New Program Proposal
Master of Engineering in Biomedical Engineering
Clemson University

Summary

Clemson University requests approval to offer a program leading to the Master of Engineering in Biomedical Engineering to be implemented in Fall 2014. The proposed program is to be offered through traditional instruction on campus. The following chart outlines the stages for approval of the proposal; the Advisory Committee on Academic Programs (ACAP) voted to recommend approval of the proposal to the Committee on Academic Affairs and Licensing (CAAL). The full program proposal is attached.

Stages of Consideration	Date	Comments
Program Planning Summary received and posted for comment	2/15/2013	
Program Planning Summary considered by ACAP through electronic review	4/1/2013	USC's representative stated that the institution is also developing a Master of Engineering in Biomedical Engineering. She stated that USC and Clemson have been in communication to coordinate the two efforts because the intent is for both universities to offer essentially the same degree, with courses shared by both programs. According to the ACAP member, there are substantial arguments to justify both schools offering this degree to meet biomedical economic development needs in the state.
Program Proposal Received	1/15/2014	Please note that Clemson delayed submission of its proposal so that it could be considered simultaneously with USC's proposal for the same program.
ACAP Consideration	2/20/2014	Both Clemson and USC representatives discussed the collaborative nature of their two programs. Both representatives stated that the two programs are designed to complement each other to address the biochemical and biomechanical needs of the state and that the programs were designed in consultation with SCBIO[1] and local industry boards. ACAP also discussed the need for professional practitioners of this applied engineering program. In addition, ACAP members noted that MUSC, USC, and Clemson formed a bioengineering alliance focused on economic development.

[1] SCBIO unites the industry's major leaders, research institutions, and smaller organizations and individuals in a common vision for healing, feeding and fueling the world through life sciences. See www.scbio.org.

Stages of Consideration	Date	Comments
Comments and suggestions from CHE staff to the institution	2/21/2014	Staff requested the proposal be revised to include the following: • a detailed summary of the collaboration with USC • more information about programmatic assessment; and • a corrected "Estimated Costs and Sources of Financing" chart showing total costs, not just new costs.
Revised Program Proposal Received	3/21/2014	

Recommendation

The staff recommends that the Committee on Academic Affairs and Licensing commend favorably to the Commission the program leading to the Master of Engineering in Biomedical Engineering at Clemson University to be implemented in Fall 2014.

NEW PROGRAM PROPOSAL

CLEMSON UNIVERSITY

Master of Engineering in Biomedical Engineering
(M. Eng. In Biomedical Engineering)

SUBMITTED TO THE SOUTH CAROLINA
COMMISSION ON HIGHER EDUCATION

Revised March 13, 2014

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James Clements, President

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2. Classification

a) Program title:
   - **Master of Engineering in Biomedical Engineering**

b) Concentrations, options, and tracks: Not applicable

c) Academic unit in which the program resides: Department of Bioengineering

d) Designation, type, and level of degree (if baccalaureate, specify four- or five-year): Master of Engineering Degree

e) Proposed date of implementation: August 15, 2014

f) Current CIP code of the program to be modified:

g) Site: 1) Clemson University Main Campus - 300 Rhodes, Clemson SC 29634-0905
   2) CUBEInC – Clemson University Biomedical Engineering Innovation Campus 200 Patewood Rd, Suite 400C, Greenville, SC 29621

h) Whether the program qualifies for supplemental Palmetto Fellows Scholarship and LIFE Scholarship awards: Not applicable

i) Delivery mode: Traditional in-class lectures and laboratory sessions in which significant site attendance is required

j) Area of certification (only for programs that prepare teachers and other school professionals): Not applicable

3. Institutional Approval

a) Curriculum Committee – Department of Bioengineering – October 12, 2012
b) Clemson University Academic Council – December 10, 2012
c) Clemson University Board of Trustees – January 31, 2013
d) Curriculum Committee – College of Engineering and Science – February 14, 2013
e) Curriculum Committee – Clemson University – April 12, 2013

4. Purpose

a) Statement of the purpose of the program:
In today's competitive technology environment, industries need to have highly skilled practicing engineers who are flexible in their professional capabilities. The M.Eng. in Biomedical Engineering (BME) program is a practice oriented, focused degree and caters to the needs of the biomedical device and technology industry where graduates will contribute significantly to the technical competitiveness of business and industry. It provides a graduate degree that focuses on the practice of engineering in order to better serve industrial needs. Rather than culminate in a research experience and a thesis as for the Master of Science degree, the Master of Engineering curriculum provides skills and expertise that enhance the individual's ability to contribute to the technical workforce.

The program provides advanced training to students interested in expanding their knowledge and expertise. The degree adds significant depth to an individual's understanding of the practice of engineering to fill technology gaps to assure the State's and Nation's global competitiveness of its constantly evolving biomedical and biotechnology industry.

b) Program objectives:
The major objective of the M.Eng. in Biomedical Engineering (BME) degree program is to provide an in-depth advanced engineering education to students who have completed a bachelor of science degree in engineering and desire to embrace an industrial career in the field of medical technology. It will provide an intellectually rigorous professional graduate education that emphasizes clinical applications and biomedical engineering design, in order to better train a workforce to sustain a growing biomedical industry in South Carolina and in the United States. This program is based on core biomedical engineering, plus relevant clinical applications, providing the basis for strong technical contributions in industry. This program will prepare engineering graduates for professional practice in BME and leadership roles in the biomedical science and technology private sector to help develop and sustain economic growth. The program success is measured by student enrollment, graduation and placement in the field. Students are surveyed one and three years following graduation as part of the ongoing process of program assessment.

More specifically, students in the program will acquire a broad perspective of the biomedical engineering discipline that complements their undergraduate training in engineering or science, and an in-depth knowledge of an essential area in biomedical engineering. Graduates will be equipped to design biomedical devices and develop therapeutic strategies within the bounds of health care economics, the needs of patients and physicians, the regulatory environment for medical devices and pharmaceuticals, and stringent ethical standards of biomedical engineering practice. Overall, the program will graduate students who:

- Demonstrate advanced level academic expertise and practical engineering experience necessary to function as biomedical engineering professionals in a modern, ever-changing world. (**Advanced Knowledge and Life-long Learning**)
- Display competence by being selected for employment by industrial, academic or government entities or further professional/graduate studies. (**Career Opportunities**)
- Understand the broad, social, ethical and professional issues of contemporary engineering practice. (**Awareness and Responsibility**).

These Program Educational Objectives are consistent with the mission of Clemson University. In addition to the University Mission Statement, the university has a vision statement "Clemson will be one of the nation's top-20 public universities", which influences faculty hiring decisions and resource allocation (http://www.clemson.edu/about/mission-vision.html). Our Program Educational Objectives are consistent with this vision, as graduates who are capable of continuing to develop their technical and professional careers, and able to continue to learn and adapt to the world of constantly evolving technology will contribute to the economic future of the state, nation and world.

In order to achieve these objectives, the Master of Engineering has the following student learning outcomes (SLO) set for its graduates. All M.Eng. graduates will:

1. apply Mathematics, Life Sciences, Physical Sciences, and Engineering to advanced biomedical engineering problems. (SLO1)
2. demonstrate proficiently designing and validating experiments, systems, components, or processes to meet desired needs. (SLO2)
3. demonstrate proficiently identifying, formulating, and solving advanced biomedical engineering problems. (SLO3)
4. demonstrate proficient contemporary technical and scientific comprehension and lifelong learning. (SLO4)
5. demonstrate proficient technical and scientific communication. (SLO5)
6. use advanced techniques, skills, and modern engineering tools necessary for biomedical engineering practice. (SLO6)

5. Justification

a) Need for the program in the state and impact on South Carolina's economic development:

The aging baby-boom generation is expected to increase demand for biomedical devices and procedures, such as hip and knee replacements, because this generation seeks to maintain its healthy and active lifestyle. In recent years, South Carolina has become an attractive retirement destination for this population demographic. Additionally, as the public has become aware of medical advances, increasing numbers of people are seeking biomedical devices for themselves from their physicians. Professional biomedical engineers will likely experience more demand for their services because of the breadth of activities they engage in, made possible by the diverse nature of their training.

In 2012, *Forbes* magazine ranked biomedical engineering as the #1 major in the United States [1]. A 2010 CNN Money Report ranked Biomedical Engineering among the 10 best jobs for the future, and noted that "as more schools award biomedical engineering degrees … that credentials will become a must. In this perspective, credentials are associated with advanced degrees such as the M.Eng. degree" [2].

A recent release from the Bureau of Labor Statistics indicated prediction of a 62% job growth rate in the biomedical engineering profession from 2012 – 2020 [3]. Therefore nationally, there is a demand for engineers to serve an industrial need. A 2012 Battelle Institute study reports that bioscience employment in South Carolina grew by more than 45% during the last decade [4]. According to Battelle, 985 business establishments in the bioscience industry have been identified in South Carolina, with medical device manufacturing being the biggest subsector.

Bioscience represents the fast-growing sector of the innovation economy in which state inventors earned 357 life science patents over the last six years. The report indicates that South Carolina is developing a diverse biomedical industry sector where its largest subsector, medical devices, has steadily grown, even since 2007. According to SCBIO, more than 572 biomedical and biotechnology companies and institutions employ 13,520 people with an average annual wage of $53,275 in South Carolina [5]. In the past 10 years, initiatives by the South Carolina Legislature, such as the SmartState Centers, have provided tremendous incentives for economic development in the biomedical technology sector. Accordingly, these businesses need employees with knowledge and leadership skills to ensure their competitiveness. Therefore, there is a critical need to establish a

formal professional degree program in biomedical engineering to provide professionals who will work in this new knowledge-based economy. Not only is this new program is aimed at developing a workforce needed to address the specialized skills needed by South Carolina bioscience based companies, it will provide leverage for recruiting medical device companies to South Carolina where advanced engineering and leadership skills are sought in employees. In this regard, the proposed M.Eng. in BME program curriculum has been developed with the input of the Industrial Advisory Board of the Bioengineering Department at Clemson University representing the international biomedical industry and with the SCBIO Workforce Committee to address current and future state needs.

b) Centrality of the program to the Commission-approved mission of the institution:
The mission of Clemson University is to fulfill the covenant between its founder and the people of South Carolina to establish a "high seminary of learning" through its historical land-grant responsibilities of teaching, research and extended public service. Clemson University is committed to foster the economic development of South Carolina through education and research that will provide leadership to the state. Clearly, the Bioengineering department has endorsed the mission of the university and served as a substantial tool to better serve the state of South Carolina. The M. Eng. in BME program supports workforce and economic development and emphasizes the mission of the institution.

c) Relationship of the proposed program to other related programs within the institution:
Clemson University currently offers Bachelor of Science (B.S.), Masters of Science (M.S.), and Doctor of Philosophy (Ph. D.) degrees in Bioengineering. The B.S. degree program include two concentration areas (Biomaterials and Bioelectrical) and is designed to provide technical training appropriate for entry-level industrial positions and preparation for further professional training either through graduate school or medical/dental school. The M.S. and Ph. D. degrees are research-focused programs of study designed to prepare graduates to join (M.S.) and/or lead (Ph. D.) industrial and/or academic research efforts to develop new biomedical technologies. As noted above, industry is increasingly demanding post-baccalaureate training. The proposed M.Eng. program will provide a defined curriculum with an emphasis on practical training that will provide graduates with access to higher-level entry positions in product and technology development or other related focus areas.

d) Comprehensive list of similar programs in the state:
Both Clemson University and The University of South Carolina are concurrently requesting approval for a Master of Engineering Degree in Biomedical Engineering. Even though offering the same degree, both institutions are proposing different curricula that will result in engineers with different skills sets diversifying the workforce needed to attract to and retain in South Carolina the biomedical and biotechnology industry. Clemson University focused its M.Eng. curriculum on current faculty expertise and physical resources for biomaterials engineering and bioelectrical engineering, both approved concentrations for the B.S. degree in Bioengineering. The former addresses medical device and technology design through new materials synthesis, characterization and simulation. The latter includes medical imaging engineering, bioinstrumentation (pacemakers, biosignal processing and acquisition), and surgical robotics. The engineering graduates from this program will be employed by medical device manufacturers and imaging companies. The M. Eng. program at The University of South Carolina is aligned with the B.S. degree in Biomedical Engineering with faculty expertise

and strengths focusing on biochemical engineering and biomechanical engineering. Both fields are highly conducive to generate a workforce that will address regenerative medicine challenges, meet the needs of the pharmaceutical industry, and propose advanced technology for functional devices and therapy. Both programs offer different fundamental trainings that jointly address the needs incurred by biomedical engineering economic development in the state.

The proposed programs have been discussed and planned by both institutions. The department chairs, Dr. LaBerge and Dr. Bayoumi, and the faculty members at both institutions have synergistically developed the curriculum to address workforce gaps through their unique expertise. Since 1985, through the Bioengineering Alliance of South Carolina and more recently through the South Carolina Medical Translational Technology Program instigated in 2010, Clemson and the University of South Carolina are partners in research, education, and economic development. From a research perspective, their students and faculty collaborate on numerous joint projects including NIH COBRE SCBioMAT, and INBRE among others.

Overall, by both offering M.Eng. degrees in Biomedical Engineering, Clemson University and the University of South Carolina will be central and pivotal in developing the workforce to secure market advantage in this economic sector for South Carolina. M.Eng. in Biomedical Engineering graduates are highly sought out by industries surrounding medical imaging, medical devices, bioinstrumentation, software, orthopedics, tissue & cell engineering, diagnostics, drug discovery, pharmaceuticals, genomics, bioinformatics and more. This includes large pharmaceutical and medical device manufacturers like Roche, Sanofi, Pfizer, Novartis, AstraZeneca and GE, as well as Bioscience start-up companies or Testing and Medical Laboratories. Pharmaceutical and medical device companies are continuing to have a bigger impact in South Carolina's industry with a selection of companies listed in Table 1. Medical device industry in South Carolina has steadily grown over the last decade and, despite an overall economic slowdown in the last years. [4] Both Clemson Bioengineering and USC Biomedical Engineering programs are working these companies for co-op, internships, and employments for their graduates.

Table 1: Selected Pharmaceutical and Medical Device companies in South Carolina

Company name	**Company name**
AAIPharma	Nephron Pharmaceuticals
BASF	Resmed
Bausch & Lomb	Roche
Becton Dickinson	Rockwell Medical
Cell and Tissue Systems	Rhythmlink
Charles River Laboratories	SensorTech, LLC
Covidien	St. Jude Medical
CreatiVasc Medical, LLC	The Rite Dose Corporation
Deltex Medical	ToxStrategies
Kiyatec	Trumpf Medical Systems
Medtronic	Varian Medical Systems

Currently, there is no similar program at a public or private university in South Carolina. Both Clemson University and the University of South Carolina offer Master of Science (M.S.) degrees in Bioengineering / Biomedical Engineering but do not offer a

professional degree for the practice of biomedical engineering at the advanced level. The M.S. degree is a research-focused advanced degree intended to prepare students for a research career. The new M.Eng. program will provide an integrated education and internship experience preparing students for product and technology development. It is considered a professional terminal degree.

e) Similarities and differences between the proposed program and those with similar objectives offered at other institutions in the state, the region, and the nation:
Other M.Eng. in Biomedical Engineering programs are offered at other universities in the United States (Table 2). The closest universities to South Carolina are Vanderbilt University (Tennessee) and Duke University (North Carolina) and are both private institutions.

Table 2: Master of Engineering Programs in Biomedical Engineering/Bioengineering [6]

Institution	State
Tufts University	Massachusetts
Montana State University	Montana
University of California, San Diego	California
The Catholic University of America	Virginia
Stevens Institute of Technology	New Jersey
Tennessee State University	Tennessee
University of Virginia	Virginia
Worcester Polytechnic Institute	Massachusetts
Boston University	Massachusetts
Widener University	Pennsylvania
Cornell University	New York
University of Florida	Florida
Southern Illinois University Carbondale	Illinois
Texas A&M University	Texas
Vanderbilt University	Kentucky
Rice University	Texas
Duke University	North Carolina

ASEE Statistics 2013 - http://www.asee.org/papers-and-publications/publications/468-521.pdf

Additionally, such a program is not offered to South Carolina residents through the Southern Regional Education Board's Academic Common Market or as an online degree. Compared to both Vanderbilt and Duke's M.Eng. in Biomedical Engineering programs, Clemson's curriculum is unique and focuses on the unique strengths and expertise in biomaterials and medical devices of Clemson University for the past 50 years. Both above programs address mainly bioinstrumentation and bioimaging. Additionally, the proposed M.Eng. program was developed following observations and critical analysis from the Biomedical Engineering Society (BMES) membership committee, the Council of Chairs of Bioengineering/Biomedical Engineering Departments in the United States, and SCBIO Workforce Committee; emphasizing the critical need to integrate leadership, entrepreneurship and commercialization of medical device skills for biomedical engineering graduates to better address industrial expectations.

Even though, there is currently no other M. Eng. programs in the state in Biomedical Engineering, The University of South Carolina is in the process of establishing a M.Eng.

degree program in Biomedical Engineering. However, the program at The University of South Carolina is aligned with their existing BS, MS, and PhD degrees with foundations in chemical engineering and mechanical engineering. The program to be implemented at Clemson University is significantly different and targets existing education and training strengths in the Department of Bioengineering: biomaterials engineering and Bioelectrical engineering. Both programs will offer different fundamental trainings that will jointly address the needs of biomedical engineering economic development in the state. Overall, by offering M.Eng. in Biomedical Engineering degrees, Clemson University and the University of South Carolina will be central and pivotal in developing the workforce to secure market advantage in this economic sector for South Carolina.

6. Admission Criteria

Admission to a graduate level program is controlled by the Graduate School at Clemson University. M.Eng. in BME applicants must meet the minimum requirements established by the University for admission to a graduate program. In addition, individuals with the following qualifications will be admitted into the M.Eng. program:

- Must hold a BS degree from an ABET-accredited program (or equivalent if from an international university) in Bioengineering, biomedical engineering or other related engineering and technology discipline and must provide transcripts from the institution where the degree was obtained.
- A minimum undergraduate grade point average (GPA) of 3.0 is required for admission.
- International students are required to submit TOEFL scores.
- Individuals may request a waiver of some of the above requirements (e.g., undergraduate GPA less than 3.0, or undergraduate degree not in engineering) and admission to the program if they provide sufficient evidence to the graduate program director that they have had sufficient industrial experience to warrant a waiver. It will be up to the program to accept or decline this request.

7. Enrollment

a) Table 3 – Projected Total Enrollment

PROJECTED TOTAL ENROLLMENT						
YEAR	**FALL**		**SPRING**		**SUMMER**	
	Headcount	Credit Hours	Headcount	Credit Hours	Headcount	Credit Hours
2014 – 15	12	144	12	144	12	72
2015 – 16	16	192	16	192	16	96
2016 – 17	21	252	21	252	21	126
2017 – 18	28	336	28	336	28	168
2018 – 19	37	444	37	444	37	222

b & c) Process by which these estimates were made, including the academic origin of students to be served and enrollment:

A poll of the Clemson Bioengineering graduating seniors (BS) in the past three years indicated that at least 12 students would have enrolled annually in the M.Eng. degree in biomedical engineering, if offered. Based on enrollment data available through ASEE for M.Eng. in Bioengineering / biomedical engineering programs in Georgia, Virginia and North Carolina since their implementation (average 6 years), it is conservatively estimated that the program could enroll at least 15 new students in August 2014, and thereafter. Additionally, we expect that this new professional program coupled with the stellar reputation of Clemson University as the leader in biomedical devices and biomaterials development will create a substantial interest from international applicants. Not to be neglected is the steady growth of the medical and pharmaceutical industry in South Carolina requiring a workforce to sustain their needs. The Department of Bioengineering will work closely with SCBIO and its members to assure that the curriculum that will be delivered through this professional degree will meet their needs. Therefore, we anticipate that in year one, 12 students will enroll, followed by a 30% increase annually for a cap of 45 students enrolled annually and a graduation rate of 39-42 annually.

8. Curriculum

The M.Eng. curriculum provides skills and expertise that enhance the individual's ability to contribute to the technical workforce. The degree will provide professionals in the technical workforce an opportunity to continue their education and development in the context of an advanced degree. The M.Eng. also serves the practicing engineer to further his/her career in the context of an application of engineering knowledge, as opposed to a master's of science in a research context, which is focused on discovering new knowledge.

The minimum requirement for this degree is one year of full-time graduate study, or its equivalent. Eligibility for graduation requires a minimum of thirty (30) graduate credits consisting of 15-17 credits from a recommended core and 13-15 credits of technical elective courses. An internship of 1-2 credits is expected for graduation. No thesis is required for this degree. A student who has previous graduate work at another institution that has not been used towards a degree may petition the Graduate Committee to transfer up to nine (9) semester credit hours of relevant course work with grades of 'B' or better. No curricular changes are required for the proposed modification. New technical elective courses have been added to the graduate curriculum as listed below:

Core:
BIOE 8000-Seminar (1 credit) (1,0)
BIOE 8130-Industrial Bioengineering (3 credits) (3,0)
BIOE 8140-Medical Device Commercialization (3 credits) (3,0)
BIOE 8500-Mentoring Undergraduates (1 credit) (1,0)
BIOE 8010-Biomaterials (3 credits) (3,0)
BIOE 8200-Biomechanics (3 credits) (3,0)
BIOE 6350-Computer Modeling of Multiphysics Problems (3 credits) (2,0)
BIOE 6351-Computer Modeling of Multiphysics Problems Laboratory (0 credits) (0,3)

Internship:
BIOE 8900-Internship 1-2 credits (45-90 contact hours)

Choice of technical electives:
BIOE 6120-Orthopaedic Engineering (3 credits) (3,0)
BIOE 6230-Cardiovascular Engineering (3 credits) (3,0)
BIOE 6310-Medical Imaging (3 credits) (2,0)
BIOE 6311-Medical Imaging Laboratory (0 credits) (0,3)
BIOE 6400-Biotechnology for Bioengineers (3 credits) (3,0)
BIOE 6710-Biophotonics (3 credits) (3,0)
BIOE 8020-Compatibility of Materials (3 credits) (2,0)
BIOE 3021 Compatibility of Materials Laboratory (0 credits) (0,3)
BIOE 8110-Sterilization and Cleaning Engineering for Medical Devices (3 credits) (2,0)
BIOE 8111-Sterilization and Cleaning Engineering for Medical Devices Laboratory (0 credits) (0,3)
BIOE 8150-Design, Manufacturing, and Validation Methods for Reusable Medical Devices (3 credits) (3,0)
BIOE 8240 Cellular and Molecular Analysis in Tissue Engineering 4 (3)
BIOE 8241 Cellular and Molecular Analysis in Tissue Engineering Laboratory 0 (3)
BIOE 8250 Cardiac Pathophysiology and Pharmacology 3 (3)
BIOE 8270 Cardiac Electrophysiology and Arrhythmias 3 (3)
BIOE 8280 Implantable Cardiac Devices 3 (1)
BIOE 8281 Implantable Cardiac Devices Laboratory 0 (6)
BIOE 8300 Interventional Electrophysiology Imaging 2 (6)
BIOE 8310 Advanced Electrophysiology Procedures 2 (6)
BIOE 8320 Advanced Electrophysiology Problem Solving 2 (6)
BIOE 8460-Biomedical Basis for Engineered Replacement (3 credits) (3,0)
BIOE 8470-Transport Processes in Bioengineering (4 credits) (4,0)
BIOE 8480 Cellular Interactions with Biomaterials 4 (2)
BIOE 8481 Cellular Interactions with Biomaterials Laboratory 0 (2)
BIOE 8700-Bioinstrumentation (3 credits) (2,0)
BIOE 8701-Bioinstrumentation Laboratory (0 credits) (0,3)

9. Assessment

a. Assessment Process

The assessment process is a faculty-driven process involving all bioengineering department faculty members. The Department of Bioengineering will assess the M.Eng. program at multiple levels and using both direct and indirect measures for the Student Outcomes as currently conducted for its B.S., M.S., and Ph.D. degrees in Bioengineering. The Department has a standing Assessment Committee that evaluates its programs. This committee is composed of at least four assigned members, including the chair of the committee. The committee organizes assessment for the entire department including assessment for both undergraduate and graduate programs. A sub-committee for M.Eng. Assessment will be formed with responsibility to oversee the academic curriculum and coordinate the presentation of all curriculum changes to the faculty at-large for approval. The chair of the M.Eng. Assessment Sub-Committee will sit on the Departmental Curriculum Committee and Graduate Affairs Committees. This structure allows for fluid communication between the Committees such that the formal assessment milestones are obtained. The assessment process assigns responsibility for all assessment activities, ties the assessment instruments (measures) to the Program Education Objectives and Student Outcomes, and determines an assessment cycle for each instrument.

b. Student Learning Outcomes

Assessment of this new degree program will include a program assessment plan and reporting using WEAVE online. As mentioned in Section 4B, all M.Eng. graduates will demonstrate the following student learning outcomes (SLO):

- apply Mathematics, Life Sciences, Physical Sciences, and Engineering to advanced biomedical engineering problems. (SLO1)
- proficiently designing and validating experiments, systems, components, or processes to meet desired needs. (SLO2)
- proficiently identifying, formulating, and solving advanced biomedical engineering problems. (SLO3)
- proficient contemporary technical and scientific comprehension and lifelong learning. (SLO4)
- proficient technical and scientific communication. (SLO5)
- use advanced techniques, skills, and modern engineering tools necessary for biomedical engineering practice. (SLO6)

c. Assessment Instruments

There are eight assessment tools/instruments to be used to evaluate the Student Outcomes:

1. Student ePortfolios (M1)
2. Course Notebooks (M2).
3. Employer Survey (M3).
4. Student evaluation for BIOE 8500 – Mentoring Undergraduates (M4)
5. Internship preceptor evaluation (M5)
6. BIOE 8000 presentation (M6)
7. Exit survey (M7)
8. Departmental safety compliance program (M8)

These measurement instruments encompass both direct and indirect measures, but with at least one direct measure per Student Outcome. Table 4 lists descriptions of the assessment instruments with the responsible party and schedule, as well as evaluation criteria. Table 5 maps these assessment instruments to particular Student Outcomes and program objectives.

Table 4: Description of Assessment Instruments

Assessment Instrument	Description of Assessment Instrument	Responsibility	Schedule	Evaluation Criteria
M1- ePortfolio	Digital collection of the student's work with artifacts demonstrating competency in biomedical engineering design, oral/written communication, industrial practices, and mentoring/ leadership addressing the program learning objectives.	Assessment Sub-Committee and departmental industrial advisory board (consisting of practicing bioengineers in the biomedical device and technology industry).	Every year	Assessment sub-Committee and advisory board sub-committee will conclude that the ePortfolio is complete and outcomes have been met.
M2 - Course Notebooks	A course notebook contains examples of all graded work collected from students (e.g., exams, homework, lab reports, etc.), course syllabus, and textbook(s). Made for each course.	Course Instructors and Assessment Committee	Every third year in December and May	Assessment Committee will conclude that the Student Outcomes examined during a particular review have been achieved.
M3 - Employer Survey	Employers are queried for assessment of Student Outcomes of graduates employed at their institutions. Additionally, BIOE Advisory Board members meet with students during their campus visits.	Department Chair and Assessment Committee	Every other year in March	BIOE Advisory Board member surveys will indicate that graduating seniors have achieved the Student Outcomes
M4 -BIOE 8500 student evaluation	Mentoring undergraduate students is a core course where M.Eng. candidates will practice management and mentoring skills through supervision. Mentor will be evaluated by mentees.	Course Instructor and Assessment Committee	Every year	At least 80% of the mentees will concur that their mentors are effective and have met outcomes SLO4 and SLO5.
M5 - Internship preceptor evaluation	A performance report following the completion of the internship by the assigned preceptor reviews technical, professional, leadership, and communication skills of the intern.	Department Chair and Assessment Committee	Every year	At least 80% of preceptors will concur that students have met outcomes.
M6- BIOE 8000 presentation	Students are evaluated for their oral communication skills through a departmental rubric by their peers and faculty.	Department Chair and Assessment Committee	Every year	At least 80% of students will agree that the Student Outcomes are achieved.
M7- Exit Survey	Department Chair surveys graduating students using Exit Survey Form	Department Chair	Before GS7 submitted to GS and every three year thereafter	At least 80% of students will agree that the Student Outcomes are achieved.
M8- Safety compliance program	CITI training and institution courses for Use of Animals in Research, Use of Human in Research, Professional Ethical Conduct, Conflict of Interest.	Department Chair	Every year	At least 90% of students will achieve compliance and meet outcome.

Table 5 – Summary of the M.Eng. Program Assessment Plan

Program Objectives	Student Learning Outcomes	Measures
Advanced Knowledge and Life-long Learning	SLO1 SLO2 SLO3 SLO4 SLO6	M1,M2, M7 M1, M2, M7 M1, M2, M7 M4, M5, M8 M1, M2, M5
Career Opportunities	SLO3 SLO5 SLO6	M1, M2, M7 M1, M3, M6 M1, M3, M6
Awareness and Responsibility	SLO4	M4, M5, M8

At the annual Spring Faculty Retreat, all results from assessment instruments are collated and presented to the faculty by the M.Eng. Assessment sub-committee. Faculty are encouraged to bring to the discussion any concerns they have observed. These discussions will result in three possible actions: 1) Continue to watch student learning, 2) change a particular course's content, 3) change the pre-requisite course or content. The goal of any change is to strengthen the program and improve the education provided to our students.

Employment of students following degree will be monitored through the Bioengineering Professional Development office staffed with a student services coordinator. This office provides guidance on biomedical engineering career fair held annually (Southeast and Mid-Atlantic Biomedical Engineering Regional Career Conference (SEMABECC) as well as maintains an electronic network where students can search for job postings. The network consists of biomedical device industry in South Carolina (SCBIO) and bioengineering alumni. Over the past 50 years, Clemson University has awarded BS, MS, and PhD bioengineering degrees to more than 700 professionals who hold leadership positions in the field. Students are followed following employment through LinkedIn and other social networks, and will be asked to fill a follow-up survey every three years following graduation. As mentioned earlier, we are confident that we will meet our goal of 100% employment early.

10. Faculty

As of fall 2013 semester, the Department of Bioengineering comprised 23 full-time T/TT faculty members who participate in the delivery of graduate curriculum and research advising. The faculty members have on average delivered Bioengineering instruction and advising for more than 10 years. They are collectively experienced teachers and advisors. Clemson University tenured and tenure-track faculty members are expected to dedicate their time to teaching, research and scholarly activities, and service to the university, profession, and community. The academic year (fall and spring semesters) workload of a faculty member is based on an eight-block load where each block is equivalent to a 3-credit course. Research active faculty members are assigned one block each semester for scholarly research activities including publications, grant management, and grant development. Committee work, graduate and undergraduate research supervision, graduate and undergraduate coordinator, student organization advisory, administrative responsibilities, professional society activities, etc. are credited on the basis of one block for a minimum of 150 clock hours of assigned activity each semester (where 1 credit

hour is equivalent to a minimum of 50 clock hours).

a) Table 6– Faculty List

List Staff by Rank (e.g. Professor #1, Professor #2, Associate Professor #1, etc.)	Highest Degree Earned	Field of Study	Teaching in Field (Yes/No)
Professor #1	PhD	Biomedical engineering	Yes
Professor #2	PhD	Bioengineering	Yes
Professor #3	PhD	Bioengineering	Yes
Professor #4	PhD	Bioengineering	Yes
Professor #5	PhD	Medical Physics	Yes
Professor #6	PhD	Chemistry	Yes
Associate Professor #1	PhD	Bioengineering	Yes
Associate Professor #2	PhD	Biomedical engineering	Yes
Associate Professor #3	PhD	Chemical Engineering	Yes
Associate Professor #4	PhD	Biomedical engineering	Yes
Associate Professor #5	PhD	Biomedical engineering	Yes
Associate Professor #6	PhD	Molecular Biology	Yes
Associate Professor #7	PhD	Inorganic chemistry	Yes
Associate Professor #8	PhD	Electrical Engineering	Yes
Assistant Professor #1	PhD	Bioengineering	Yes
Assistant Professor #2	PhD	Bioengineering	Yes
Assistant Professor #3	PhD	Biomedical engineering	Yes
Assistant Professor #4	PhD	Materials Science and Eng	Yes
Assistant Professor #5	PhD	Pharmaceutics	Yes
Assistant Professor #6	PhD	Biochemistry	Yes
Assistant Professor #7	PhD	Biological Sciences	Yes
Assistant Professor #8	PhD	Bioengineering	Yes
Assistant Professor #9	PhD	Physics	Yes
New Technical Specialist #1	BS-MS	Electronics	No

b) Proposed changes in assignment and of the extent to which each new assignment may require the addition of new positions to fulfill the former assignment:
No changes in faculty members' academic duties are expected. New faculty positions may be filled in the next years to provide expertise to complement the current expertise and skills in the department and provide support for teaching and research, if necessary. Each new hire will conduct undergraduate and graduate teaching, research, service activities. All new faculty hires will be enrolled in the mentoring program of the College of Engineering and Science. Departmental allocation of funds will be provided for attendance at scientific conferences, professional society meetings, grant writing workshops, and academic leadership workshops, during the first two years of employment. Technical support is crucial for teaching and training for highly specialized courses in Bioengineering. One technical classified position will be filled to support courses focused on bioinstrumentation, Bioelectronics, and bioimaging. Technical supervision is also needed for equipment maintenance, safety and compliance regulation.

c) Institutional plan for faculty development as it relates specifically to the proposed program, including but not limited to, release time for research, consulting, conferences, and curriculum development:
The university, college, and department host various professional development activities related to teaching effectiveness, research proposal development and compliance, and personal development. A list of teaching effectiveness workshops regularly offered by the Office of Teaching Effectiveness and Innovation is available on request and online at http://www.clemson.edu/OTEI/. Further, the university supports faculty development in the form of sabbatical leave. The department has organized academic leadership workshops. The purpose of these workshops is to provide necessary skills needed for the faculty to address conflict, build teams, time management, and become more assertive in their day-to-day activities. This particular workshop also provided the faculty members tools to be more confident about advising and mentoring. Faculty members are encouraged to participate in professional development activities sponsored by professional societies including American Society for Engineering Education (ASEE), Society for Biomaterials (SFB), and Biomedical Engineering Society (BMES). The department provides funds for participation in these workshops as needed and requested. Faculty members in the tenure-track process are provided with individual mentoring.

d) Institutional definition of full-time equivalent (FTE):
Clemson University defines one Full-Time Equivalent (FTE) as 12 credit hours. Faculty workload is equal to four three-credit hour courses. Faculty workload is divided among responsibilities on teaching, research, and service.

e) Table 7. Head Count – Department of Bioengineering

UNIT ADMINISTRATION/FACULTY/STAFF SUPPORT						
YEAR	**NEW**		**EXISTING**		**TOTAL**	
	Headcount	FTE	Headcount	FTE	Headcount	FTE
Administration						
2014 –15	0	0	1	.25	1	.25
2015 – 16	0	0	1	.25	1	.25
2016 – 17	0	0	1	.25	1	.25
2017– 18	0	0	1	.25	1	.25
2018 – 19	0	0	1	.25	1	.25
Faculty						
2014 –15	0	0	23	5.75	23	5.75
2015 – 16	0	0	23	5.75	23	5.75
2016 – 17	0	0	23	5.75	23	5.75
2017– 18	0	0	23	5.75	23	5.75
2018 – 19	0	0	23	5.75	23	5.75
Staff						
2014 –15	0	0	4	4	4	4
2015 – 16	0	0	0	0	0	0
2016 – 17	0	0	0	0	0	0
2017– 18	0	0	0	0	0	0
2018 – 19	0	0	0	0	0	0

11. Physical Plant

The Department offers ample instructional and laboratory facilities which are all functional and well equipped to meet the needs appropriate to our educational goals. The original classroom and laboratory teaching space occupies the majority of Rhodes Engineering Research Center; in 2009 the Department has expanded its instructional capacity by building Rhodes Annex. The Department now has dedicated over 17500 sq. ft for teaching laboratories in the Rhodes Building and Rhodes Annex with equipment and computers needed to support the program, in addition to facilities at the Clemson University Biomedical Engineering Innovation Campus (CUBEInC) in Greenville. Overall, research and teaching space in Rhodes, Rhodes Annex and CUBEInC is approximately totaling 110,000 square feet.

Inaugurated in December 2011, CUBEInC is located 35 miles from Clemson University main campus in Greenville SC on the Patewood Campus of the Greenville Health System (GHS) off highway 385. CUBEInC is linked to Clemson University main campus through a bus commuter system (Greenlink). It consists of newly built state-of-the-art research and laboratory facilities for translational biomedical engineering located above orthopaedic and vascular surgery clinics. CUBEInC houses research and education facilities, translational/incubator space, meeting and

networking accommodations for scientists and clinicians, and state-of-the-art surgical-skills facilities. It provides the essential environment to further the development of clinically relevant technology aimed at improving patient care and disease diagnosis conducted by faculty and students at Clemson University.

The general condition of all laboratories is very good. The laboratories are a combination of very specialized areas of equipment and expertise (for example, mechanical testing, or molecular biology) and general laboratories such as cell culture laboratory, design laboratory and histology laboratory. Most laboratories are operated, and maintained by faculty in the Department, while some laboratories serve as shared facilities, maintained by specialized support personnel. Program classrooms will be established through the existing smart classrooms at Clemson University and at the Clemson University Biomedical Engineering Innovation Campus (CUBEInC) in Greenville SC. In order to provide access to CUBEInC, a classroom with videoconferencing capability in Rhodes will be dedicated to the program. Teaching laboratories and new faculty hires' research laboratories will be housed in Rhodes Engineering Research Center, the current home of the Department of Bioengineering. No additional space will be needed for the program.

12. Equipment

Specialized equipment has been acquired for new laboratories that will be used for the program courses. Cell culture facility for tissue engineering and cell-material interaction ($100,500); surface engineering laboratory for the characterization of biosurfaces including tissue processing, microscopy, and imaging ($90,000); and biomechanics and biomedical design laboratory including biomedical instrumentation ($240,000) were established for the program to provide the needed environment for students to acquire technical skills.

13. Library Resources

The university libraries are fully staffed and provide up-to-date reference support for teaching and research programs including free online electronic journals and literature search support for the courses to be delivered. Because the Bioengineering graduate programs (MS and PhD) have been in existence for the past 50 years, the Cooper library subscribes to all pertinent scientific journals, in both hard copy and electronic format for on-campus and off-campus access, as well as new book release pertinent to the field of Bioengineering. The library acquires new titles as requested by the faculty representative of the Department of Bioengineering to the Libraries.

14. Accreditation, Approval, Licensure, or Certification

A master of engineering programs can also be accredited by ABET Inc. Accreditation provides institutions with a structured mechanism to assess, evaluate, and improve the quality of their program. It helps students and their parents choose quality college programs. Accreditation enables employers to recruit graduates they know are well-prepared. It is also used by registration, licensure, and certification boards to screen applicants. The proposed graduate program in biomedical engineering has been developed targeting future professional accreditation by ABET. The Bachelor of Science Degree in Bioengineering in the Department of Bioengineering is ABET accredited and faculty members are knowledgeable about requirements needed to secure ABET for a M.Eng. degree. The department will conduct self-study annually as a means of internal assessment in order to plan for accreditation of the M.Eng. in Biomedical

Engineering program. The members of the Bioengineering External ABET Advisor Board will meet regularly along with an External Constituency Committee to plan for accreditation.

15. Articulation

This program will be exclusively taught at Clemson University and its facilities including Clemson University Biomedical Engineering Innovation Campus.

16. Estimated Costs and Sources of Financing

a) Estimated Costs and Sources of Financing by Year

ESTIMATED COSTS BY YEAR						
CATEGORY	**1st**	**2nd**	**3rd**	**4th**	**5th**	**TOTALS**
Program Administration	$24,380.00	$24,380.00	$24,380.00	$ 24,380.00	$24,380.00	$121,900.00
Faculty Salaries	$ 578,645.00	$578,645.00	$578,645.00	$578,645.00	$ 578,645.00	$ 2,893,225.00
Graduate Assistants	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Clerical/Support Personnel	$ 251,593.00	$251,593.00	$251,593.00	$251,593.00	$ 251,593.00	$ 1,257,965.00
Supplies and Materials	$ 4,000.00	$ 4,000.00	$ 4,000.00	$ 4,000.00	$ 4,000.00	$ 20,000.00
Library Resources	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Equipment	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Facilities	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other (Identify)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTALS	$ 858,618.00	$858,618.00	$858,618.00	$858,618.00	$858,618.00	$4,293,090.00
SOURCES OF FINANCING BY YEAR						
Tuition Funding[1]	$101,892.00	$135,856.00	$178,311.00	$237,748.00	$314,167.00	$967,974.00
Program-Specific Fees	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
State Funding*	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Reallocation of Existing Funds**	$751,926.00	$717,362.00	$671,907.00	$609,670.00	$529,651.00	$3,280,516.00
Federal Funding	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Funding (Specify)	$4,800.00	$5,400.00	$8,400.00	$11,200.00	$14,800.00	$44,600.00
TOTALS	$ 858,618.00	$858,618.00	$858,618.00	$858,618.00	$ 858,618.00	$ 4,293,090.00

*Special legislative appropriations to support the program.
**Specify significant internal sources of reallocated funds. Add additional rows as necessary.

[1]All assumptions for tuition revenue are based on the estimated enrollment in Table 3 (Section 7) using a resident full-time tuition cost of $3,981/student/academic semester and $529/credit for summer. No unique cost or other special state appropriations will be or have been required or requested. Cost for materials and supplies needed for the laboratories will be secured through lab fees.

** As mentioned earlier, the Department of Bioengineering is an existing unit. All faculty members and staff are currently on payroll in permanent positions and the program of study will be taught as part of their ongoing teaching assignments.

17. REFERENCES

1. Forbes Magazine. 2012. (http://www.forbes.com/sites/jennagoudreau/2012/05/15/best-top-most-valuable-college-majors-degrees/).
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3. US Bureau of Labor Statistics. 2012. http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm.
4. Batelle/BIO Bioscience State Industry Development 2012. http://www.bio.org/sites/default/files/v3battelle-bio_2012_industry_development.pdf.
5. SCBIO 2013. www.SCBIO.org.
6. American Society for Engineering Education (ASEE) – 2012. *www.asee.org/papers-and-publications/publications/468-521.pdf*