

Vice Provost W. Randy Smith  
Council on Academic Affairs  
Office of Academic Affairs  
203 Bricker Hall  
190 North Oval Mall  
Columbus, OH 43210

The College of Arts and Sciences requests that the Council on Academic Affairs approve a new major entitled Data Analytics. The major will be jointly administered between the Department of Statistics and the Department of Computer Science and Engineering. The major has been vetted by and has approval of the College of Arts and Sciences, the College of Engineering, and the Fisher College of Business. If you have any questions about this new major, feel free to contact Chris Hadad (hadad.1@osu.edu) or David Tomasko (tomasko.1@osu.edu).

#### ATTACHMENTS

1. BS Data Analytics Major advising sheet - general
2. Business Analytics specialization
3. Computational Analytics specialization
4. Biomedical Informatics specialization

## **EXECUTIVE SUMMARY**

As part of The Ohio State University's initiative to explore new ideas in STEM education, the College of Arts and Sciences and the College of Engineering have worked together to create a new major entitled Data Analytics. At the beginning of the 2013 spring semester, a small group met to develop a list of program objectives for this new major. Once the initial list was developed, the group expanded and eventually included faculty from the College of Arts and Sciences, the College of Engineering, the Fisher College of Business, and the College of Medicine. Starting in June 2013, the group met weekly to discuss how the new major would be structured and administered. In addition, meetings were held with interested businesses such as IBM, JPMorgan Chase, Nationwide Insurance and Battelle to gather their input on the major.

The major will be structured in three parts: core subject matter, discipline-specific specializations, and an integrative experiential education component. Each specialization will consist of a number of technical courses and a capstone experience that is ideally optimized for the subject. In the short term, as enrollments may be initially small, some specializations may combine their capstone experience as needed in order to have critical enrollments for offering the ideal pedagogical experience. Business, Computer Science and Engineering, and Biomedical Informatics have submitted specializations as part of this proposal, and as additional specializations are created, they will go through an approval process that is discussed in the proposal.

## MAIN BODY

### Rationale & Chronology

The Harvard Business Review has referred to data science and analytics as the “sexiest job in the twenty first century.” The notion of “Big Data” has created a stir and promises to revolutionize all walks of human endeavor ranging from the financial industry to the health-care industry, from the social sciences (e.g., study of personalized and social interactions) to engineering (e.g., analyzing sensory data from the manufacturing process), and from scientific discovery to cyber-security. Increasingly one is seeing companies locally (e.g. Nationwide, JPMorgan Chase, IBM), nationally (e.g. Microsoft, IBM, Google), and even internationally (e.g. TATA Group, Infosys) looking for employees who have the skills to build and query large data sets but also understand how to ask the right questions and extract actionable knowledge. Data Analytics includes the set of skills necessary to identify how to manage, represent and manipulate large and complex data stores, how to abstract, model, and effectively analyze such data to facilitate the identification and evaluation of appropriate hypothesis and actionable patterns, and how to create quantitative visual cues to help explain and take informed decisions from those data. These skills draw heavily from traditional academic areas such as computer science, mathematics, operations research, and statistics. In fact, current departments of analytics in corporations are staffed largely with computer science, mathematics, statistics, and some social science majors who are being trained to develop a complete set of analytics and software skills required for the particular operation. Based on input from companies (see Consultative Process below), it appears that a critical need exists for graduates who have both quantitative computational and modeling skills along with behavioral psychology and critical thinking skills. This input from companies was specifically requested with respect to an *undergraduate* degree and was universally and enthusiastically positive.

A brief review of employment prospects shows universal agreement of the demand for employees with skills in in this area. As noted in a recent editorial in the New York Times: *“To meet demand from employers, the United States will need to increase the number of graduates with skills handling large amounts of data by as much as 60 percent, according to a report by McKinsey Global Institute. There will be almost half a million jobs in five years, and a shortage of up to 190,000 qualified data scientists, plus a need for 1.5 million executives and support staff who have an understanding of data.”*

A broad analysis of labor statistics, census data and economic indicators by McKinsey & Company shows that data analysis is now an integral business function and important factor for production in nearly every segment of the economy. Figure 1 is taken from that report and shows the projected demand for people with deep analytical skills outstripping supply by 140,000-190,000 by 2018. Table 1 shows a more local analysis based on the Occupational Outlook Handbook from the Bureau

of Labor Statistics. It shows strong growth expected for four job functions most closely related to Data Analytics (Data Analytics as a job function is not yet tracked): Database Administrators, Market Research Analysts, Statisticians and Management Analysts.

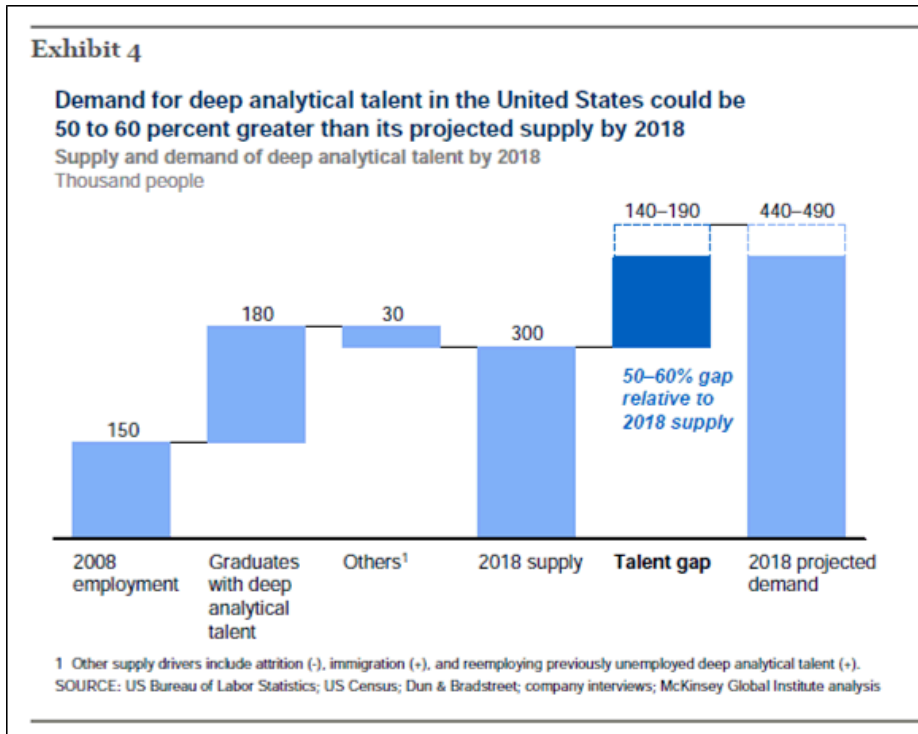


Figure 1: Demand for deep analytical talent. Numbers are in 1000's of persons or positions. Source: McKinsey Global Institute, "Big data: The next frontier for innovation, competition, and productivity" May 2011

Table 1: Excerpts from Bureau of Labor Statistics Occupational Outlook Handbook (2012-13 Ed.) for functions closely related to Data Analytics. National and Ohio information are shown.

Quick Facts	Database Administrators	Market Research Analysts	Statisticians	Management Analysts
2010 Median Pay	\$73,490 per year \$35.33 per hour	\$60,570 per year \$29.12 per hour	\$72,830 per year \$35.02 per hour	\$78,160 per year \$37.58 per hour
Entry-Level Education	Bachelor's degree	Bachelor's degree	Master's degree	Bachelor's degree
Work Experience in a Related Occupation	1 to 5 years	None	None	1 to 5 years
On-the-job Training	None	None	None	None
Number of Jobs, 2010	110,800	282,700	25,100	718,800
2010-20 projected growth rate	31% ( <sup>1</sup> Much faster than average)	41% ( <sup>2</sup> Much faster than)	14% ( <sup>3</sup> About as fast as average)	22% ( <sup>4</sup> Faster than average)

		average)		
Ohio Outlook, 2010-20 > projected growth rate	26.6%	34.7%	17.5%	14.5%
Employment Change, 2010-20	33,900	116,600	3,500	157,200

<sup>1</sup>Rapid growth in data collection by businesses, as well as increased need for database security measures, will contribute to the growth of this occupation.

<sup>2</sup>Job prospects should be best for those with a master's degree.

<sup>3</sup>Job prospects will be very good.

## Comparative Data on Similar Programs

To our knowledge, almost no universities in the U.S. offer an undergraduate degree in Data Analytics beyond a specialization out of computer science – the College of Charleston being the lone exception at the undergraduate level. Some programs, such as Bellevue College, appear to have a bachelor degree in Data Analytics in the approval process. The majority of programs in this are at the graduate level. A recent survey shows 26 Master's programs across the country ([http://analytics.ncsu.edu/?page\\_id=4184](http://analytics.ncsu.edu/?page_id=4184)).

## Proposed Major in Data Analytics: Learning Objectives

Data Analytics is the application of fundamental scientific principles towards the analysis of large, complex data sets to answer questions, extract patterns, and predict behavior associated with those data sets. Data Analytics is also concerned with the use of such analysis to guide problem-solving and decision-making. The application of Data Analytics includes a wide range of fields including Business and Finance, Energy and the Environment, Healthcare, Logistics, and Transportation and Security. It encompasses:

- *Descriptive Analytics* that mines data to identify important behaviors and trends (data management; database design; data mining; visual analytics and sense-making)
- *Predictive Analytics* that predicts the future based on historical patterns (linear models; statistical learning; forecasting; system modeling and simulation)
- *Prescriptive Analytics* that enables smart decisions based on data (linear and nonlinear optimization; decision analysis; statistical decision making)

A student graduating with a Bachelor of Science in Data Analytics will have met the following learning objectives:

- M.1 Students will demonstrate an understanding of and ability to apply computer science principles relating to data representation, retrieval, programming and analysis
- M.2 Students will demonstrate an understanding of and ability to apply mathematical and statistical models and concepts to detect patterns in data, as well as draw inferences and conclusions supported by the data
- M.3 Students will demonstrate critical thinking skills associated with problem identification, problem solving and decision making, assessing value propositions supported by data, and generating a logical synthesis of information from data
- M.4 Students will demonstrate the ability to apply knowledge gained from one area to problems and data in another
- M.5 Students will demonstrate the ability to communicate findings and their implications, and to apply them effectively in organizational settings.

These major objectives (M.# notation) will be augmented by objectives associated with each specialization (S.# notation), as appropriate. See the curriculum maps in the attachments for these objectives.

### **Structure of the Program**

The major leading to the BS degree in the College of Arts and Sciences will be structured in three parts: core fundamentals, discipline-specific specializations, and an integrative experiential education component. Each specialization will consist of a number of technical courses and a capstone experience that is ideally optimized for the subject. Detailed curriculum sheets are attached as supporting documents.

Core fundamentals focus on:

- Mathematical Foundations (calculus; linear algebra; optimization)
- Statistical Foundations (probability; statistical learning; inference; model building)
- Computing Foundations (computer programming; database design; data mining; cloud computing)
- General Education as prescribed by the College of Arts and Sciences

Discipline-specific specializations include topical approaches to the application of data analytics offered via upper division courses. These specializations may focus on one or more of the following advanced areas of analytics:

- Visual Analytics and Sense-Making (visual analytics; visualization; critical thinking; abductive reasoning)

- System Modeling (systems thinking; social, biological and physical sciences; simulation; linear models; systems engineering)
- Pattern Recognition and Machine Learning (artificial intelligence; computer vision; scalable analytics)

The most popular specialization is expected to be Business Analytics, as this is the most fully-developed market segment for graduates. Other, more technically focused specializations include Biomedical Informatics and Computational Analytics.

Integrative Experiential Education is a common feature in engineering curricula where a capstone design project is offered via one or more courses at the end of a curriculum. The base offering in this major is proposed as a capstone course where projects offered by industry partners can be assigned to individuals or teams of students to integrate and apply the principles they have learned up to that point. In conversations with industry practitioners, the desire for an internship or cooperative education component was expressed so that students might gain exposure to the practical applications of the discipline earlier in their curriculum. It is envisioned that such an experience can be substituted for the capstone via an X191 course.

## **Management and Implementation**

The Data Analytics effort for Ohio State University will occur as a jointly managed program between the Department of Statistics (in the College of Arts and Sciences) and the Department of Computer Science and Engineering (in the College of Engineering). The Chair (or their designee(s)) of each department will manage the program in conjunction with advising resources – together, the Chairs (or their designees) would represent the Management Committee for the Data Analytics major. Currently, the Department of Computer Science and Engineering manages the undergraduate degree programs for the Computer Science and Engineering undergraduate major program (in Engineering) and the Computer and Information Science undergraduate major program (in Arts and Sciences). The Management Committee will be aided by a Steering Committee with one representative from each of the approved specializations for the Data Analytics major. If a new specialization is being proposed, then the Management Committee will evaluate the proposal and then seek concurrence from the Steering Committee. Upon approval, by a majority decision of the Management and Steering Committees, then curriculum approval and concurrence will be sought from the College of Arts and Sciences and eventually the Office of Academic Affairs.

Further, we propose that an industrial advisory board be established for the major similar to those used in the Colleges of Engineering and Business. The purpose is to help ensure that the major is meeting its goal of producing graduates with requisite and desired skills to enter the workforce in this still emerging area. The board will be strictly advisory to the Steering Committee. The advisory board will be convened at the end of the first year of offering the major and annually after that.

One of the areas of focus for the board's input will be whether to seek accreditation for the major and if so, from whom.

## Implementation Issues

- Approval of New Specializations:

The Management Committee will work with the Steering Committee (as noted above) to manage the addition of new technical specializations to this major. New specializations will be expected to identify up to three learning objectives that supplement the existing learning objectives for the major.

- How will the proposal affect students, faculty, and staff outside the proposing units?

Enrollment projections are uncertain, but it is likely that students in existing majors within the College of Arts and Sciences, such as mathematics, or in the College of Engineering, such as computer science and engineering, could opt to pursue this Data Analytics major rather than existing major programs. Many of the courses proposed in this new major program already exist and are taught on an ongoing basis. There are, however, a few new courses in the Department of Statistics, Computer Science, and Industrial and Systems Engineering that will need to be developed requiring additional instructional resources in order to offer these newly designed courses for Data Analytics. It is highly likely that this program will create additional demand on already over-subscribed lower division courses offered Computer Science and Engineering.

- Advising support for the major from the College of Arts and Science

Advising of undergraduate students in the Computer and Information Science degree in the Arts and Sciences already occurs by coordination between advisors in the Arts and Sciences and the department of Computer Science and Engineering, in the College of Engineering. The Colleges have a long history of jointly managing undergraduate majors towards the best interests of the students. Administrative support will depend on the growth of the program, and the Management Committee will be able to solicit additional resources from the respective Colleges when justified by enrollment trends and other instructional demands.

- Ongoing assessment of the curriculum

On a yearly basis, the Management Committee will prepare an assessment report for the major including data from student focus groups, the industrial advisory board, and internship assessments. In consultation with the Steering Committee, they will make recommendations for the program going



forward. As appropriate, the Arts and Sciences Curriculum Committee and the Office of Academic Affairs will be consulted.

## **Approvals and Concurrence**

All units across campus were invited to participate and will still be able to propose specializations in the major. Statements of support and concurrence from Deans of those colleges involved in the proposal are included (Poon, Williams, Manderscheid, Lockwood).

## **Consultative Processes**

To establish the desired learning goals for a major in Data Analytics, a group of local experts and practitioners was convened by Vice Provost Randy Smith on April 5, 2013 at OSU. The companies/attendees included:

- Nationwide Insurance:
  - Wes Hunt, VP, Corp. Marketing Info Mgmt.
  - Vijay Gopal, VP, Enterprise Chief Architect
- Information Control Corporation:
  - Jim Gallo, National Director of Business Analytics
- Huntington Bank:
  - Paul Heller, CIO
- Battelle:
  - Pam Hartford, Director, Data Analytics

In addition, on July 17, 2013, the group developing the major visited the IBM Client Center for Advanced Analytics in Dublin, Ohio to visit with additional professionals and learn more about analytics functions in business and industry.

Beyond these on-site/off-campus visits, the following individuals have also been consulted in relation to this program. They represent a broad cross-section of government and industrial practice experts working in the area of data analytics.

- TATA Consultancy Services
  - Gautam Shroff, VP of Research and Head Technology Innovation Laboratories,
- Infosys Technologies
  - Lokendra Shastri, Associate VP and General Manager, Research Wing (SET Labs)
- IBM TJ Watson Center
  - Chid Apte, Director of Analytics, Business Analytics and Mathematical Sciences,
- JPMorgan Chase
  - Raghav Madhavan, Managing Director, Cloud and Data Analytics,

## Resource Impacts

This undergraduate teaching need complements the importance of hiring faculty to support graduate education and research in this area, as analytics is a cross-cutting theme that spans topics of central importance to many departments at OSU, as well as all three of the University Discovery Themes. The need to characterize and make sense of large data sets has become pervasive, and to meet requirements for associated graduate teaching and research, Ohio State also needs to make key hires in analytics.

- Enrollment Projections

While there is a clear job market demand for this major, it will require clear marketing and advising to generate student interest. Once made public, however, a high demand is anticipated. The proposing committee estimates that 50 students per year is a good projection for the purposes of resource allocation. In the initial year of offering (Spring of 2014), it is proposed to admit 50 freshmen to the major via an application process as well as up to 50 upperclassmen who already have the basic requirements outlined in the first year and are interested in switching into this major. The latter students would likely come from majors such as Computer and Information Science, Actuarial Science, or others. Table 2 shows an estimate of how enrollment would build over the first few years.

Table 2. Estimated enrollment projections in the DA major.

<b>Yr in Curriculum</b>	<b>Year 1</b>	<b>Year 2</b>	<b>Year 3</b>	<b>Year 4</b>	<b>Year 5</b>
<b>Freshman</b>	50	50	50	50+	50+
<b>Sophomore</b>	50*	50	50	50	50+
<b>Junior</b>		50*	50	50	50
<b>Senior</b>			50*	50	50
<b>Totals</b>	100	150	200	200+	200+

\*It is possible that these 50 students will be spread among multiple upper classes and a few may graduate in fewer than 3 years.

- New faculty needed in core and specialization areas (Statistics, CSE, FCOB, and ISE, Health Sciences).

As enrollment demand in the newly proposed major is expected to be significant, additional resources for faculty instructors will be critical for success. For example, the Department of Statistics has seen consistent growth in undergraduate credit hours for much of the last decade. Computer Science and Engineering has a similar trend line over the past 5+ years. For success in Data Analytics, University investment in tenure-track, and clinical, faculty will be critical for success. It will be essential to provide both a strong core of instruction in

mathematics, statistics, and computer science as well as a practical appreciation of how data analytics is used by businesses and health care in technical specializations. Instructional investments will be needed in all of the units involved in these courses, and many of these investments are well aligned with the University's Discovery Themes, as outlined above in the rationale.

A number of these courses are new. Furthermore, many of the courses that are already being offered are required of the students in those Departments and are consequently filled to capacity. Given the expected growth rate for this major, in order for the participating Departments and Colleges to offer these core and elective specialization courses, additional tenure-track and/or clinical faculty will be required. Given the current definition of this major and its associated specializations, this includes faculty in Statistics, Computer Science and Engineering, Business, the Health Sciences, and Integrated Systems Engineering.

In short, there is a compelling need to hire tenure-track and/or clinical faculty with expertise relevant to analytics in order to simultaneously meet the needs of Ohio State in undergraduate education, graduate education and research. A separate document outlining specific needs in each of the relevant units has been presented to the Deans of the participating Colleges.

## ATTACHMENTS

1. BS Data Analytics Curricular Requirements
2. Business Analytics specialization
3. Computational Analytics specialization
4. Biomedical Informatics specialization

**B.S. Degree—Data Analytics Major  
Program Requirements**

**The Ohio State University  
College of Arts and Sciences**

The program requirements for the Bachelor of Science degree with a major in **Data Analytics** are given below. A minimum of 127 credit hours is required.

1. Data Analytics Core Requirements

Data Analytics Core Requirements	Course Number(s)	Credit Hours	Cr. Hrs. counted toward major*
Calculus I	Math 1151	5	0
Calculus II	Math 1152	5	0
Software I	CSE 2221	4	4
Software II	CSE 2231	4	4
Foundations I	CSE 2321	3	3
Systems I or Systems for Data Analytics	CSE 2421 or CSE 2xxx	4	4
Linear Algebra	Math 2568	3	3
Databases I	CSE 3241	3	3
Probability & Uncertainty	Stat 3201	3	3
Statistical Inference	Stat 3202	4	4
Optimization and Systems Modeling	ISE 3230	3	3
Modeling for Discovery I	Stat 3301	3	3
Modeling for Discovery II	Stat 3302	3	3
Statistical Decision Making	Stat 3303	3	3
Introduction to Statistical Learning	Stat 4620	2	2
Databases II or Adv DB and Cloud Computing	CSE 5242 or CSE 5xxx	3	3
Data Mining	CSE 5243	3	3
Visualization	CSE 5544 <b>or</b> ISE 5xxx	3	3
<b>Total</b>		<b>61</b>	<b>51</b>

\* Math 1151 and Math 1152 are used in the Data Analytics Major Curriculum to fulfill General Education Requirements and so their credit hours do not count toward the major.

2. Data Analytics Specialization

Complete the requirements for one of the approved Data Analytics Specializations. The minimum number of credit hours for a specialization is **14**, which must include an approved capstone course or course sequence. The approved specializations are

in the areas of **Business Analytics, Computational Analytics and Biomedical Informatics**. The requirements for each specialization are provided in Specialization Requirements sheets below. Note that some specializations require courses that may be used to fulfill requirements for particular General Education categories.

### 3. General Education Requirements

Satisfy the General Education requirements for the Bachelor of Science degree in the College of Arts and Sciences.

Note that Math 1151 and Math 1152 are required for the major core curriculum. It is suggested that students use these courses to satisfy the categories shown in the table below.

GE Category	Required Course	Course Hours	Category Hours
Writing			6
Quantitative and Logical Skills	Math 1151	5	5
Natural Science*	Physical Science (lab)	5	12
	Biological Science (lab)	4	
		3	
Literature			3
Arts			3
Social Science	**		6
Historical Study			3
Culture and Ideas or Historical Study	***		3
Language			12
Open Option 1	Math 1152		5
Open Option 2	****		3
ACS/NMS Survey			1
<b>Total</b>			<b>62</b>

\*Physics 1250 is suggested for the physical science course. Students choosing the Biomedical Informatics specialization should take Biology 1113 and 1114 for the Biological Science requirement.

\*\*Economics 2001.01 and 2002.01 are required courses for the Business Analytics specialization. Students choosing this specialization should use these courses to fulfill the GE requirements for the Social Sciences category.

\*\*\*Students choosing to focus on Linguistics and Text Analysis in the Computational Analytics specialization should take Ling 2000 to fulfill the Culture and Ideas requirement.

\*\*\*\*Stat 2450 is suggested, but not required, to fulfill the second Open Option requirement.

## BS Data Analytics Advising Sheet

Total Cr-Hrs for BS Data Analytics Degree: 129

Autumn (1st Semester)		Spring (2nd Semester)	
ASC 1100.xx ASC/NMS Survey	1	<i>CSE 2221 Software I</i>	4
Math 1151 <b>Calculus I</b>	5	<b>Math 1152 Calculus II</b>	5
Phys 1250 Physics I	5	<i>Stat 2450 Intr. to Stat. Analysis (also for GE Math/Stu</i>	3
Gen Ed Foreign Language 1	4	Gen Ed Foreign Language 2	4
Total	15	Total	16
Autumn (3rd Semester)		Spring (4th Semester)	
<i>CSE 2231 Software II</i>	4	<i>CSE 2421 or CSE 23 Systems I or Systems for Analytics</i>	4
<i>CSE 2321 Foundations I</i>	3	Math 2568 Linear Algebra (pre: MA1152 & CSE23)	3
<i>Stat 3201 Probabilistic Foundations of Uncerta</i>	3	<i>Stat 3202 Modern Statistical Inference</i>	4
Gen Ed Writing Level 1	3	Gen Ed Writing Level 2	3
Gen Ed Foreign Language 3	4	Gen Ed Historical Study	3
Total	17	Total	17
Autumn (5th Semester)		Spring (6th Semester)	
CSE 3241 <i>Intro to Database Systems I</i>	3	CSE 5243 <i>Introduction to Data Mining</i>	3
<i>Stat 3301 Modeling for Discovery I</i>	3	<i>Stat 3302 Modeling for Discovery II</i>	3
Choice <i>Visualization</i>	3	<i>Stat 3303 Bayesian Analysis and Decision Mak</i>	3
see * below Biological Science	4	Technical Elective	3
<i>ISE 3230 Optimization and Systems Modeling</i>	3	Gen Ed Social Science 1	3
Total	16	see * below Natural Science	3
Total	16	Total	18
Autumn (7th Semester)		Spring (8th Semester)	
CSE 5242 or CSE x3 <i>DB II or Adv DB with Cloud Compu.</i>	3	CAPSTONE CAPSTONE	4
<i>Stat 4620 Intro. to Statistical Learning</i>	2	Technical Elective	3
Gen Ed Social Science II	3	Gen Ed Arts	3
Technical Elective	3	Gen Ed Cultural & Ideas or Historical Study	3
Technical Elective	3	Gen Ed Literature	3
Total	14	Total	16

\* Although the official ASC requirement is stated as a minimum of 10 cr-hrs of GE natural science courses in physical science and biological science. Students in this major may take three GE natural science courses to meet this requirement: Phys 1250 (5 cr-hrs), plus two more courses of which at least one is in biological science with a lab (totaling 6-7 cr-hrs).

**BS Data Analytics Advising Sheet II**

**Total Cr-Hrs for BS Data Analytics Degree: 129**

<b>Autumn (1st Semester)</b>			<b>Spring (2nd Semester)</b>		
ASC 1100.xx	ASC/NMS Survey	1	CSE 2221	Software I	4
Math 1151	Calculus I	5	Math 1152	Calculus II	5
Phys 1250	Physics I	5	Stat 2450	Intr. to Stat. Analysis (also for GE Math/Stat)	3
Gen Ed	Foreign Language 1	4	Gen Ed	Foreign Language 2	4
		Total			Total
		15			16
<b>Autumn (3rd Semester)</b>			<b>Spring (4th Semester)</b>		
CSE 2231	Software II	4	CSE 2421 or CSE 2423	Systems I or Systems for Analytics	4
CSE 2321	Foundations I	3	Math 2568	Linear Algebra (pre: MA1152 & CSE23)	3
Stat 3201	Probabilistic Foundations of Uncertainty	3	Stat 3202	Modern Statistical Inference	4
Gen Ed	Writing Level 1	3	Gen Ed	Writing Level 2	3
Gen Ed	Foreign Language 3	4		Tech Elective	3
		Total			Total
		17			17
<b>Autumn (5th Semester)</b>			<b>Spring (6th Semester)</b>		
CSE 3241	Intro to Database Systems	3	CSE 5243	Introduction to Data Mining	3
ISE 3230	Optimization and Systems Modeling	3	Stat 3302	Modeling for Discovery II	3
Stat 3301	Modeling for Discovery I	3	Gen Ed	Social Science II	3
Choice	Visualization	3		Tech Elective	3
	Tech Elective	3	see * below	Biological Science	4
Gen Ed	Social Science I	3			
		Total			Total
		18			16
<b>Autumn (7th Semester)</b>			<b>Spring (8th Semester)</b>		
CSE 5242 or CSE 5243	DB II or Adv DB with Cloud Compu.	3	Gen Ed	Historical Study	3
Stat 4620	Intro. to Statistical Learning	2	Stat 3303	Bayesian Analysis and Decision Mak	3
	Tech Elective	3	CSE/STAT	CAPSTONE	4
see * below	Natural Science	3	Gen Ed	Cultural & Ideas or Historical Study	3
Gen Ed	Arts	3	Gen Ed	Literature	3
		Total			Total
		14			16

**Template 2 -- spreads tech electives over 3 semesters**

\* Although the official ASC requirement is stated as a minimum of 10 cr-hrs of GE natural science courses in physical science and biological science. Students in this major may take three GE natural science courses to meet this requirement: Phys 1250 (5 cr-hrs), plus two more courses of which at least one is in biological science with a lab (totaling 6-7 cr-hrs).



## Curriculum map for the B.S. degree in Data Analytics

### Specialization: Business Analytics

#### Outcomes from the Core Courses

- M.1** Students will demonstrate an understanding of and ability to apply computer science principles relating to data representation, retrieval, programming and analysis.
- M.2** Students will demonstrate an understanding of and ability to apply mathematical and statistical models and concepts to detect patterns in data, as well as draw inferences and conclusions supported by the data.
- M.3** Students will demonstrate critical thinking skills associated with problem identification, problem solving and decision-making, assessing value propositions supported by data, and generating a logical synthesis of information from data.
- M.4** Students will demonstrate the ability to apply knowledge gained from one area to problems and data in another.
- M.5** Students will demonstrate the ability to communicate findings and their implications, and to apply them effectively in organizational settings.

#### Outcomes from the Technical Courses for the Specialization

- S.1** Students demonstrate an understanding of how research and data analytics is done in business
- S.2** Students demonstrate proficiency at designing and implementing analysis to carry out a firm's business objectives.
- S.3** Students can identify and assess ethical issues surrounding business decisions

#### **Program outcomes** (*B=beginner, I=intermediate, A=advanced*)

<b>Course</b>	<b>M.1</b>	<b>M.2</b>	<b>M.3</b>	<b>M.4</b>	<b>M.5</b>	<b>S.1</b>	<b>S.2</b>	<b>S.3</b>
Math 1151		B						
Math 1152		B						
Math 2568		I						
CSE 2221	B				B			
CSE 2231	I		B		B			
CSE 2321	I	B	B		B			
CSE 2421/2xxx	B		B		B			
CSE 3241	A		I		I			
STAT 3201		B			B			
STAT 3202		B	B		B			
ISE 3230		I	I		I			
STAT 3301	B	I	I	B	I			
STAT 3302	B	A	I	B	I			
STAT 3303		I	A	I	I			
STAT 4620	B	A	I	B	I			
CSE 5242	A		A	B	A			
CSE 5243	A	I	A	I	A			
CSE 5544 or ISE 5xxx	CSE: A ISE: I	ISE: I	A	I	A			
BUSFIN 3120 or 3220			I			B	B	B

### Curriculum map for the B.S. degree in Data Analytics

Course	M.1	M.2	M.3	M.4	M.5	S.1	S.2	S.3
BUSFIN 3222						I	I	
BUSFIN 3250						I	I	
BUSFIN 4201		A				A	A	
AMIS 2000 or 5000			B		I	B	B	B
AMIS 3600	B		I		B	I	I	B
AMIS 4210		B	A		A	A	I	
AMIS 4650	I	I	A		A	I	I	
AMIS 4310	B/I	A	A	B	A	A	A	B
AMIS 7350	B	A	A		A	A	A	A
BUSML 3150 or 3250			I		B	B		B
BUSML 4202	B	I				I	I	
BUSML 4210	A	A	A		A	A	A	I
BUSML 4211	A	A	A		I	A	A	
BUSML 4212	A	A	A		I	A	A	I
BUSML 3380	B		I			B		
BUSML 4382	A	A	A		A	A	A	
BUSML 4386	A	A	A		A	A	A	
BUSMGT 2321	B		I			B		B
BUSMGT 3230	I		I			I	I	
BUSMGT 4250	A	I	I			A	I	
BUSMGT 4251	A	I	A		A	A	A	
BUSADM 3630.05	I	I	I	I	I	I	I	I
BUSADM 3631.05	A	A	A	A	A	A	A	A

**Business Analytics**

Total credit hours: 14

1. Required Courses: BUSADM 3630.05 and 3631.05 (table below), and Economics 2001.01 and 2002.01. (A minimum GPA of 3.0 is required for a student to enroll in BUSADM 3630.05.) Students choosing this specialization should use the Economics courses to fulfill the General Education requirements in the Social Sciences category.

Required Core/ Capstone Sequence	Course Number	Credit Hours	Pre-req
Business Analytics: Principles & Concepts	BUSADM 3630.05	2	
Business Analytics: Applications & Experience	BUSADM 3631.05	3	

2. 9 credit hours of coursework from the elective list below. Courses are grouped to show possible focus areas but students may select any combination of courses (having met appropriate pre-requisites) to meet the 9 credit hours.

Elective Courses		Course Number	Credit Hours	Pre-req
Finance	Business Finance	BUSFIN 3120 or 3220	3	*
	Foundations of Investments	BUSFIN 3222	3	3120
	Foundations of International Finance	BUSFIN 3250	3	3120
	Financial Data	BUSFIN 4201	1.5	3120
AMIS	Foundations of Accounting	AMIS 2000 or 5000	3	*
	Accounting Information Systems	AMIS 3600	3	2000
	Financial Statement Analysis	AMIS 4210	3	2000
	Decision Support Systems	AMIS 4650	3	
	Topics in Managerial Acct	AMIS 4310	3	
	Fraudulent Financial Reporting	AMIS 7350	3	2000
Customer Insights	Foundations or Principles of Marketing	BUSML 3150 or 3250	3	*
	Marketing Research	BUSML 4202	1.5	3150
	Advanced Marketing Research	BUSML 4210	1.5	3150
	Market Analysis, Development & Forecasting	BUSML 4211	1.5	3150
Ops & Logistics	Customer Relationship Management	BUSML 4212	1.5	3150
	Business Analytics	BUSMGT 2321	3	
	Operations Mgt.	BUSMGT 3230	3	*
	Six Sigma Principles	BUSMGT 4250	3	3230
	Six Sigma Project	BUSMGT 4251	3	3230
	Logistics Management	BUSML 3380	1.5	*
	Logistics Analytics	BUSML 4382	3	3380
Logistics Technology & Applications	BUSML 4386	1.5	3380	

\* Pre-requisite MA 1152 and CSE 2321

**BS Data Analytics Advising Sheet: Business Analytics Track Total Cr-Hrs for BS Data Analytics Degree: 127**

<b>Autumn (1st Semester)</b>			<b>Spring (2nd Semester)</b>		
ASC 1100.xx	ASC/NMS Survey	1	CSE 2221	Software I	4
Math 1151	Calculus I	5	Math 1152	Calculus II	5
Phys 1250	Physics I	5	Stat 2450	Intr. to Stat. Analysis (also for GE Math/Stat)	3
Gen Ed	Foreign Language 1	4	Gen Ed	Foreign Language 2	4
		Total			Total
		15			16
<b>Autumn (3rd Semester)</b>			<b>Spring (4th Semester)</b>		
CSE 2231	Software II	4	CSE 2421 or CSE 2423	Systems I or Systems for Analytics	4
CSE 2321	Foundations I	3	Math 2568	Linear Algebra (pre: MA1152 & CSE23)	3
Stat 3201	Probabilistic Foundations of Uncertainty	3	Stat 3202	Modern Statistical Inference	4
Gen Ed	Writing Level 1	3	Gen Ed	Writing Level 2	3
Gen Ed	Foreign Language 3	4		Business Foundation	3
		Total			Total
		17			17
<b>Autumn (5th Semester)</b>			<b>Spring (6th Semester)</b>		
CSE 3241	Intro to Database Systems	3	CSE 5243	Introduction to Data Mining	3
ISE 3230	Optimization and Systems Modeling	3	Stat 3302	Modeling for Discovery II	3
Stat 3301	Modeling for Discovery I	3	Gen Ed	Econ 2002.01	3
Choice	Visualization	3		Bus Analytics: Applications & Experiments	3
	Bus Analytics: Principles & Concepts	2	see * below	Biological Science	4
Gen Ed	Econ 2001.01	3			
		Total			Total
		17			16
<b>Autumn (7th Semester)</b>			<b>Spring (8th Semester)</b>		
CSE 5242 or CSE 5243	DB II or Adv DB with Cloud Computing	3	Gen Ed	Historical Study	3
Stat 4620	Intro. to Statistical Learning	2	Stat 3303	Bayesian Analysis and Decision Making	3
	Business Analytics Elective	3	see * below	Natural Science	3
	Business Analytics Elective	3	Gen Ed	Cultural & Ideas or Historical Study	3
Gen Ed	Arts	3	Gen Ed	Literature	3
		Total			Total
		14			15

\* Although the official ASC requirement is stated as a minimum of 10 cr-hrs of GE natural science courses in physical science and biological science. Students in this major may take three GE natural science courses to meet this requirement: Phys 1250 (5 cr-hrs), plus two more courses of which at least one is in biological science with a lab (totaling 6-7 cr-hrs).

## Curriculum map for the B.S. degree in Data Analytics

### Specialization: Computational Analytics

#### Outcomes from the Core Courses

- M.1** Students will demonstrate an understanding of and ability to apply computer science principles relating to data representation, retrieval, programming and analysis.
- M.2** Students will demonstrate an understanding of and ability to apply mathematical and statistical models and concepts to detect patterns in data, as well as draw inferences and conclusions supported by the data.
- M.3** Students will demonstrate critical thinking skills associated with problem identification, problem solving and decision-making, assessing value propositions supported by data, and generating a logical synthesis of information from data.
- M.4** Students will demonstrate the ability to apply knowledge gained from one area to problems and data in another.
- M.5** Students will demonstrate the ability to communicate findings and their implications, and to apply them effectively in organizational settings.

#### Outcomes from the Technical Courses for the Specialization

- S.1** Students will demonstrate an understanding of the principles governing an advanced computational focus area (Cyber-security, Machine Intelligence, Systems/Theory, Linguistics and Text analytics).
- S.2** Students will demonstrate an advanced understanding of and the ability to use analytic techniques in one or more focus areas.

#### **Program outcomes** (*B=beginner, I=intermediate, A=advanced*)

Course	M.1	M.2	M.3	M.4	M.5	S.1	S.2
Math 1151		B					
Math 1152		B					
Math 2568		I					
CSE 2221	B				B		
CSE 2231	I		B		B		
CSE 2321	I	B	B		B		
CSE 2421/2xxx	B		B		B		
CSE 3241	A		I		I		
STAT 3201		B			B		
STAT 3202		B	B		B		
ISE 3230		I	I		I		
STAT 3301	B	I	I	B	I		
STAT 3302	B	A	I	B	I		
STAT 3303		I	A	I	I		
STAT 4620	B	A	I	B	I		
CSE 5242	A		A	B	A		
CSE 5243	A	I	A	I	A		
CSE 5544 or ISE 5xxx	CSE: A ISE: I	ISE: I	A	I	A		
<i>Cybersecurity Focus</i>							

## Curriculum map for the B.S. degree in Data Analytics

Course	M.1	M.2	M.3	M.4	M.5	S.1	S.2
CSE3461	A		I	B	I	B	B
CSE4471	A		I	I	A	I	I
CSE5472	A	I	A	I	A	A	A
<i>Machine Intelligence Focus</i>							
CSE2231	A	I	I	I	I	B	
CSE3521	A	B	I	I	A	I	B
CSE5524	A	B	A	I	A	A	I
CSE 5523	A	A	A	I	I	A	A
<i>Systems/Theory Focus</i>							
CSE2331 or CSE 2431	A A	I -	I I	I I	I I	B B	
CSE 390x	A		A	A	A	I	I
CSE 5425 or CSE 5441	A A	I -	A A	A A	A A	A A	A A
<i>Linguistics and Text Focus</i>							
Ling 2000 (GED)				B	B	B	
Ling Choice 4100,4200,4300,4400				I	I	I	B
Ling 5801	I		I	I	I	I	I
Ling 5802	I		I	I	I	A	I
CSE5525	A		A	I	A	A	A
Capstone (e.g., CSE 4xxx)	A	A	A	A	A	A	A

**Computational Analytics**

Total credit hours: 14 hours minimum selected from the list below

Courses are grouped to show possible focus areas but students may select any combination of courses (having met appropriate pre-requisites) to meet the 14 credit hours.

Students choosing the Linguistics and Text Analytics focus should plan on taking Ling 2000 to satisfy the General Education requirements in the Culture and Ideas category.

Elective Courses		Course Number	Credit Hours	Pre-req
Cyber-security Focus	Computer Networking and Internet Tech.	CSE 3461	3	
	Information Security	CSE 4471	3	
	Information Security Projects or Introduction to Network Security	CSE 5472 or CSE 5473	3	
	Capstone in Data Analytics	CSE 59xx/Stat 5xxx	4	
Machine Intelligence Focus	Foundations II	CSE 2331	3	
	Introduction to AI	CSE 3521	3	
	Computer Vision for HCI	CSE 5524	3	
	Machine Learning and Stat. Pattern Rec. OR Introduction to Neural Networks	CSE 5523 or CSE 5526	3	
	Capstone in Data Analytics	CSE 59xx/Stat 5xxx	4	
Core (Systems or Theory) Focus	Foundations II or Systems II	CSE 2331 or CSE 2431	3	
	CSE Junior Project Choice	CSE 3901, 3902, 3903	4	
	Numerical Methods or Intro to Parallel Computing	CSE 5361 or CSE 5441	3	
	CSE Senior Capstone Choice	CSE 5901, 5902, 5903	4	
Linguistics and Text Analytics Focus	Intro to Languages and Humanities	Ling 2000	3	* GE
	Introduction to Computational Linguistics I	Ling 5801	3	
	Introduction to Computational Linguistics II	Ling 5802	3	
	Speech and Language Processing	CSE 5525	3	
	Linguistics Choice Elective -- Phonetics; Syntax; Phonology; or Linguistic Meaning	Ling 4100 or Ling 4200 or Ling 4300 or Ling 4400	3	
	CSE/Linguistics Capstone	CSE 59xx/Ling 5xxx	4	

**BS Data Analytics Advising Sheet: Computational Specialization: Cybersecurity Focus**

**Total Cr-Hrs for BS Data Analytics Degree: 129**

<b>Autumn (1st Semester)</b>		<b>Spring (2nd Semester)</b>	
ASC 1100.xx ASC/NMS Survey	1	CSE 2221 Software I	4
Math 1151 Calculus I	5	Math 1152 Calculus II	5
Phys 1250 Physics I	5	Stat 2450 Intr. to Stat. Analysis (also for GE Math/Stat)	3
Gen Ed Foreign Language 1	4	Gen Ed Foreign Language 2	4
Total 15		Total 16	
<b>Autumn (3rd Semester)</b>		<b>Spring (4th Semester)</b>	
CSE 2231 Software II	4	CSE 2421 or CSE 242 Systems I or Systems for Analytics	4
CSE 2321 Foundations I	3	Math 2568 Linear Algebra (pre: MA1152 & CSE23)	3
Stat 3201 Probabilistic Foundations of Uncertainty	3	Stat 3202 Modern Statistical Inference	4
Gen Ed Writing Level 1	3	Gen Ed Writing Level 2	3
Gen Ed Foreign Language 3	4	Choice CSE Elective	3
Total 17		Total 17	
<b>Autumn (5th Semester)</b>		<b>Spring (6th Semester)</b>	
CSE 3241 Intro to Database Systems	3	CSE 5243 Introduction to Data Mining	3
ISE 3230 Optimization and Systems Modeling	3	Stat 3302 Modeling for Discovery II	3
Stat 3301 Modeling for Discovery I	3	Gen Ed Econ 2002.01	3
Choice Visualization	3	CSE4471 Information Security	3
CSE3461 Computer Networking and Internet T	3	see * below Biological Science	4
Gen Ed Econ 2001.01	3		
Total 18		Total 16	
<b>Autumn (7th Semester)</b>		<b>Spring (8th Semester)</b>	
CSE 5242 or CSE 524 DB II or Adv DB with Cloud Compu.	3	CHOICE CSE/STAT CAPSTONE	4
Stat 4620 Intro. to Statistical Learning	2	Stat 3303 Bayesian Analysis and Decision Mak	3
CSE5472 Information Security Projects	3	see * below Natural Science	3
Gen Ed Historical Study	3	Gen Ed Cultural & Ideas or Historical Study	3
Gen Ed Arts	3	Gen Ed Literature	3
Total 14		Total 16	

\* Although the official ASC requirement is stated as a minimum of 10 cr-hrs of GE natural science courses in physical science and biological science. Students in this major may take three GE natural science courses to meet this requirement: Phys 1250 (5 cr-hrs), plus two more courses of which at least one is in biological science with a lab (totaling 6-7 cr-hrs).



## Curriculum map for the B.S. degree in Data Analytics

### Specialization: Biomedical Informatics

#### Outcomes from the Core Courses

- M.1** Students will demonstrate an understanding of and ability to apply computer science principles relating to data representation, retrieval, programming and analysis.
- M.2** Students will demonstrate an understanding of and ability to apply mathematical and statistical models and concepts to detect patterns in data, as well as draw inferences and conclusions supported by the data.
- M.3** Students will demonstrate critical thinking skills associated with problem identification, problem solving and decision-making, assessing value propositions supported by data, and generating a logical synthesis of information from data.
- M.4** Students will demonstrate the ability to apply knowledge gained from one area to problems and data in another.
- M.5** Students will demonstrate the ability to communicate findings and their implications, and to apply them effectively in organizational settings.

#### Outcomes from the Technical Courses for the Specialization

- S.1** Students will demonstrate an understanding of the core sub-disciplines of biomedical informatics that play a role in the design, implementation, and management of clinical, research, and translational information systems.
- S.2** Students will demonstrate an understanding of the contributing theoretical frameworks that are conventionally used to inform the design and use of biological and medical information systems, and integrative data discovery and analysis tools.
- S.3** Students will demonstrate critical evaluation skills that allow for the analysis of system design and or utilization of biomedical information systems and data.

Program outcomes (*B=beginner, I=intermediate, A=advanced*)

Course	M.1	M.2	M.3	M.4	M.5	S.1	S.2	S.3
Math 1151		B						
Math 1152		B						
Math 2568		I						
CSE 2221	B				B			
CSE 2231	I		B		B			
CSE 2321	I	B	B		B			
CSE 2421/2xxx	B		B		B			
CSE 3241	A		I		I			
STAT 3201		B			B			
STAT 3202		B	B		B			
ISE 3230		I	I		I			
STAT 3301	B	I	I	B	I			
STAT 3302	B	A	I	B	I			

**Curriculum map for the B.S. degree in Data Analytics**

<b>Course</b>	<b>M.1</b>	<b>M.2</b>	<b>M.3</b>	<b>M.4</b>	<b>M.5</b>	<b>S.1</b>	<b>S.2</b>	<b>S.3</b>
STAT 3303		I	A	I	I			
STAT 4620	B	A	I	B	I			
CSE 5242	A		A	B	A			
CSE 5243	A	I	A	I	A			
CSE 5544 or ISE 5xxx	CSE: A ISE: I	ISE: I	A	I	A			
BMI 5710	I	I	A	I	A	B	I	A
BMI 5720	I	I	I		A	I	I	A
BMI 5730	I	I	A	I	A	B	I	A
BMI 5740	A	I	A	I	A	A	A	A
Capstone (e.g., CSE 4xxx)	A	A	A	A	A	A	A	A

**Biomedical Informatics**

Total credit hours: 21

Students choosing this specialization should take Biology 1113 and 1114 to meet the GE Natural Science requirements.

Although the official ASC requirement is stated as a minimum of 10 credit hours of GE natural science courses in physical science and biological science, students often take three GE natural science courses to meet this requirement: Phys 1250 (5 credit hours), plus two more courses of which at least one is in biological science with a lab (totaling 7-8 credit hours).

Course	Course Number	Credit Hours	Pre-req
Integrated Molecular and Cellular Biology for Non-Biologists	Mol Gen 5660	5	
Introduction to Biomedical Informatics	BMI 5710	3	
Imaging Informatics	BMI5720	3	
Introduction to Bioinformatics	BMI5730	3	
Introduction to Research in Bioinformatics	BMI 5740	3	
Capstone in Data Analytics	CSE 59xx/ Stat 5xxx	4	

**BS Data Analytics - Biomedical Informatics -- Advising Sheet** **Total Cr-Hrs for BS Data Analytics Degree: 135**

<b>Autumn (1st Semester)</b>			<b>Spring (2nd Semester)</b>		
ASC 1100.xx ASC/NMS Survey		1	<i>CSE 2221 Software I</i>		4
Math 1151 <b>Calculus I</b>		5	<b>Math 1152 Calculus II</b>		5
Phys 1250 Physics I		5	<i>Stat 2450 Intr. to Stat. Analysis (also for GE Math/Stu</i>		3
Gen Ed Foreign Language 1		4	Gen Ed Foreign Language 2		4
Gen Ed Writing Level 1		3			
Total			Total		
18			16		
<b>Autumn (3rd Semester)</b>			<b>Spring (4th Semester)</b>		
<i>CSE 2231 Software II</i>		4	<i>CSE 2421 or CSE 2422 Systems I or Systems for Analytics</i>		4
<i>CSE 2321 Foundations I</i>		3	Math 2568 Linear Algebra (pre: MA1152 & CSE23)		3
<i>Stat 3201 Probabilistic Foundations of Uncerta</i>		3	<i>Stat 3202 Modern Statistical Inference</i>		4
*GE Natural :Biology 1113		4	Gen Ed Writing Level 2		3
Gen Ed Foreign Language 3		4	*GE Natural :Biology 1114		4
Total			Total		
18			18		
<b>Autumn (5th Semester)</b>			<b>Spring (6th Semester)</b>		
CSE 3241 <i>Intro to Database Systems I</i>		3	CSE 5243 <i>Introduction to Data Mining</i>		3
<i>Stat 3301 Modeling for Discovery I</i>		3	<i>Stat 3302 Modeling for Discovery II</i>		3
<i>Choice Visualization</i>		3	Gen Ed Arts		3
MolGen 5660 Molecular Genetics 5660		5	BMI 5710 Introduction to Biomedical Informati		3
<i>ISE 3230 Optimization and Systems Modeling</i>		3	Gen Ed Social Science 1		3
			Gen Ed Historical Study		3
Total			Total		
17			18		
<b>Autumn (7th Semester)</b>			<b>Spring (8th Semester)</b>		
<i>CSE 5242 or CSE 5243 DB II or Adv DB with Cloud Compu.</i>		3	CSE/STAT CAPSTONE		4
<i>Stat 3303 Bayesian Analysis and Decision Mak</i>		3	BMI 5740 Introduction to Research in Bioinforr		3
Gen Ed Social Science II		3	<i>Stat 4620 Intro. to Statistical Learning</i>		2
BMI5720 Imaging Informatics		3	Gen Ed Cultural & Ideas or Historical Study		3
BMI5730 Introduction to Bioinformatics		3	Gen Ed Literature		3
Total			Total		
15			15		

\* Although the official ASC requirement is stated as a minimum of 10 cr-hrs of GE natural science courses in physical science and biological science. Students in this major may take three GE natural science courses to meet this requirement: Phys 1250 (5 cr-hrs) plus Biology 1113 and 1114 (8 cr-hrs)