New Program Proposal
Master of Science in Biomedical Data Science and Informatics
Clemson University

Summary

Clemson University requests approval to offer a program leading to the Master of Science in Biomedical Data Science and Informatics to be implemented in August 2017. The proposed program is to be offered through traditional instruction. The following chart outlines the stages of approval for the proposal; the Advisory Committee on Academic Programs (ACAP) and the Committee on Academic Affairs and Licensing (CAAL) voted to recommend approval of the proposal. The full program proposal is attached.

Stages of Consideration	Date	Comments
Program Proposal Received	10/3/16	Not Applicable
ACAP Consideration	11/17/16	The Clemson representative explained the need for the proposed program as a stop-out option for the proposed Ph.D. in Biomedical Data Science and Informatics, which is to be offered as a joint program with the Medical University of South Carolina (MUSC). The Clemson representative then stated there is a workforce need for individuals prepared at the master's degree level as well as at the doctoral level. The representative further explained that this master's program will not be a joint program with MUSC but the tuition generated from this program will help support the joint program. In response to a question from an ACAP member, the Clemson representative explained that students enrolled in the Ph.D. program at MUSC will be treated as transfer students to Clemson should they decide to complete the M.S. program instead. ACAP members also addressed the delivery method of the proposed program given that the proposed Ph.D. program is to be offered jointly with MUSC. The Clemson representative explained that courses will be delivered via technology on the Clemson and MUSC campuses, but that the program proposal best fit the description for traditional delivery, especially since students will be conducting research on campus, based on the Commission's definitions for modes of curriculum delivery. In terms of employment opportunities, particularly for data scientists, ACAP members also discussed the needs of the state as compared to the needs nationally, concluding that the state has greater need because there are currently no graduate programs in biomedical data science and informatics. ACAP

Stages of Consideration	Date	Comments
		members also discussed the growing number of national initiatives that are data-driven, which exacerbates this need. With no further discussion, ACAP voted to approve the program proposal.
Comments and suggestions from CHE staff sent to the institution	12/6/16	Staff requested the proposal be revised to: • Explain why this program is only offered by Clemson given that the Ph.D. is a joint program with MUSC; • State that the program is a stop-out option for the joint Ph.D.; • Include the response provided at ACAP about students enrolled in the Ph.D. program at MUSC who will be treated as transfer students to Clemson should they decide to complete the M.S. program instead; • Provide program objectives in addition to the student learning objectives; • Provide employment data specific to South Carolina as well as elaborate on the data provided; and discuss the needs of the state in more detail as compared to the needs nationally; • Provide details about the physical facilities needed to support the program; • Resolve a discrepancy between the projected enrollment for 2017 and the tuition funding for that year; and • Identify the funding needed for library resources.
Revised Program Proposal Received	12/12/16	The revised proposal satisfactorily addressed the requested revisions.
CAAL Consideration	1/12/17	The Clemson representative explained the need for the proposed program as a stop-out option for the proposed Ph.D. in Biomedical Data Science and Informatics, which is to be offered as a joint program with the Medical University of South Carolina (MUSC). The M.S. prepares individuals at the master's degree level to meet workforce needs and provides a career advancement option for those currently in the discipline's workforce. The Committee asked about the program's delivery site, curriculum, and anticipated enrollment. The Clemson representative responded as follows: 1) that the program would be offered on the same three sites as the proposed Ph.D. program; 2) that the degree would be a subset of the proposed Ph.D. program coursework, and explained that the master's level coursework is comprehensive in providing the information

Stages of Consideration	Date	Comments
		required to work in the field and the doctoral level coursework is for specialization. Regarding enrollment, the Clemson representative stated the enrollment projections are conservative. In response to Committee inquiries about tuition and offering other degree types, such as the Masters of Public Health (MPH) in this field in the future, the representative stated 1) there is a single tuition with no in-state/out-of-state differential and 2) that all health professions programs at Clemson include public health so the University has no plan to offer a MPH.

Review

Proposal consideration focused on the need for the program, program delivery sites, the curriculum, anticipated enrollment, and plans for similar programs in the future. College representatives responded satisfactorily, addressing the need for more data scientists in the state, explaining the coursework design and the enrollment projections, and discussing the rationale for the single tuition and focus on the MS and not the MPH.

Recommendation

The Committee on Academic Affairs and Licensing recommends the Commission approve the program leading to the Master of Science in Biomedical Data Science and Informatics to be implemented in August 2017.

Name of Institution: **Clemson University**

Name of Program (include concentrations, options, and tracks)
Biomedical Data Science and Informatics, M.S.

Program Designation

☐ Associate's Degree ☒ Master's Degree
☐ Bachelor's Degree: 4 Year ☐ Specialist
☐ Bachelor's Degree: 5 Year ☐ Doctoral Degree: Research/Scholarship (e.g., Ph.D. and DMA)
☐ Doctoral Degree: Professional Practice (e.g., Ed.D., D.N.P., J.D., Pharm.D., and M.D.)

Does the program qualify for supplemental Palmetto Fellows and LIFE Scholarship awards?

☐ Yes
☒ No

CIP Code: 51.2706

Proposed Date of Implementation: August 2017, first full cohort 2018

Delivery Site(s)
Medical University of South Carolina
Clemson University (main campus)
Clemson University (CURI campus/ Zucker Family Graduate Education Center)
University Center at Greenville (Clemson University)

Delivery Mode

☒ Traditional/face-to-face*
*select if less than 50% online

☐ Distance Education
☐ 100% online
☐ Blended (more than 50% online)
☐ Other distance education

Program Contact Information (name, title, telephone number, and email address)
Dr. Eileen Kraemer
Professor and C. Tycho Howle Director, School of Computing
864-656-5874
etkraem@clemson.edu

University Contact:
Dr. Debra Jackson
Special Assistant to the Provost
dbj@clemson.edu; 864-656-4592

Institutional Approvals and Dates of Approval:
School of Computing Graduate Affairs Committee: September 5, 2016
School of Computing Faculty: September 7, 2016
College of Engineering, Computing and Applied Sciences Curriculum Committee: September 16, 2016
University Graduate Curriculum Committee: November 11, 2016
Provost: October 1, 2016
President: October 1, 2016
Board of Trustees: October 14, 2016

Background Information

State the nature and purpose of the proposed program, including target audience and centrality to institutional mission. (1500 characters)

Biomedical data science and informatics is an interdisciplinary field that applies concepts and methods from computer science and other quantitative disciplines together with principles of information science to solve challenging problems in biology, medicine and public health.

The nation's transition to new healthcare delivery models and the exponential growth in biomedical data translate to a need for professionals with expertise in data science focused in biomedical research who can leverage big data to improve health in the state and the nation. Specialized tracks will initially include precision medicine, population health, and clinical and translational informatics. The program is a unique collaboration for transformation of the health systems of South Carolina that leverages Clemson's strengths in computing, engineering, and public health and MUSC's expertise in biomedical sciences. The proposed joint PhD program will prepare the next generation of data scientists allowing MUSC and Clemson to lead a world of increasing big data sources from mobile sensors to genomic and imaging technologies, providing a talent pool for South Carolina medical, academic and industrial enterprises. While we need doctoral-prepared data scientists, we also need to develop individuals prepared at the master's level as well. The main difference is that it is expected that those with the PhD will propose and lead research projects and those with an MS will either participate in a research project led by a PhD or work as a practicing data scientist in a medical environment, government, or industry. The target constituency for the program is individuals with computer science, math, engineering, or biomedical sciences backgrounds who wish to make a contribution to biomedical sciences or individual and societal health. The MS program is designed so that it builds on the courses developed for the joint MUSC/Clemson doctoral program and that MS students may select courses, under the guidance of the program coordinator, from both Clemson and MUSC. In addition, the MS program serves as stop-out option for the joint PhD program. Students enrolled in the joint Ph.D. program at MUSC who elect this stop-out option will be admitted to the MS program as transfer students to Clemson, per university policy. The program will be offered only by Clemson, and not jointly by MUSC and Clemson because MUSC currently offers a master's degree in Health Informatics (MSHI) within its College of Health Professions. Although the MSHI differs significantly from the MS Biomedical Data Sciences and Informatics in that the MSHI is an online degree program and is a professional degree (not a research degree), MUSC elects to offer only one masters degree in Informatics.

List the program objectives. (2000 characters)

The program is based on integrating core competencies from the fields of biomedical informatics described in the literature [Kulikowski et al 2012, Valenta et al 2016] and data science described by the National Institutes of Health's Big Data to Knowledge (BD2K) initiative [Margolis et al. 2014]. Program objectives include:

1. To offer a professional masters level program that prepares its graduates to perform as leaders in the critical area of biomedical data science and informatics.
2. To develop an inter-disciplinary program that builds on the strengths of students from diverse backgrounds ranging from science, engineering, mathematics, and computing to health sciences, public health and medicine.
3. To prepare students to participate in research programs in academia, healthcare, public health and industry, as well as to apply the knowledge in clinical, government and industry settings.
4. To seek external funding that will support and advance the mission and educational activities of the biomedical data science and informatics program.

We will collect data on student retention, graduation, and placement of graduates and use these data in an annual internal review focused on continuous improvement. See the evaluation and assessment section for details.

The program is designed to include the following high level competency areas:

I. Biomedical Informatics foundations and applications:
Understand the fundamentals of biomedical informatics concepts with focus on data science:

- Understand and apply syntactic, semantic, cognitive, social, and pragmatic theories as they are used in biomedical informatics.
- Understand, and analyze the types and nature of biomedical data, information, and knowledge.
- Understand and apply a wide array of research design methodologies.
- Comprehend basic ethical and legal principles pertaining to the collection, maintenance, use and dissemination of data.
- Understand biomedical data representation including data standards and ontologies.
- Understand the principles and fundamentals in one or more of the following concentration areas of informatics: precision medicine, population health, and clinical and translational informatics.

II. Computer science, mathematics foundations, statistics and engineering
Understand theoretical basis and apply technological approaches in the context of biomedical problems. For example:

- Image processing and signal analysis.
- Information documentation, storage, and retrieval.
- Machine learning, including data mining and statistics.
- Networking, security, databases.
- Natural language processing, semantic technologies.
- Representation of logical and probabilistic knowledge and reasoning.
- Simulation and modeling.
- Software engineering.

III. Health systems, quality and safety

- Identify the principles and limitations of public health and health care programs.

- Describe a public health problem in terms of magnitude, person, time and place.
- Design, analyze and evaluate epidemiologic studies that utilize data science and informatics tools.
- Analyze the global, cultural and social context of health and disease.

IV. Domain biology and medicine
Understand the foundations of biomedical sciences and the relevance of data science in biomedical applications. This includes but is not limited to the following general areas: biochemistry, molecular biology, pathology and genomics.

Assessment of Need

Provide an assessment of the need for the program for the institution, the state, the region, and beyond, if applicable. (1500 characters)

The proposed degree program will help fill a growing need for qualified data professionals with biomedical knowledge. The program will provide graduates with marketable skills for informatics careers in biology, medicine or public health focused on the development of prescriptive analytics from large data sources. These uniquely trained master's graduates will be critical to existing efforts to improve health outcome rankings in SC. Currently funded initiatives (e.g. NSF South Big Data hub (Clemson participates) and the NIH Big Data to Knowledge (BD2K) will require data scientists. The economic impact will be large, creating jobs, and attracting associated entrepreneurial efforts to SC. Those who earn the MS will be able to provide value to health employers in areas such as precision medicine and provision of best value approaches at a population health. Building a stronger presence in data sciences and informatics – in clinical practice, research, and education – is, therefore, a high priority for the institutions. The MS in Biomedical Data Sciences and Informatics also prepares students to participate in research programs in academia, healthcare, public health and industry, as well as to apply the knowledge in clinical, government and industry settings. The program is unique to SC, and very few programs nationally focus on data science applied to health and biomedical science. The program will provide a new career path for citizens of SC and help to meet the huge projected demand in the current and future workforce.

Employment Opportunities

Is specific employment/workforce data available to support the proposed program?

☒Yes

☐No

If yes, complete the table and the component that follows the table on page 4. If no, complete the single narrative response component on page 5 beginning with "Provide supporting evidence."

Occupation	Expected Number of Jobs 2014 (US)	Expected Number of Jobs 2014 (SC)	Employment Projection 10yr	Data Source
Computer and Information Research Scientists	25,600	310	11%	BLS
Computer and Information Systems Managers	341,250	3010	15%	BLS
Computer Systems Analysts	567,800	5700	21%	BLS
Epidemiologists	5,800	40	6%	BLS
Medical Scientists	107,900	230	8%	BLS
Statisticians	30,000	400	33.8%	BLS
Management Analysts	758,000	8170	14%	BLS
Operations research analysts	91,300	780	30%	BLS
Biomedical Engineers	22,100	50	23%	BLS

**Data only available for 2012 BLS: Bureau of Labor Statistics*

Provide additional information regarding anticipated employment opportunities for graduates. (1000 characters)

Current Bureau of Labor Statistics data do not fully reflect the demand for new careers that will emerge in this field. For example, the following emerging job titles are not reflected in the data sets that are currently available: data scientist, chief medical information officer, medical informatics professional, precision medicine analyst, etc.

The fast growing opportunities for applying data science and informatics to needs across a broad spectrum of the healthcare ecosystem demand new professions in government (federal, regional, and state), health care systems, industry, and academia. Our graduates would assist health system and hospital chief medical informatics officers in bridging the gap between IT providers and clinics, hospitals and health systems in navigating big, biomedical data to solve clinical, population health, and business operation challenges. Other graduates will be employed in the health insurance industry, developing strategies to mine large data for accurate assessment of risk profiles.

Regional employers experiencing or expected to experience growth in data science and informatics include but are not limited to MUSC Health, Greenville Health System, AnMed Health, McLeod Health, Palmetto Health, Self Regional Healthcare, Spartanburg Regional Healthcare, PokitDok (https://pokitdok.com), Benefit Focus (https://www.benefitfocus.com/company/careers), and BlueCross BlueShield of South Carolina.
[1]

[1] Additional supporting data for SC can be found at: http://www.bls.gov/oes/current/oes_sc.htm

Provide supporting evidence of anticipated employment opportunities for graduates, including a statement that clearly articulates what the program prepares graduates to do, any documented citations that suggests a correlation between this program and future employment, and other relevant information. Please cite specific resources, as appropriate. (3000 characters)

N/A

Note: Only complete this if the Employment Opportunities table and the section that follows the table on page 4 have not previously been completed.
Will the proposed program impact any existing degree programs and services at the institution (e.g., course offerings or enrollment)?

☐Yes

☒No

Additional supporting data for the US at: http://www.bls.gov/emp/ep_table_102.htm

List of Similar Programs in South Carolina

Currently, no comparable MS program exists in the state of South Carolina. The most closely related programs include:

Program Name	Institution	Similarities	Differences
PhD, Statistical Genetics & Genetic Epidemiology	University of South Carolina	Some elements of our curriculum are common with this program, specifically those related to our population health track.	While our population health track shares many goals in common with this program, our outlook is broader than statistical analysis and epidemiology, and includes more emphasis on technology, "big data", large-scale computation, and learning healthcare systems. As the USC program has more of a macro-scale outlook, our precision medicine track differs substantially, with focus on improving individual health outcomes, in line with national initiatives (e.g., the recent precision medicine initiative from the White House). Moreover, our emphasis is not just on genetics, but on integration of large-scale multimodal data sources that are increasingly available in healthcare and the wider environment.
Bachelors, Data Science Program	College of Charleston	This program focuses on data science at an undergraduate level.	This is an undergraduate program. There is no emphasis on methods relevant to biology, medicine and population health. However it would serve as an excellent source of qualified applicants for our program.
MS, Health Informatics	MUSC	Some elements of our curriculum are common with this program (specifically the classes offered at MUSC). For example, fundamental informatics courses might be shared between the two programs. Both programs seek to produce individuals who can contribute to enhancement of the quality of care in health care delivery settings using informatics.	Biomedical Data Sciences and Informatics graduates will be trained to be qualified to be the developers of new and innovative tools for precision medicine and population health. The participants in MS Health Informatics program would be qualified to apply the tools developed by Data Sciences and Informatics program graduates into existing electronic health records systems and health care delivery processes.
PhD, Biomedical Imaging	MUSC	Certain aspects of this program, such as foundational knowledge of linear algebra and pattern recognition albeit focused on image processing, are in common with this proposal. Some of these courses may be provided as electives.	This program focuses on image acquisition technologies and imaging data analysis methods, whereas the Biomedical Data Sciences and Informatics PhD focuses on broader applications of informatics and analytics, to a variety of big data problems across a multitude of biomedical and health sciences.

Description of the Program

Projected Enrollment						
Year	**Fall**		**Spring**		**Summer**	
	Headcount	Credit Hours	Headcount	Credit Hours	Headcount	Credit Hours
2017*	0	0	0	0	0	0
2018	5	70	5	70	5	30
2019	8	112	8	112	8	48
2020	20	280	20	280	20	120
2021	25	350	25	350	25	150
2022	30	420	30	420	30	180

*Year 2017 is not included in the budget on page 22.

In 2017, the masters will serve as a "stop-out" for enrolled joint PhD students if necessary, and as noted in the table, we expect that number to be zero students. Recruitment will begin with the CHE approval. Full-time students should finish the program in 2-3 semesters (one calendar year), averaging 14 credit hours in the fall, 14 credit hours in the spring, and the remaining 5-6 credit hours in the summer (six hours was used to calculate summer credit hours). Please note that the Financial Table starts with the Budget Year 2018 when the first of the master's students are recruited and enrolled.

Besides the general institutional admission requirements, are there any separate or additional admission requirements for the proposed program?

☒Yes

☐No

If yes, explain. (1000 characters)

Admissions criteria:

Required:

- Bachelor's degree in biomedical/health sciences, computing, mathematics, statistics, engineering, or related discipline
- General GRE or hold a US graduate or professional degree in a related area from an accredited program
- One year of calculus; one year of college biology
- Computer programming coursework

Recommended:

- Competency in a second related area of the above list (biomedical/health sciences, computing, mathematics, statistics, engineering or related discipline), as demonstrated by completion of a major, minor or certificate
- Relevant research or work experience
- Coursework in multivariate calculus, linear algebra, probability and statistics, and biostatistics
- One year of computer science coursework that focuses on the fundamentals of computer science and software engineering principles, including abstraction, modularity, and object-oriented programming

Are there any special articulation agreements for the proposed program?

☐Yes

☒No

If yes, identify. (1000 characters)

Curriculum

Elements of the degree:

Coursework (32-34 hours): Each student will work with the graduate coordinator to construct a program of study that conforms with the requirements outlined below and takes into account both the student's prior preparation and intended focus area. In cases where the student comes to the program with prior coursework in a required area, the graduate coordinator may approve a substitution. In cases where a student lacks pre-requisites for a required course, the student will be asked to complete both the pre-requisite coursework and the required course. Because the curriculum will be tailored to each student, the time needed to complete the degree will vary, but in general, it is expected that full-time students can complete the degree in 2-3 semesters (one calendar year), and that part-time students can complete the degree in 5-6 semesters (two courses per semester). A minimum of one-third of the coursework must be completed at Clemson.

a. Area I – Biomedical foundations and applications (12 hours)
b. Area II – Computing/Math/Stat/Engineering (12 hours)
c. Area III – Health Systems, Quality and Safety (5-6 hours)
d. Area IV – Domain Biology/Medicine (3-4 hours)

Curriculum by Category

	Curriculum by Category*					
Area	**Sub-area**		**Course number**	**Course name**		**Credit Hours**
Area I – Biomedical informatics foundations and applications						**12**
	Research Foundations				Choose 1 course	3
			CLEM:HLTH 8210	*Health Research I: Design and Measurement (3)*		
			CLEM:BIOE 6150	*Research Principles and Concepts (3)*		
			MUSC:HIN-708	*Applied Statistical and Research Methods (3)*		
			MUSC:DHA-866	*Applied Research (3)*		
	Biomedical Informatics Foundations				2 required courses	6
			MUSC: (NEW BMI)	*Intro to Biomedical Informatics (3)*		
			MUSC: (NEW BMI)	*Biomedical Data standards and ontology (3)*		
	Track-specific core course				Choose 1 course	3
			MUSC: (NEW BMI)	*Precision medicine informatics (3)*		
			MUSC: (NEW BMI)	*Population health informatics (3)*		
			MUSC: (NEW BMI)	*Clinical and translational informatics (3)*		

Curriculum by Category*						
Area	**Sub-area**		**Course number**	**Course name**		**Credit Hours**
Area II – Computing/Math/Stat/Engineering						**12**
	Mathematical and Computing Foundations				**Choose 1 course**	**3**
			CLEM:MATH 8050	*Data Analysis (3)*		
			CLEM:STAT 8010	*Statistical Methods (3)*		
			MUSC:BIOMI 810	*Mathematical Methods in Biomedical Imaging (3)*		
	Data Science					
		Machine Learning / Data Science			**Choose 1 course from this group**	**3**
			CLEM:CPSC 8100	*Intro to Artificial Intelligence (3)*		
			CLEM:CPSC 6810	*Data Science (3)*		
			MUSC: (NEW BMI)	*Machine Learning (3)*		
					Choose 1 course from remaining groups	**3**
		Biostatistics				
			CLEM:STAT 8190	*Biostatistics (3)*		
			CLEM:HLTH 8310	*Quantitative Analysis in Health Research I (3)*		
			MUSC: BMTRY 700	*Introduction to Clinical Biostatistics (Biostatistics I) (5)*		
			MUSC: BMTRY 701	*Biostatistical Methods II (4)*		
		Data Mining				
			CLEM:CPSC 8650	*Data Mining (3)*		
			CLEM:ECE 8560	*Pattern Recognition(3)*		
			CLEM:CPSC 8480	*Network Science (3)*		
			CLEM: MATH 8070	*Applied Multivariate Statistical Analysis (3)*		
			MUSC:BMTRY 719	*Bayesian Biostatistics (3)*		

		Visualization and exploratory data analysis				
			CLEM:CPSC 8040	*Data Visualization (3)*		
			CLEM:CPSC 8810	*Advanced Visualization (3)*		
		Image processing				
			CLEM:ECE 6930	*Introduction to Computer Vision (3)*		
			CLEM:ECE 8770	*Computer Vision (3)*		
			CLEM:ECE 8470	*Digital Image Processing (3)*		
			CLEM:BIOE 6310	*Medical Imaging (3) (&6311 non-credit lab)*		
			MUSC:BIOMI 812	*Signal and Image Processing (3)*		
		Decision analysis/Knowledge integration / modeling				
			CLEM:MATH 6410	*Introduction to Stochastic Models (3)*		
			CLEM:ECE 6420	*Knowledge Engineering (3)*		
			CLEM:IE 8030	*Engineering Optimization and Applications (3)*		
			CLEM:IE 8520	*Prescriptive Analytics (3)*		
		Geospatial analysis				
			CLEM:PADM 8420	*GIS for Public Administrators (3)*		
			MUSC: (DPHS NEW)	*GIS and Mapping for Public Health (3)*		
		Algorithms/Data Structures				
			CLEM:CPSC 8400	*Design & Analysis of Algorithms (3)*		
			CLEM:CPSC 8380	*Advanced Data Structures (3)*		
		Natural Language Processing				
			MUSC: (NEW BMI)	*Biomedical Natural Language Processing (3)*		
	Systems and Data Management				**Choose 1 course**	**3**
		Data management tools and technology				
			CLEM:CPSC 6620	*Database management (3)*		
			CLEM:CPSC 8620	*Database management system design (3)*		
			CLEM:CPSC 8470	*Introduction to information retrieval (3)*		
			MUSC:HIN 700	*Database Management (3)*		

		Computing environments				
			CLEM:CPSC 6550	*Computational Science: Methods & Software Systems (3)*		
			CLEM:CPSC/ECE 6780	*General Purpose Computation on GPUs (3)*		
			CLEM : ECE 8780	*High-Performance Computing with GPUs (3)*		
			CLEM:CPSC 8200	*Parallel Architectures (3)*		
			CLEM:ECE 6730	*Introduction to Parallel Systems (3)*		
			CLEM:ECE 8750	*Peer-to-Peer, Wireless, and Cloud Computing (3)*		
			CLEM:CH 9300	*Introduction to Scientific Computing (3)*		
		Performance and scalability				
			CLEM:CPSC 8300	*Systems Modeling (3)*		
		Human factors / HCI / Usability				
			CLEM: CPSC 6140	*Human and Computer Interaction (3)*		
			CLEM:HCC 8310	*Fundamentals of Human-Centered Computing (3)*		
			CLEM:IE 6880	*Human Factors Engineering (3)*		
			CLEM:IE 8000	*Human Factors Engineering (3)*		
		Applied Software Engineering				
			CLEM:CPSC 8710	*Foundations of Software Engineering (3)*		

	Curriculum by Category*					
Area	**Sub-area**		**Course number**	**Course name**		**Credit Hours**
Area III – Health Systems, Quality and Safety					Choose 2 courses	**5-6**
			CLEM:HLTH 8110	*Health Care Delivery Systems (3)*		
			CLEM:HLTH 8020	*Health Economics (3)*		
			CLEM: HLTH 8140	*Health System Quality Improvement (2)*		
			MUSC:HAP 632 (3)	*Quality Management of Health Care Services (3)*		

	Curriculum by Category*					
Area	**Sub-area**		**Course number**	**Course name**		**Credit Hours**
Area IV– Domain Biology/Medicine					Choose 1 course	3 -4
	Foundations of Biomedical Sciences					
			CLEM:BIOE 8460	*Biomedical Basis for Engineered Replacement (3)*		
			MUSC:CGS-765	*Proteins: Dynamic Structure and Functions (3)*		
			MUSC:CGS-766	*Genes: Inheritance and Expression (4)*		
			MUSC:CGS-767	*Cells: Organization and Communication (3)*		

Course Descriptions for New Courses

Please note: While these courses are listed as part of the MS proposed program, they are in development in support of the PhD program and will be scheduled for implementation when the PhD is implemented jointly by the two universities. The Clemson course is approved and ready for implementation.

Course Name	Description
Data Science (3) (CLEM)	Being able to extract knowledge from large, complex data sets is one of the most critical skills in today's data-driven world. This course provides an introduction to fundamental concepts and techniques of Data Science. Students will learn to combine tools and methods from computer science, statistics, data visualization, and the social sciences to extract knowledge from data. Concepts taught in the course will be illustrated with case studies drawn from fields such as business, public health, and the social sciences. Programming languages used to analyze and visualize data will include R and Python.
Intro to Biomedical Informatics (3) (MUSC)	This course provides an introduction to the fundamental principles of biomedical informatics. Students will examine the unique characteristics of biomedical data and methods for representation of data, information, and knowledge to further the science and improve health. The course provides an introduction to data standards, information security and confidentiality, and methods underlying many biomedical informatics applications, including information retrieval, medical decision making, evaluation of evidence and knowledge representation.
Biomedical Data standards and ontology (3) (MUSC)	This course will explore the concepts of interoperability across a variety of biomedical information systems and tools. Students will examine several categories of data standards including controlled vocabularies, standard data models and ontologies. Students will learn value of a standards-based approach to integration. Standards critical for healthcare interoperability and research systems will be examined in greater depth. Examples include but are not limited to HL7 RIM, ICD, LOINC, and SNOMED. Use cases will be examined for the utilization of these standards in various national and industry-wide efforts. Students will gain experience in navigating through standards repositories, documents and tools.
Precision medicine informatics (3) (MUSC)	This course will focus on the inherent translational informatics challenges, concerns, and opportunities afforded by precision medicine to provide a more accurate, personalized characterization of patient populations based on various characteristics including molecular (e.g., genomic, proteomic), clinical (e.g., comorbidities), environmental exposures, lifestyle, patient preferences and other information. Informatics is a necessary component to tackle precision medicine. This includes managing big data, creating learning systems for knowledge generation, providing access for individual involvement, and ultimately supporting the optimal delivery of precision treatments derived from translational research.
Population health informatics (3) (MUSC)	This course will introduce students to the principles of and methods underlying assessment of the health of and management of populations using informatics and data sciences. The scope of the course will span from traditional public health to healthcare applications. Specific topics covered will include syndromic surveillance, outbreak simulation and modeling, population health assessment, healthcare quality measurement, health status and functional outcome measurement, patient reported outcome and quality of life measurement, risk stratification and severity of illness modeling, similarity measurement, time series analysis, statistical process

	control including open and closed loop control techniques, discrete event simulation, traditional and Bayesian mixed effects non-linear models, and expert-system methods.
Clinical and translational informatics (3) (MUSC)	This course will introduce the student to the principles of clinical and translational research informatics. Topics include the design of clinical research, clinical trial administration, good clinical data management, research participant recruitment, use of administrative databases, registries and electronic health records in research, standards in terminology and messaging for clinical research, and research collaboration. Students will also be familiarized with existing systems, tools and national efforts in the translational research community (such as i2b2, REDCap, and PCORnet) along with cutting edge research in this area.
Biomedical Natural Language Processing (3) (MUSC)	In this course the students will examine current natural language processing (NLP) methods and their applications in the biomedical domain. The course will provide a systematic introduction to basic knowledge and methods used in NLP research as well as hands-on experience with existing biomedical NLP systems. Students will gain knowledge and skills in various NLP tasks such as information extraction, information retrieval, named entity recognition, classification tasks and concept mapping.
GIS and Mapping for Public Health (3) (MUSC)	In this course students will learn practical Geographic information systems (GIS) skills that can be applied in any public health setting. There are two goals for this course: 1) for students to develop a GIS toolkit by learning the most frequently used GIS skills; and 2) for students to learn how to apply GIS in public health setting through the exploration of applicability of GIS to public health data. The course will involve hands-on training in GIS methods and tools.

Faculty

Faculty and Administrative Personnel (Clemson) – *computer science*				
Rank	**Full- or Part-time**	**Courses Taught or To be Taught, Including Term, Course Number & Title, Credit Hours**	**Academic Degrees and Coursework Relevant to Courses Taught, Including Institution and Major**	**Other Qualifications and Comments (i.e., explain role and/or changes in assignment)**
Professor 1 (Supervisor)	Full-time	CPSC 8470-Introduction to Information Retrieval (3)	PhD Computer Science, Georgia Institute of Technology	
Professor 2	Full-time	CPSC 8200-Parallel Architecture (3)	PhD Computer Science, Vanderbilt University	
Professor 3	Full-time	CPSC 8620-Database Management System Design (3), CPSC 6620-Database Management Systems (3), CPSC 8650-Data Mining (3)	PhD Computer Science, University of Central Florida	
Professor 4	Full-time	CPSC 6780-General Purpose Computation on Graphical Processing Units (3)	PhD Mathematics, University of Notre Dame	
Professor 5	Full-time	CPSC 8040-Data Visualization (3)	PhD Visual Computing, UMass Amherst	
Professor of Practice 1	Full-time	CPSC 6810-Selected Topics in Data Science (3)	PhD Political Science, New York University	
Professor Emeritus 1	Part-time	CPSC 8380-Advanced Data Structures (3)	PhD Communication Sciences, University of Michigan	
Professor Emeritus 2	Part-time	CPSC 6550-Computational Science (3)	PhD Mathematical Sciences, Clemson University	
Associate Professor 1	Full-time	CPSC 8400-Design & Analysis of Algorithms (3),	PhD Computer Science, MIT	
Associate Professor 2	Full-time	CPSC 6140-Human and Computer Interaction (3)	PhD Engineering Psychology, Georgia Institute of Technology	
Associate Professor 3	Full-time	CPSC 8100-Introduction to Artificial Intelligence (3)	PhD Computer Science, University of Texas at Dallas	
Associate Professor 4	Full-time	CPSC 8300-Systems Modeling (3)	PhD Electrical Engineering, North Carolina State University	
Associate Professor 5	Full-time	CPSC 8710-Foundations of Software Engineering (3)	PhD Computer Science, Vanderbilt University	

Note: Individuals should be listed with program supervisor positions listed first. Identify any new faculty with an asterisk next to their rank

Faculty and Administrative Personnel (Clemson) – *computer science, engineering & mathematics*				
Rank	**Full- or Part-time**	**Courses Taught or To be Taught, Including Term, Course Number & Title, Credit Hours**	**Academic Degrees and Coursework Relevant to Courses Taught, Including Institution and Major**	**Other Qualifications and Comments (i.e., explain role and/or changes in assignment)**
Professor 1	Full-time	IE 8520-Prescriptive Analytics (3), IE 6880 – Human Factors Engineering (3)	PhD Industrial & Systems Engineering, Virgina Tech	
Professor 2	Full-time	BIOE 6150-Research Principles and Concepts (1)	PhD Biomedical Engineering, University of Montreal, Quebec	
Professor 3	Full-time	MATH 6410-Introduction to Stochastic Models (3)	PhD Mathematics, Carnegie-Mellon University	
Professor 4	Full-time	STAT 8010-Statistical Methods I (3)	PhD, Clemson University	
Professor 5	Full-time	MATH 8050-Data Analysis (3) MATH 8070-Applied Multivariate Analysis (3)	PhD Biometry, Medical University of South Carolina	
Associate Professor 1	Full-time	BCHM 6360-Molecular Biology: Genes to Proteins (3)	PhD Biochemistry, Louisiana State University	
Associate Professor 2	Full-time	ECE 6730-Introduction to Parallel Systems (3)	PhD Computer Science, Georgia Tech	
Associate Professor 3	Full-time	IE 8030-Engineering Optimization & Application (3)	PhD Industrial & Systems Engineering, University of Florida	
Assistant Professor 1	Full-time	CPSC 8480-Network Science (3), CPSC 8490-Principles of Scientific Computing (3), CPSC 8810-Advanced Visualization (3)	PhD, Weizmann Institute of Science, Israel	
Assistant Professor 2	Full-time	HCC 8310-Fundamentals of Human-Centered Computing (3)	PhD Informatics, University of California	
Assistant Professor 3	Full-time	IE 8000-Human Factors Engineering (3)	PhD Industrial Engineering, University of Iowa	
Assistant Professor 4	Full-time	BIOE 6310-Medical Imaging (2) BIOE 6311-Medical Imaging Lab 2)	PhD Biomedical Engineering, Vanderbilt University	
Adjunct Professor 1	Part-time	ECE 8770-Computer Vision (3) ECE 8470-Digital Image Processing (3)	PhD Electrical Engineering, Stanford University	

Note: Individuals should be listed with program supervisor positions listed first. Identify any new faculty with an asterisk next to their rank

Faculty and Administrative Personnel (Clemson) – *public health sciences*				
Rank	**Full- or Part-time**	**Courses Taught or To be Taught, Including Term, Course Number & Title, Credit Hours**	**Academic Degrees and Coursework Relevant to Courses Taught, Including Institution and Major**	**Other Qualifications and Comments (i.e., explain role and/or changes in assignment)**
Professor 1	Full-time	HLTH 8140-Health System Quality Improvement (2)	PhD, Health Policy; Brandeis University	
Professor 2	Full-time	HLTH 8130-Population Health & Research (2)	PhD, Public Health Education and Promotion, University of South Carolina, Arnold School of Public Health	
Associate Professor 1	Full-time	HLTH 8110-Health Care Delivery Systems (3)	PhD Public Administration & Policy, SUNY Albany	
Associate Professor 2	Full-time	HLTH 8090-Epidemiological Research (3)	PhD, Nutritional Epidemiology; John Hopkins University MD, Jiao Tong University School of Medicine	
Associate Professor 3	Full-time	HLTH 8020-Health Economics (3); HLTH 8100-Health Policy (3)	PhD, Policy Analysis; Pardee RAND Graduate School	
Assistant Professor 1	Full-time	HLTH 8310-Quantitative Analysis in Health Research I (3)	PhD, Policy Analysis; Pardee RAND Graduate School	
Assistant Professor 2	Full-time	HLTH 8210-Health Research I: Design & Measurement (3)	PhD, International Health; Harvard University School of Public Health	

Faculty and Administrative Personnel (MUSC) – *biomedical informatics*				
Rank	**Full- or Part-time**	**Courses Taught or To be Taught, Including Term, Course Number & Title, Credit Hours**	**Academic Degrees and Coursework Relevant to Courses Taught, Including Institution and Major**	**Other Qualifications and Comments (i.e., explain role and/or changes in assignment)**
Associate Professor 1 (supervisor)	Full time	Clinical and translational informatics (3)	MD American Univ of Beirut. Fellowship (Informatics) Harvard/MIT	
Professor 1	Full time	Population health informatics (3)	MD Univ of California, Los Angeles, MSc (medical informatics) Stanford Univ	
Professor 2	Full time	Database Management MUSC:HIN 700 (3), Applied Statistical and Research Methods MUSC:HIN-708 (3)	PhD (Computer Science) Flinders Univ of South Australia	
Professor 3	Full time	Bayesian Biostatistics MUSC:BMTRY 719 (3)	PhD (Statistics) Univ of St Andrews, UK	
Associate Professor 2	Full time	Precision medicine informatics (3)	PhD (Computer Science), Fellow (Biomedical Informatics) Vanderbilt Univ	
Associate Professor 3	Full time	Biomedical Data standards and ontology (3)	PhD or MD (Biomedical Informatics)	
Assistant Professor 1	Full time	Intro to Biomedical Informatics (3),	PhD (Biomedical Informatics) Univ of Utah	
Assistant Professor 2	Full time	Biomedical Natural Language Processing (3)	MD North Sichuan Medical School, China, MS (Computer Science) Purdue Univ	

Total FTE needed to support the proposed (PhD and MS) program (i.e., the total FTE devoted just to the new program for all faculty, staff, and program administrators). No additional FTE, beyond those required for the PhD, are required for the MS program.

Clemson:

Faculty	1.0 FTE /yr	Staff	0.3 FTE/yr	Administration	0.10 FTE/yr

Faculty /Administrative Personnel Changes

Provide a brief explanation of any additional institutional changes in faculty and/or administrative assignment that may result from implementing the proposed program. (1000 characters)

One new faculty member to support teaching of new courses in machine learning and data science for the doctoral program, 0.30 FTE for staff support and 0.10 for faculty member to serve as program co-director at Clemson are required for the MS/PhD program. No additional faculty are required for the MS program.

Library and Learning Resources

Identify current library/learning collections, resources, and services necessary to support the proposed program and any additional library resources needed. (1000 characters)

Current MUSC library resources are adequate to support the proposed program. The library is a database and knowledge center, academic computing support unit, electronic education center, and leader in information planning. Online resources include the full catalog as well as major biomedical and health-related databases. The library employs over 20 staff, including more than 10 librarians, and each college at MUSC has a specific librarian assigned to serve its students. The MS students will have access to the holdings at MUSC.

The Clemson University Library holdings and electronic access are adequate to support the program. All major journals in our files are available online or through open access. No additional library resources are anticipated. The libraries hold more than 1.8 million items including books, periodicals, electronic resources, digital media collections, government publications and patents, musical recordings, maps, and microforms. In conversations with the librarian, required resources for the program would be gathered through Interlibrary Loan and PASCAL which are available to students and faculty without cost as they are covered by the R.M. Cooper Library existing budget. In addition, places to study and meet are available for student teams as needed in addition to technology items (e.g., photography, video, projectors, etc.).

Student Support Services

Identify academic support services needed for the proposed program and any additional estimated costs associated with these services. (500 characters)

No additional support services are required for the MS students.

Physical Resources

Identify any new instructional equipment needed for the proposed program. (500 characters)

No additional physical resources beyond those needed for the joint PhD program are required for the MS program. We anticipate that the MS students will occupy otherwise unfilled seats in existing classes.

Will any extraordinary physical facilities be needed to support the proposed program?

☐Yes

☒No

Identify the physical facilities needed to support the program and the institution's plan for meeting the requirements, including new facilities or modifications to existing facilities. (1000 characters)

No additional space beyond that needed for the joint PhD program is required for the MS program. Non-thesis MS students typically do not engage in research under the supervision of an advisor. Rather, they attend classes and are able to perform their out of class work in existing public spaces such as the library, which has adequate conference rooms and seminar space for students to engage in group projects.

Financial Support

MS Program Estimated New Costs by Year						
Category	**1st (2018)**	**2nd (2019)**	**3rd (2020)**	**4th (2021)**	**5th (2022)**	**Total**
Program Administration						
Faculty & Staff Salaries	33,043	51,036	105,032	125,712	110,875	425,699
Graduate Assistants						-
Equipment						-
Facilities	21,553	40,368	109,606	143,858	181,262	496,648
Supplies & Materials	30,592	34,594	38,614	39,753	41,403	184,957
Library Resources						-
Other Admin Cost	35,791	51,232	119,455	149,050	166,800	522,327
Total	**120,980**	**177,231**	**372,708**	**458,373**	**500,340**	**1,629,631**
Sources of Financing						
Category	**1st**	**2nd**	**3rd**	**4th**	**5th**	**Total**
Tuition Funding	132,267	261,855	765,903	1,005,475	1,253,387	3,418,887
State Funding (i.e., Special State Appropriation)						
Reallocation of Existing Funds						
Federal Funding						
Other Funding						
Total	**132,267**	**261,855**	**765,903**	**1,005,475**	**1,253,387**	**3,418,887**
Net Total (i.e., Estimated New Costs)	**11,287**	**84,625**	**393,195**	**547,102**	**753,047**	**1,789,255**

*Provide an explanation for these costs and sources of financing in the budget justification.

Budget Justification

Provide a brief explanation for the other new costs and any special sources of financing (state funding, reallocation of existing funds, federal funding, or other funding) identified in the Financial Support table. (1000 characters)

Note: Institutions need to complete this budget justification *only* if any other new costs, state funding, reallocation of existing funds, federal funding, or other funding are included in the Financial Support table.

Expenses:

Faculty & Staff Salaries

- The program will leverage existing faculty within the interdisciplinary department areas at Clemson supporting the joint MUSC/CU doctoral program. As the Master's program grows, funding for new course sections will be added to accommodate growth and ensure appropriate student to faculty ratios. Proposed part-time support for a graduate program and administrative coordination has been budgeted.

Facilities

- Support for debt service and facilities.

Other Admin Cost:

- Support for information technology, student services, and academic services.
- ·Marketing to ensure appropriate student quality and demand.

Revenues:

Tuition Funding:

- Enrollment is projected to grow incrementally to 30 students by year 5 and tuition has been proposed at a market-based professional master's level and set by the Board at $14,420/semester for both resident and non-resident students.

Evaluation and Assessment

Programmatic Assessment: Provide an outline of how the proposed program will be evaluated, including any plans to track employment. Identify assessment tools or software used in the evaluation. Explain how assessment data will be used. (3000 characters)

Each academic degree program engages in continuous quality improvement through annual self-assessment of performance on program outcomes (PO) and student learning outcomes (SLO). These data will support continuous quality improvement in the program.

Program Outcomes

PO1: The program performs well on indices of quality.
Measure 1: The percent of students who complete the program within four semesters.
Target: 90%
Source: Office of Enrollment Management records

Measure 2: Percent of graduating students who obtain full-time employment in a relevant field within one year of graduating.
Target: 90%
Source: Graduate student exit survey

PO 2: The program performs well on indices of satisfaction.
Measure 1: Percent of graduating students who agree that they would recommend the program to other prospective students.
Target: 90%
Source: Graduating student exit survey

Measure 2: Percent of graduating students who agree that the program met their expectations.
Target: 90%
Source: Graduating student exit survey

Student Learning Outcomes
SLO 1: Graduating students demonstrate professional skills appropriate for a practicing biomedical data and informatics scientist.

Measure 1: Percentage of graduates rated as "meets or exceeds expectations" on a survey of employers.
Target=93%
Source=Employer survey

Measure 2: Percentage of graduates who rate their skills as very good or excellent based on the stated core competencies and learning outcomes (found on pages 2 and 3).
Target=93%
Source: Student Exit survey

Will the proposed program seek program-specific accreditation?

☐Yes

☒No

If yes, provide the institution's plans to seek accreditation, including the expected timeline for accreditation. (500 characters)

Will the proposed program lead to licensure or certification?

☐Yes

☒No

If yes, explain how the program will prepare students for licensure or certification. (500 characters)

Teacher or School Professional Preparation Programs

Is the proposed program a teacher or school professional preparation program?

☐Yes

☒No

If yes, complete the following components.

Area of Certification

Please attach a document addressing the South Carolina Department of Education Requirements and SPA or Other National Specialized and/or Professional Association Standards.