Health Care Data Analytics (HCDA)

Program Director: Aundrea L. Price, M.B.A., M.H.I.
Health Care Data Analytics website (http://www.marquette.edu/grad/programs-healthcare-data-analytics.php)

DEGREE OFFERED
Master of Science, Plan B only

PROGRAM DESCRIPTION
This interdisciplinary program is designed to synergistically combine Mathematics, Statistics and Computer Science and Health courses, wherein five MSCS courses compose the program's data analytics core and five HEAL courses provide the context for applying the skills developed in the data analytics core.

The health and data analytics curricular combination is designed to provide an intersection between information systems and health that is particularly appropriate for preparing graduates to be successful and impactful as health care data analysts. It also takes advantage of the strengths and trajectories of Mathematics, Statistics and Computer Science and Nursing, as well as Marquette's unique position in the Jesuit tradition and Catholic social teaching.

PREREQUISITES FOR ADMISSION
Applicants should have:

- An earned baccalaureate degree in any field with a GPA of at least 3.000.
- Information systems (coding/programming) competency, or successful completion of the coding bootcamp course MSCS 6500 Foundations of Computing (offered by MSCS or an equivalent taken elsewhere).
- A foundational undergraduate or graduate statistics class that includes descriptive statistics, validity, reliability, power analysis, parametric and non-parametric analysis, general linear model (predictive models with continuous outcomes), with emphasis on appropriate data analysis for study design, level of measurement, and interpretation of results.

APPLICATION DEADLINES
Applications are reviewed on a rolling basis, and admitted students may begin their program in summer, fall or spring.

APPLICATION REQUIREMENTS
Applicants must submit, directly to the Graduate School:

1. A completed application form and fee online (http://marquette.edu/grad/future_apply.shtml).
2. Copies of all college/university transcripts except Marquette.*
3. A statement of purpose stating career goals and how the program will help in reaching those goals.
4. (For international applicants only) a TOEFL score or other acceptable proof of English proficiency.

Applicants will be given the option to provide up to two letters of recommendation and a resume.

* Upon admission, final official transcripts from all previously attended colleges/universities, with certified English translations if original language is not English, must be submitted to the Graduate School within the first five weeks of the term of admission or a hold preventing registration for future terms will be placed on the student’s record.

Health Care Data Analytics Master's Requirements

Specialization: Ethically Centered Data Science

This 30-credit interdisciplinary program is composed of 15 credit hours in data analytics courses and 15 credit hours in health courses.

The data analytics core provides students with the knowledge and skills to understand and quantify the value of decisions based on ethically balanced analyses. It teaches students to explore, analyze and visualize data, coupled with the knowledge about the organization of data for analysis and the tools for data and text mining to explain historical events or predict future outcomes. It uniquely includes an examination of the moral, ethical and societal impacts of data analytic problems, approaches and decisions important to many areas of application, and provides an understanding of the processes to justify value and the ethical choices being made. When ethically focused analytical skills are combined with knowledge of an application area, such as healthcare, they enable the analyst to suggest and verify the value of decisions from both a monetary and ethical viewpoint. An ethical focus is arguably especially important to the application of analytical skills to health care. The focus on ethically centered data analytics positions Marquette uniquely in the field of data analytics programs, and even more so in the more limited field of health care data analytics programs.
Health Care Data Analytics (HCDA)

The health curriculum in this program provides the context and application for the skills and knowledge developed by the data analytics core. Through the health curriculum, students develop comprehensive lenses for harnessing analytical tools to address pressing questions in health care organizations, and approach data from the viewpoint of clinical and business operations. Without this viewpoint, the data are hollow and the analyses are theoretical. This context includes an overview of the U.S. health care system, its component parts and their inter-relationships, as well as its issues and challenges. It also includes the ways in which health care technology and data are structured and employed, and can be used to effectively to solve problems and address a host of issues, including quality improvement, individual and societal impacts of data use and data analytics, policy development and cost reduction. The program culminates in a practicum providing students an opportunity to pursue the analysis of relevant health care issues from identification through the development of analytics-driven, values-based decisions based on values that include non-quantifiable ethical concerns.

PROGRAM REQUIREMENTS

A student must complete a minimum of 30 credits of course work, with at least 24 credits at the 6000 level or higher. Required courses are:

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<thead>
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<th>Data Analytics Core</th>
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<tr>
<td>MSCS 6510</td>
<td>Business Intelligence</td>
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<tr>
<td>MSCS 6520</td>
<td>Data Analytics</td>
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<tr>
<td>MSCS 6931 or MSCS 6060 or MSCS 6380</td>
<td>Topics in Mathematics, Statistics and Computer Science (Topic: Data at Scale) or Parallel and Distributed Systems or Advanced Database Systems</td>
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<tr>
<td>MSCS 6931</td>
<td>Topics in Mathematics, Statistics and Computer Science (Topic: Advanced Data Science)</td>
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<tr>
<td>MSCS 6931</td>
<td>Topics in Mathematics, Statistics and Computer Science (Topic: Ethical and Social Implications of Big Data)</td>
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<th>Health Care Context</th>
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<td>HEAL 6840</td>
<td>The Environment of Health Care Delivery</td>
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<td>HEAL 6830</td>
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<td>HEAL 6931</td>
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Total Credit Hours 30

Specialization

The five MSCS courses that constitute the analytics core of the program form the specialization in ethically centered data science. The data analytics core provides the data science skills and knowledge that underpin the degree and consists of five courses offered by MSCS.

Students who first complete the certificate in ethically centered data science and later enroll in the master of science in health care analytics have the courses from the certificate transferred into the master’s in health care data analytics program but do not earn the specialization in ethically centered data science. Students who complete the five MSCS courses while enrolled in the health care data analytics master's program who elect to leave the program earn the certificate in ethically centered data science.

Health Courses

HEAL 5200. Natural Family Planning. 3 cr. hrs.
Physiological, behavioral, and spiritual aspects important to teaching and using natural family planning.

HEAL 5201. Natural Family Planning Practicum. 3 cr. hrs.
Practical application of theory and skills for teaching natural family planning.

HEAL 5901. Interdisciplinary Palliative Care. 3 cr. hrs.
Provides an understanding of the breadth and depth of palliative care practices and services available to caregivers, patients and their families.

HEAL 5931. Topics in Health. 3 cr. hrs.
Selected topics in Health. The topics will be designated in the Schedule of Classes.

HEAL 5951. Marquette Led Travel and Study Abroad in Health. 3 cr. hrs.
Course taught in an international setting by Marquette professors and where students earn Marquette credit. Prereq: Cons. of dept. ch.

HEAL 6010. Translational Research. 3 cr. hrs.
Principles of evidence-based practice and implementation science applied to the translation of evidence to health care practice. Prereq: NURS 6010, HEAL 8015 or equiv.

HEAL 6012. Epidemiology. 3 cr. hrs.
Study of patterns of health/illness in specific populations and analysis of risk. Application of epidemiology methods, including biostatistics.
HEAL 6049. Outcomes Management. 3 cr. hrs.
Evolution of outcomes management. Exploration of methodologies, assessment instruments and issues that guide outcomes research. Prereq: NURS 6010 or cons. of instr.

HEAL 6152. Death and Dying. 3 cr. hrs.
Multidisciplinary perspective on death and dying. Includes historical, sociocultural, legal, and ethical dimensions, the dying process, grief and bereavement, and communities of care.

HEAL 6814. Seminar in Moral and Legal Implications of Health Care. 3 cr. hrs.
The field of moral decision-making in health care and the legal implications. Open to all graduate students.

HEAL 6820. Health Care Program Development. 3 cr. hrs.
Principles of population assessment, critical analysis of data, program development, implementation and evaluation. Includes one credit of practicum. Prereq: NURS 6009; or cons. of instr.

HEAL 6825. Quality & Patient Safety in Health Care. 3 cr. hrs.
Theories and principles of leadership and organizational change applied to quality and patient safety in health care. Strategies for developing the culture and infrastructure needed to support patient safety and quality improvement initiatives.

HEAL 6830. Quality Improvement Science in Health Care. 3 cr. hrs.
Explores improvement science including quality and patient safety theories, models, methods and tools. Application of measurement, data management and analysis to quality improvement and patient safety challenges.

HEAL 6835. Health Care Informatics, Technology and Professional Issues. 3 cr. hrs.
Examines current health care realities, with an emphasis on the use of technology for policy, regulation, collaboration and interdisciplinary practice issues. Includes information technology applications in healthcare administration, clinical practice and education.

HEAL 6840. The Environment of Health Care Delivery. 2-3 cr. hrs.
Overview of U.S. health care system, environmental influences, and current models for health care delivery (e.g., fee for service, modified fee for service, managed care, capitated care, IPOs, HMOs), and the ascendancy/descendency of various models in different geographic regions and in response to economic incentives. Prereq: Enrolled in Graduate School.

HEAL 6841. Health Care Finance. 3 cr. hrs.
Examination of financial principles, budgeting and reimbursement issues in health care. Prereq: NURS 6009; or cons. of instr.

HEAL 6845. Case Management. 3 cr. hrs.
Care services coordination of individuals and families to maximize resources for optimal health outcomes. Emphasis on integration of clinical and management processes. Includes one credit of practicum. Prereq: Health profession experience or cons. of instr.

HEAL 6846. Health Care Informatics. 3 cr. hrs.
Study of informatics in health care with emphasis in information systems and use of communication technology. Includes evaluation of actual and potential applications of informatics in health care administration, clinical practice, research and education.

HEAL 6848. Health Care Policy. 3 cr. hrs.
Concepts of public policy including the political process. Analysis of health care issues using a variety of policy models.

HEAL 6931. Topics in Health Care. 1-4 cr. hrs.
In-depth study of current issues in health care. Course content will be announced each term.

HEAL 6963. Individual Study and Practice. 1-3 cr. hrs.
Individual study and development of in-depth knowledge and skill in a selected area of health care. Experience and activities planned in an area for specialization, based on aptitude and interests of the student. May be repeated for credit. Prereq: Cons. of instr.

HEAL 6995. Independent Study in Health Care. 1-3 cr. hrs.
Prereq: Cons. of instr.

HEAL 7010. Translational Research. 3 cr. hrs.
Principles of evidence-based practice and implementation science applied to the translation of evidence to health care practice. Prereq: NURS 6010, HEAL 8015 or equiv.

HEAL 7012. Epidemiology. 3 cr. hrs.
Study of patterns of health/illness in specific populations and analysis of risk. Application of epidemiology methods, including biostatistics.

HEAL 7049. Outcomes Management. 3 cr. hrs.
Evolution of outcomes management. Exploration of methodologies, assessment instruments and issues that guide outcomes research. Prereq: NURS 6010 or cons. of instr.

HEAL 7825. Quality and Patient Safety in Health Care. 3 cr. hrs.
Theories and principles of leadership and organizational change applied to quality and patient safety in health care. Strategies for developing the culture and infrastructure needed to support patient safety and quality improvement initiatives.
HEAL 7830. Quality Improvement Science in Health Care. 3 cr. hrs.
Explores improvement science including quality and patient safety theories, models, methods and tools. Application of measurement, data management and analysis to quality improvement and patient safety challenges.

HEAL 7835. Health Care Informatics, Technology and Professional Issues. 3 cr. hrs.
Examines current health care realities, with an emphasis on the use of technology for policy, regulation, collaboration and interdisciplinary practice issues. Includes information technology applications in health care administration, clinical practice and education.

HEAL 8002. Qualitative Research. 3 cr. hrs.
Analysis of key qualitative research methods, issues related to these approaches, and the nature of knowledge generated.

HEAL 8003. Quantitative Research. 3 cr. hrs.
Explores and analyzes advanced quantitative methodologies and issues related to these approaches. Prereq: HEAL 8015, which may be taken concurrently and HEAL 8016, which may be taken concurrently.

HEAL 8015. Applied Statistics for Health Sciences. 3 cr. hrs.
Overview of applied statistics, including descriptive statistics, probability, sampling, power calculations, bivariate parametric and non-parametric analysis, and introduction to multivariate analysis. Emphasis on appropriate statistics for study design, level of measurement, and interpretation of results.

HEAL 8016. Advanced Applied Statistics. 3 cr. hrs.
An overview of advanced applied statistics focusing on multivariate analysis, including multivariate normal distribution, principle components analysis, factor analysis and cluster analysis. Emphasizes appropriate statistics for study design, level of measurement and interpretation of results. Prereq: HEAL 8015 or equiv., or cons. of instr.

HEAL 8018. Advanced Measurement in Health Care. 3 cr. hrs.
Theory and science of measurement commonly used in health care. Analytic procedures for addressing measurement issues. Prereq: HEAL 8015 or PSYC 8101; HEAL 8016 or PSYC 8102, which may be taken concurrently; or cons. of instr.


MSCS 5020. The Teaching of Mathematics. 3 cr. hrs.
Historical background, problems, curricular materials, and teaching procedures in the various areas of mathematics pertinent to the needs of a secondary school mathematics teacher. In addition, a three-hour time block on one day each week between 8 a.m. and 3 p.m. must be kept free for clinical experience.

MSCS 5030. Concepts in Geometry and Calculus from an Advanced Standpoint. 3 cr. hrs.
Topics chosen primarily from geometry and calculus, taught from an advanced standpoint to enrich and deepen the student's understanding. Emphasis on alternative approaches, generalizations, historical contexts and connections with prior mathematical studies.

MSCS 5040. Concepts in High School Algebra and Number Theory from an Advanced Standpoint. 3 cr. hrs.
Topics closely related to the high school mathematics curriculum, chosen primarily from algebra and number theory, taught from an advanced standpoint to enrich and deepen the student's understanding. Emphasis on alternative approaches, generalizations, historical contexts and connections with prior mathematical studies.

MSCS 5110. Formal Languages and Computability. 3 cr. hrs.
Regular languages, finite state automata, and lexical analysis; context free languages, push-down automata, parsing, and the rudiments of LL and LR parsers; general phrase-structure languages, Turing machines, the Chuch-Turing thesis, the halting problem, universal programming languages.

MSCS 5120. Abstract Algebra 1. 3 cr. hrs.
Sets, mappings, operations on sets, relations and partitions. A postulational approach to algebraic systems including semigroups, groups, rings and fields. Homomorphisms of groups and rings, number systems, polynomial rings.

MSCS 5121. Abstract Algebra 2. 3 cr. hrs.
A continuation of MSCS 5120 with emphasis on groups, rings, fields, and modules.

MSCS 5200. Intermediate Analysis 1. 3 cr. hrs.
Limits and continuity, differentiability, Riemann integration. Topology of N-dimensional spaces.

MSCS 5201. Intermediate Analysis 2. 3 cr. hrs.
Transformations of N-spaces, line and surface integrals, sequences and series, uniform convergence.

MSCS 5210. Complex Variables. 3 cr. hrs.
Complex numbers, analytic functions, differentiation, series expansion, line integrals, singularities, and residues.

MSCS 5290. Real-Time and Embedded Systems. 3 cr. hrs.
Focuses on event-driven programming, real-time scheduling, and synchronization; worst-case execution time analysis and deadline analysis; real-time operating systems and real-time programming languages.

MSCS 5300. Networks and Internets. 3 cr. hrs.
Focuses on data communication and network protocols, including the TCP/IP protocol suite; Internet transport, packet switching and routing; network programming and network applications. May consist of a 3 hr. lec. or a 2 hr. lec. and 2 hr. lab.
MSCS 5310. History of Mathematical Ideas. 3 cr. hrs.
Topics include: development of the number system (need for irrational and complex numbers); development of geometry including the effects of the discovery of non-Euclidean geometry; limit concept; need for axiomatic structures; 20th century problems. Current mathematics research and place of mathematics in today's world.

MSCS 5320. Theory of Numbers. 3 cr. hrs.
Integers, unique factorization theorems, arithmetic functions, theory of congruences, quadratic residues, partition theory.

MSCS 5360. Computer Security. 3 cr. hrs.
Fundamentals of computer security, including cryptography, access control, security policy models, attacks, surveillance, privacy, and forensics. Draws examples of security vulnerabilities and defenses from many areas of computer science such as operating systems, databases, networks and software engineering.

MSCS 5400. Compiler Construction. 3 cr. hrs.
Lexical analysis, parsing, code generation, and optimization. Includes theoretical foundations and the practical concerns of implementation.

MSCS 5420. Foundations of Geometry. 3 cr. hrs.
Modern postulational development of Euclidean and non-Euclidean geometries.

MSCS 5450. Topology. 3 cr. hrs.
Topological spaces, mappings, metric spaces, product and quotient spaces. Separation axioms, compactness, local compactness and connectedness.

MSCS 5500. Theory of Differential Equations. 3 cr. hrs.
Existence and uniqueness theorems, linear and non-linear systems, numerical techniques, stability.

MSCS 5510. Elementary Partial Differential Equations. 3 cr. hrs.
Fourier series, method of separation of variables, eigenfunction expansions, application of eigenfunctions to partial differential equations, Green's functions and transform methods.

MSCS 5540. Numerical Analysis. 3 cr. hrs.
Numerical solution of algebraic and transcendental equations, linear systems and the algebraic eigenvalue problem, interpolation and approximation, numerical integration, difference equations, numerical solution of differential equations, and finite difference methods.

MSCS 5600. Fundamentals of Artificial Intelligence. 3 cr. hrs.
An introduction to the broad field of artificial intelligence. Topics include: problem solving by searching, knowledge representation, reasoning, planning, decision-making, learning, perception, and language processing.

MSCS 5610. Data Mining. 3 cr. hrs.
Techniques for extracting and evaluating patterns from large databases. Introduction to knowledge discovery process. Fundamental tasks including classification, prediction, clustering, association analysis, summarization, and discrimination. Basic techniques including decision trees, neural networks, statistics, partitioning clustering, and hierarchical clustering.

MSCS 5630. Mathematical Modeling and Analysis. 3 cr. hrs.
Construction and analysis of mathematical models from biological, behavioral, and physical sciences.

MSCS 5650. Theory of Optimization. 3 cr. hrs.
Fundamental theorems describing the solution of linear programs and matrix games. Minimax, duality, saddle point property, simplex and specialized algorithms. Zero sum games, transportation and assignment problems, applications to economics.

MSCS 5670. Applied Combinatorial Mathematics. 3 cr. hrs.
Permutations and combinations, recurrence relations, inclusions and exclusion, Polya's theory of counting, graph theory, transport networks, matching theory.

MSCS 5700. Theory of Probability. 3 cr. hrs.
Random variables, distributions, moment generating functions of random variables, various derived probabilistic models and applications.

MSCS 5710. Mathematical Statistics. 3 cr. hrs.
Sampling theory and distributions, estimation and hypothesis testing, regression, correlation, analysis of variance, non-parametric methods, Bayesian statistics.

MSCS 5720. Statistical Methods. 3 cr. hrs.
Probability, discrete and continuous distributions. Treatment of data, point and interval estimation, hypothesis testing. Large and small sample method, regression, non-parametric methods. An introduction to the basic understanding of statistical methods. Applications-oriented.

MSCS 5740. Biostatistical Methods and Models. 3 cr. hrs.
Introduction to the statistics of life science and the use of mathematical models in biology. Data analysis and presentation, regression, analysis of variance, correlation, parameter estimation and curve fitting. Biological sequence analysis, discrete and continuous mathematical models and simulation.

MSCS 5760. Time Series Analysis. 3 cr. hrs.
MSCS 5780. Regression Analysis. 3 cr. hrs.
Basic concepts of statistical inference, simple linear regression, multiple linear regression, diagnostic analysis, selecting the best equation, stepwise methods, nonlinear regression, use of statistical software.

Topics include: database concepts and architecture, data modeling, formal query languages such as relational algebra, commercial query language SQL, database access from application programs and a brief examination of advanced concepts including transactions, distributed databases, security and XML.

MSCS 5860. Component-Based Software Construction. 3 cr. hrs.
Introduction to software components in the context of the object-oriented paradigm. Component development, component selection and adaptation/customization, component deployment and assembly/integration, and system architecture. Industry standards such as JavaBeans, CORBA Component Model, and Microsoft COM/DOM/COM+.

MSCS 5931. Topics in Mathematics, Statistics and Computer Science. 1-3 cr. hrs.
Topics selected from one of the various branches of mathematics, statistics or computer science. Specific topics to be announced in the Schedule of Classes.

MSCS 6010. Probability. 3 cr. hrs.
Foundations of probability for modeling random processes and Bayesian approaches, including: counting techniques, probability of events, random variables, distribution functions, probability functions, probability density functions, expectation, moments, moment generating functions, special discrete and continuous distributions, sampling distributions, prior and posterior distributions, Law of Large Numbers, Central Limit Theorem, Bayesian paradigm. Prereq: Three semesters of mathematics beyond calculus.

MSCS 6020. Simulation. 3 cr. hrs.

MSCS 6030. Applied Mathematical Analysis. 3 cr. hrs.
Foundational topics in analysis considered from a modeling and numerical viewpoint. Emphasizes techniques of proof and approximation, and their role in the solution of problems arising in applications. Prereq: Multivariable calculus and linear algebra.

MSCS 6040. Applied Linear Algebra. 3 cr. hrs.
Foundational linear algebra considered from a numerical viewpoint. Focus is on solutions of linear systems of equations, eigenvalues and eigenvectors, and transformations. Emphasizes and illustrates proof and numerical implementation using problems arising in applications. Prereq: Multivariable calculus and linear algebra.

MSCS 6050. Elements of Software Development. 3 cr. hrs.
Students explore the software design and development processes through a term project. Concepts covered include: requirements gathering and analysis, mapping requirements to a design, sound coding and documentation practices, configuration management, testing and quality assurance, system deployment and maintenance. Prereq: Programming in a high-level language, knowledge in data structures such as stacks, recursion, queues, trees and graphs.

MSCS 6051. Professional Software Engineering 1. 3 cr. hrs.
Covers software engineering topics typically including the Software Development Lifecycle (SDLC), development methodologies, software quality overview, configuration management, designing for risks and fault tolerance, languages and design, object-oriented programming, observational research and prototyping, requirements, software architectures, operating systems design and real time systems. Offered at General Electric facilities. As this course extends beyond the Marquette term, students receive the grade of IC initially. The IC grade converts to an A-F grade at the completion of the course. Prereq: GE employee in the Software Edison program.

MSCS 6052. Professional Software Engineering 2. 3 cr. hrs.
Covers software engineering topics typically including systems and communication networks, security and distributed systems, interoperability and standards, design for "lility" (e.g., usability and reliability) and performance, design for parallel processing, embedded systems hardware for software developers, embedded systems software, software design patterns and algorithms. Offered at General Electric facilities. As this course extends beyond the Marquette term, students receive the grade of IC initially. The IC grade converts to an A-F grade at the completion of the course. Prereq: GE employee in the Software Edison program.

MSCS 6053. Professional Software Engineering 3. 3 cr. hrs.
Covers software engineering topics typically including database systems, decision science, data quality and analytics, user interface design, design for globalization, debugging and troubleshooting, approach, method, implementation and emerging software technologies. Offered at General Electric facilities. As this course extends beyond the Marquette term, students receive the grade of IC initially. The IC grade converts to an A-F grade at the completion of the course. Prereq: GE employee in the Software Edison program.

MSCS 6054. Professional Software Engineering 4. 3 cr. hrs.
Covers design topics related to system design with embedded computing. Topics typically include design of controls, design for low cost, design for serviceability, design for usability, design for reliability, program management, innovation, requirements management and design thinking. Offered at General Electric facilities. As this course extends beyond the Marquette term, students receive the grade of IC initially. The IC grade converts to an A-F grade at the completion of the course. Prereq: GE employee in the Software Edison program.
MSCS 6055. Software Quality Assurance. 3 cr. hrs.
Provides a perspective on people, organizations, controls, processes, and tools that collectively influence the success of a Software Quality Assurance (SOA) strategy. Discussion topics include quality approaches as they apply to requirements, design, release, configuration management, testing, defect management, operations and support. Topics are discussed in the context of a traditional development approach (waterfall, CMMI) and more contemporary models driven by lean and agile practices. Covers considerations specific to implementing an SOA approach within a regulated setting. The approach emphasizes a hands-on view of SOA, thereby providing realistic takeaways to practice in a professional career.

MSCS 6060. Parallel and Distributed Systems. 3 cr. hrs.
Students use and develop software for parallel and distributed computing systems. Topics include: job submission and management, tools for parallel and distributed software development, approaches for implementing parallel and distributed computation, parallel and distributed system architectures, and essential evaluation techniques. Prereq: Data Structures and Algorithms 2 or equiv.

MSCS 6090. Research Methods/Professional Development. 1 cr. hr.
Designed to introduce the process of research and communication of research in the computational sciences, including presentation and publication of research, preparation of grant proposals, and ethical considerations. May be repeated.

MSCS 6110. Applied Discrete Mathematics. 3 cr. hrs.
Applied discrete mathematics for the mathematics, engineering and computer science graduate student. Emphasis on graph theory and counting problems that serve as a foundation for research areas in the second term. Theory and applications are covered for topics including trees, graph coloring, chromatic polynomials, generating functions, recurrence relations, distinct colorings and Polya's Theorem. Prereq: COSC 1020 and MATH 1450 or equiv.; MATH 1451 and MATH 2100 or equiv.

MSCS 6120. Optimization. 3 cr. hrs.

MSCS 6130. Dynamical Systems. 3 cr. hrs.
Theory of discrete and continuous dynamical systems. Periodic solutions, bifurcations, chaotic systems, attractors, fractal dimension, and simulation of these systems. Prereq: MATH 5200 or equiv.

MSCS 6210. Theory of Statistics. 3 cr. hrs.
Brief review of sampling distributions, Central Limit Theorem and Law of Large Numbers. Estimation, testing hypotheses, regression and correlation analysis, non-parametric methods.

MSCS 6220. Analysis of Variance and Covariance. 3 cr. hrs.

MSCS 6230. Multivariate Statistical Analysis. 3 cr. hrs.
Basic properties of random vectors, multivariate normal distribution, estimations of mean vector and covariance matrix, Wishart distribution, hypothesis testing, Hotelling's T2, multivariate analysis of variance, principal component analysis, factor analysis, canonical correlation analysis, classification and discriminant analysis. Prereq: MATH 3100 and MATH 5710.

MSCS 6240. Design of Experiments and Data Analysis. 3 cr. hrs.
Single factor, two-factor and multi-factor designs and their analysis, Latin-square design and its analysis; power analysis and sample size selection; 2^k factorial designs; confounding/blocking designs; orthogonality and orthogonal contrasts; 3^k factorial designs; response surface methodology. Prereq: A course in statistical methods, such as MATH 4720/MSCS 5720.

MSCS 6250. Advanced Multivariate Data Analytics. 3 cr. hrs.
Multivariate data and exploratory analysis; random vector and multivariate normal distribution; multivariate linear regression; principal component and other dimensional reduction techniques; linear discriminant analysis; recursive partition and tree-based methods including classification tree and regression tree; cluster analysis; neural network; support vector machine. Prereq: A course in statistical methods, such as MATH 4720/ MSCS 5720, and a course in linear algebra.

MSCS 6330. Data Mining. 3 cr. hrs.
Techniques for extracting "interesting" relationships and knowledge hidden in data, such as decision trees, association rules, clustering, neural networks, Bayesian classifiers, feature selection, pattern assessment, inductive logic programming, outlier analysis, data imputation, and data integration. Prereq: COSC 2100 and COSC 5600; or COSC 2100 and COSC 5800; or COSC 2100 and MATH 5720; or equiv.

MSCS 6340. Component Architecture. 3 cr. hrs.
Focuses on designing and implementing software components, and ways of specifying their interconnection and interaction. The primary technology is Java Beans, although other approaches such as ActiveX are also considered. Examines general notions relating to specifying and identifying components and the general distribution of resources.

MSCS 6350. Distributed Computing. 3 cr. hrs.
Focuses primarily on the interconnection of software components, both in the way they communicate with one another, and in the way they are themselves distributed. The concentration is not as much on the technical detail of standards such as Corba, Java RMI, and Distributed Network Architecture, but on the ways these technologies can be used to construct dynamic infrastructures for welding diverse local environments into one community of cooperating parts. The emphasis is very much upon allowing heterogeneity, and on solving business problems related to distributed concentrations of data.
MSCS 6355. Mobile Computing. 3 cr. hrs.
Focuses on the fundamentals of mobile computing, challenges in mobile computing, mobility management, mobile data management, context
awareness and wireless communications, ubiquity of wireless communication technologies and standards, seamless access network services and
resources from anywhere, at anytime, middleware for mobile computing, operation systems, programming languages, network protocols and security
aspects of mobile computing, concepts in sensor networks, including operating systems, programming languages, network protocols, and programming
models. Prereq: COSC 2100 or equiv.

MSCS 6360. Enterprise Architecture. 3 cr. hrs.
Focuses totally on the server side of communications, and on the ways of using software components as wrappers of all kinds of objects, so they
can participate in highly distributed environments involving security and transactions. Attention is paid to establishing universal environments for
naming resources and finding them, and to ways of managing the life cycle of both data and program components. The main technology considered is
Enterprise Java Beans.

MSCS 6370. Information Representation. 3 cr. hrs.
Focuses on using special grammars and their associated language for communicating business information universally amongst very diverse systems.
The attention is not on the formalities of the grammars, but on the ways one can take advantage of knowing that documents are valid with respect to
those grammars. The particular technology primarily considered is XML, and considers and uses many current standards from the XML community.

MSCS 6380. Advanced Database Systems. 3 cr. hrs.
Accessing databases from Web, JavaScript, JDBC, Java Servlets, database technology to Web related areas such as semi-structured databases and
data integration, XML, XQuery, XPath, XML Schemas, distributed database design, distributed database transactions, and distributed query processing.
Prereq: Database Systems or equiv.

MSCS 6390. Professional Seminar in Computing. 1 cr. hr.
Topic to be chosen each term from among issues important to all professionals in computing. All students in the computing program are expected to
participate for the fall and spring terms, and one of the two summer terms. S/U grade assessment. Prereq: Enrolled in M.S. in computing program.

MSCS 6410. Real Analysis. 3 cr. hrs.
Involves study of algebraic structures of real analysis, function spaces, introduction to linear operators, measure and integration theory, convergence
theorems, limits, continuity, derivatives. Prereq: MATH 5200.

MSCS 6420. Algebra. 3 cr. hrs.
Studies groups, rings, fields and vector spaces including Sylow's theorems, field of quotients of an integral domain, structure of finitely generated
modules over a principal ideal domain, Galois theory of equations, ordered fields, classical groups. Prereq: MATH 5120 or equiv.

MSCS 6430. Logic and Set Theory. 3 cr. hrs.
Naive set theory, first-order logic, elementary model theory, non-standard analysis, Godel's incompleteness theorems for elementary arithmetic, axioms
for set theory, ordinal and cardinal arithmetic, the continuum hypothesis, methods of inner models and forcing for proving consistency and independence
results. Prereq: MATH 5120 or equiv.

MSCS 6440. Topology. 3 cr. hrs.
Metric spaces, fundamental topology notions, subspace topology, product spaces, quotient spaces, separation axioms, Tietze's theorem, compactness,
metrization, uniform spaces, function spaces, homotopy relation, fundamental group, computing manifold groups. Prereq: MATH 5200 or equiv.

MSCS 6500. Foundations of Computing. 7 cr. hrs.
Prepresents the breadth and current status of computer science in our computerized society and the fundamentals of professional knowledge, skills,
and abilities. Foundational topics are intermixed with study of software development which include an introduction to abstraction, algorithmic thinking,
simulation and testing for computer based problem solving using higher-level programming languages. Algorithm analysis and computational complexity
are presented in the context of considering data structures, algorithms and alternatives. Students program exercises using graphical user interfaces,
data base connections, parallel computing and interfaces to the World Wide Web (WWW). Experience includes using an interactive development
environment, studying software development methodology, testing code, basic system administration, computer networking and operating system
configuration.

MSCS 6510. Business Intelligence. 3 cr. hrs.
Foundational topics in business intelligence. Includes properties and benefits for business intelligence and methodology for the development of business
intelligence solutions. Examines technology employed for managing data and creating visualizations and dashboards. Topics include developing a
business case, evaluating performance and managing data. Presents overview of data architectures commonly used in business intelligence solutions
and includes exercises using common techniques for prediction and time series analysis.

MSCS 6520. Business Analytics. 3 cr. hrs.
Foundational topics in the analysis of data from a business perspective. Includes methodology for the development of business analytics systems.
Examines technology employed for business analytics in a variety of industry segments and the benefits derived from business analytics. Foundations
of text and data mining techniques commonly used for classification, clustering and prediction. Students are presented techniques for developing a
business case, evaluating predictive performance and managing data. Includes exercises using analytic technology and a project to apply analytics to a
customer application.
MSCS 6530. Concepts of Data Warehousing. 3 cr. hrs.
Provides an introduction to data warehouse design. Topics in data modeling, database design and database access are reviewed. Data warehouse planning, design, implementation and administration. The role of data warehouse in supporting Decision Support Systems (DSS), Business Intelligence and Business Analytics.

MSCS 6550. Introduction to Cybersecurity. 3 cr. hrs.
Provides an introduction to cybersecurity threats, methods and security techniques. Foundations of various cybersecurity frameworks and methods for applying them to different types of organizations. Includes cyber threat environment, along with methods, tools and techniques that can help mitigate vulnerabilities and reduce risks to an organization.

MSCS 6560. Principles of Service Management and System Administration. 3 cr. hrs.
Introduction to the concepts, principles and practices involved in the operations of secure computing systems. Presents principles of service management and explores how the principles of system administration are derived from concepts of delivering quality services. Lab exercises performing rudimentary tasks of a system administrator using virtual machine environments. Foundation topics include cryptography, popular operating systems for servers, network configuration, system components, networked systems, host management, user management, configuration of servers and services, incident management, change management, security, monitoring and analysis of operations. Prereq: Basic knowledge of scripting, operating systems and services.

MSCS 6570. Innovations in Secondary Mathematics: Meeting the NCTM Standards. 3 cr. hrs.
Online course designed for teachers of secondary mathematics. Emphasizes relevant NCTM standards through discussion, projects, and implementation in a secondary mathematics classroom. Mathematics content amplifies and extends selected topics of secondary mathematics. Title and content vary. Credit may be earned multiple times-once for each title. Prereq: Cons. of dept. ch.; one term of calculus and access to an algebra or geometry class of secondary students; or cons. of course coordinator. For students in MSST or College of Education.

MSCS 6591. Topics in Mathematics, Statistics and Computer Science. 3 cr. hrs.

MSCS 6593. Seminar in Mathematics Curriculum Development and Material 1. 3 cr. hrs.
The historical evolution of mathematics learning theories and research-generated conceptions of mathematics learning; comparisons of various learning theories and their impact on research in mathematics learning; implications of research and learning theories on curriculum development; implications of mathematics learning research/theories on the teaching and learning of mathematics. Prereq: Teaching experience in secondary mathematics. For students in MSST or College of Education.

MSCS 6594. Seminar in Mathematics Curriculum Development and Material 2. 3 cr. hrs.
Philosophy of education with particular attention to mathematics education; development by students of useful curricula in the form of teaching units, evaluation materials, and student and teacher bibliographies for specific topics, grade levels, and ability groups; aspects of supervision as related to the role of department chairperson. Prereq: MSCS 6593. For students in MSST or College of Education.

MSCS 6596. Seminar in Mathematics, Statistics and Computer Science. 1-3 cr. hrs.

MSCS 6599. Independent Study in Mathematics, Statistics and Computer Science. 1-5 cr. hrs.

This course for computing professionals involves practical application of the knowledge and skills being studied concurrently, and previously studied, in other course work. Prereq: Admission into the Integrated Practicum Option; Cons. Of Director of Graduate Studies for the Computing Program or cons. of dept. ch.

MSCS 6974. Practicum for Research in Computational Sciences. 1-3 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

MSCS 6975. Practicum for Statistical Consulting. 3 cr. hrs.
Provides students with the opportunity to explore real-world examples of data analysis as a statistical consultant. Prereq: 3.00 MU GPA; must be enrolled in the Plan B option of the M.S. program in applied statistics, and have completed at least 18 credit hours. Cons. of the applied statistics dir. of graduate studies; or cons. of dept. ch.

Prereq: Cons. of dept. ch.

MSCS 6998. Professional Project in Mathematics, Statistics and Computer Science. 0 cr. hrs.
SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 6999. Master's Thesis. 1-6 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

MSCS 8995. Independent Study in Math, Statistics and Computer Science. 1-3 cr. hrs.
In-depth research on a topic or subject matter usually not offered in the established curriculum with faculty and independent of the classroom setting. Prereq: Cons. of dept. ch.

MSCS 8999. Doctoral Dissertation. 1-12 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.
MSCS 9970. Graduate Standing Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9974. Graduate Fellowship: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9975. Graduate Assistant Teaching: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9976. Graduate Assistant Research: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9987. Doctoral Comprehensive Examination Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9988. Doctoral Comprehensive Examination Preparation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9989. Doctoral Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9991. Professional Project Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9992. Professional Project Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9993. Professional Project Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9994. Master's Thesis Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9995. Master's Thesis Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9996. Master's Thesis Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9997. Doctoral Dissertation Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9998. Doctoral Dissertation Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MSCS 9999. Doctoral Dissertation Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.