. 		
<p><i>Fail / unacceptable example:</i></p> <ul style="list-style-type: none"> • Student work does not identify any applicable constraints, or identified constraints do not reflect a recognition that multiple issues exist. • Student work identifies constraints but does not discuss the effect on the design. 		

IV. Assessment Design

A. Course Goals

Once the Performance Criteria were established, the next step was to apply them to each course where goals are assessed. The student work performed regularly as part of many BME courses provides the appropriate samples to which the performance criteria can be applied.

When a faculty member constructs a syllabus for a BME course, therefore, he/she also plans the set of Performance Criteria that will be evaluated for the course. The syllabi for every BME course list all of the Performance Criteria that will be evaluated and also state the corresponding student work upon which the student will be assessed for that criterion. An example for the course BME 496 is provided in the **Self Study Ch 3**. All BME syllabi contained in **Appendix I-B of the Self Study** provide descriptions of Performance Criteria if the course is involved in our outcomes assessment process.

At the conclusion of a course, the instructor thus has a spreadsheet of Pass/Fail assessments for every student versus all of the Performance Criteria being evaluated. It is then a straightforward task for the instructor to write a Course Outcome Assessment Report. An example of such a report for course BME 496 Capstone Design II during Spring, 2007 appears in the **Self Study Ch 3**. The metric that we have chosen for embedded outcomes assessment is as follows: If 70% of the student work is judged as “Pass”, then we say that student coursework for that performance criterion for that semester warrants a pass.

Assessment Results and GAP analysis

The Executive Summary of the Course Report also provides some insight into specific factors that the faculty member believes contributed to a “Fail” assessment. The summary also provides a chance for the faculty member to suggest actions that could work to reduce the likelihood of a “Fail” assessment in the future.

For overall program assessment, we need to provide sufficient assessment of all the outcomes within the scope of the full BME curriculum. Table 3B-3 shows how the outcomes assessed are distributed across the curriculum for the Biomaterials+TissueEngineering Track. Note that not every BME course in the core or track is utilized for assessment – only those shown in the Table. Similar Tables exist for each BME track curriculum, and all are presented in the **Exhibits Section of the Self-Study**.

TABLE 3B-3 BME Outcome Performance Criteria Assessed Via BME Courses for BME Core + Biomaterial/Tissue Track

	BME Outcome Performance Criterion	FED 101	BME 301	BME 302	BME 310	BME 381	BME 382	BME 495	BME 496	BME 420	BME 422	BME 427	BME 430
		----- BME Core Courses -----								Biomaterial/Tissue Track			
A-1	Apply foundations of math, science, engineering		X	X	X	X	X					X	
B-1	Design and conduct experiments		x	x									
B-2	Properly collect, analyze, & present data		X	X	x								
B-3	Interpret meanings from analyzed data		X	X	x						X		
C-1	Assess needs and propose a design	X						X	X		x		
C-2	Identify constraints for a given design	x						X	X				
C-3	Develop tests of a proposed design solution	x							X				
D-1	Work with others & share responsibilities	X	X	x	x			X	X		x		
D-2	Build consensus and effective team interactions	x	X						X				
E-1	Formulate a potential engineering approach		x	X	X	x	x					x	x
E-2	Develop suitable solution to engineering problem		x	X		X	X					x	x
F-1	Understand current ethical issues in biomedicine			x				X	X	x			x
F-2	Grasp issues of human/animal/cell subject matter							X		x			x
G-1	Present orally tech info &/or experimental data	X		x				X	X	x	x	x	x
G-2	Present written communication of tech info/data	x	X	X		x	x	X	X	x	X	x	x
H-1	Assess impact of broad concerns on BME work							X	X	X			

H-2	Assess broad impact of a BME design								X	X			
I-1	Recognize need to update knowledge/skills							X	X	x	x		
I-2	Demonstrate the ability to self educate	x		x				X	X	x	x		
J-1	Grasp current issues affecting BME applications							X		X	x	X	X
J-2	Assess BME's impact on current issues	X								X		X	X
K-1	Use modern computational methods		X	x	X	X	X						
K-2	Use modern technology / instrumentation		X	x	x						X		
K-3	Apply high-level engineering software		X	x	x								
L-1	Grasp bio- & physiological principles		x			X	X			X			
L-2	Apply bio/physio insight for BME application			x		X	X			X			
M-1	Model bio- & physiological systems			X		X	X					X	X
M-2	Statistically analyze/interpret bio/physio data		X	x								X	X
N-1	Collect data from humans, tissues, &/or cells		X	X	x								
N-2	Analyze data from humans, tissues, &/or cells		X	X	x								
O-1	Assess interactions between living & non-living		X			x	x			X			X
O-2	Describe safe/effective living-interface strategies									X			X

Response to issues raised in recent assessments:

While full ABET Accreditation was awarded based on the Fall 2007 review (accreditation active retroactively from 2005 until 2014), one program weakness and one program concern were identified relative to student learning outcomes:

Weakness: A lack of evidence in how course assessment data on specific ABET outcomes were integrated to indicate the degree to which all *program* outcomes (a-o) are achieved.

Concern: The content of the existing survey course in probability and statistics (Math 225) in BSBME curriculum is insufficient.

The identified weakness prompted the BME Undergraduate Curriculum Committee (BUCC) to review the representation of ABET outcomes across the core curriculum, with consideration given to the degree to which they are achieved within each track. The findings indicated that assessments for several weakly represented outcomes will likely be achieved by the new laboratory courses recently introduced in the program:

BME 383 – Measurement Laboratory for Physiological Systems

BME 384 – Laboratory for Experimental Procedures in Biomechanics

BME 385 - Cell and Biomaterials Engineering Laboratory

Referring to Table 3B-1, the outcome performance criteria that could be assessed in these new courses include

B-1, B-2, B-3, C-1, C-2, C-3, I-1, I-2, K-2, K-3, N-1, N-2.

The committee recommended that BME 383 be added to the core BME curriculum, that BME 384 be required for the Biomechanics track, and BME 385 be a required course for the Biomaterials and Tissue Engineering track.

As a result, these courses were added to the BSBME curriculum in Fall 2008.

The identified concern, prompted the BUCC to recommend replacement of Math 225 with the two-credit course, Math 279: Statistics and Probability for Engineers.

As a result, Math 279 replaced Math 225 in the curriculum as of Fall 2008.

The BUCC review also concluded that assessments were weak for criteria related to human-tissue interaction. Therefore, the introduction of a new course to the core curriculum in this area was recommended by the subcommittee. The outcome criteria that to be assessed in this new course include F-1, F-2, H-1, H-2, O-1, O-2.

As a result, BME 304, Foundation in Tissue Engineering was added to the BSBME core curriculum in Fall 2009.

Sustainability of Assessment Process

The BSBME assessment process is well defined:

- At the end of every fall and spring semester, teaching faculty submit updated course reports on clearly defined performance criteria which are consistent across the curriculum.

While it may seem that there is considerable amount of verbiage to report for each performance criterion, much of this does not change from semester to semester if the course remains stable. Hence, the major work required is upfront -- in implementing the report the first time. In fact, ultimately we expect to eventually evolve an "Executive Summary", which will streamline the data portion of the report to one page. The goal is to structure the Course Assessment Report so that it will NOT be a burden on faculty. We want an assessment system that can be maintained on a continuing basis, i.e. every semester, without overburdening faculty.

- The BUCC meets to review course reports and make recommendations regarding these assessments every semester. Representatives from each track sit on this committee, assuring that assessment of each track, as well as the core curriculum, is consistent.