Dual MSES-MS Intelligent Systems Engineering Program Requirements (51 credit hours)

Students in the MSES-MS Intelligent Systems Engineering program take 51 credit hours (of which, at least 21 credits must be from both O'Neill and Luddy). Note that double-counting of courses among components is permitted as outlined below, so long as overall credit requirements are met. In double-counting, multiple requirements may be met by a single course, but credits only count once towards credit totals.

Note regarding registration: Students pursuing a second degree outside of O'Neill are expected to register equally through both schools during their time in the dual degree program. In general, students should enroll through the school in which the majority of their credits are being taken for a given term. The O'Neill Graduate Records Office will check dual degree student enrollments each term to ensure enrollments are placed under O'Neill when necessary. The O'Neill Graduate Records Office will reach out to students whose enrollments need switched to adhere to this rule.

Environmental Science Core – Required: (6 credit hours)
Take the following two courses.

		P=Prerequisite, C=Corequisite, & R=Recommendations
SPEA-E 513	Environmental Project Management	
SPEA-E 538	Statistics for Environmental Science	Or SPEA-V 506 Statistical Analysis for Effective Decision Making or, with demonstration of prior coursework in statistics and/or probability theory, these credits can be replaced with any course from the next list.

Environmental Science Core – Choose List: (3 credit hours)
Take one of the following courses.

		P=Prerequisite, C=Corequisite, & R=Recommendations
SPEA-E 431	Water Supply and Wastewater Treatment	
SPEA-E 515	Fundamentals of Air Pollution	
SPEA-E 520	Environmental Toxicology	
SPEA-E 527	Applied Ecology	
SPEA-E 536	Environmental Chemistry	
SPEA-E 550	Soil Science and Management	
SPEA-E 564	Organic Pollutants: Environmental Chemistry and Fate	
SPEA-E 574	Energy Systems	

Continued on next page

Economics, Management, and Policy Core Competencies: (6 credit hours)
Courses in this section provide context for environmental and intelligent systems engineering, including how science impacts and is impacted by social, political, and economic systems. Other O'Neill courses may be approved by an advisor.

		P=Prerequisite, C=Corequisite, & R=Recommendations
SPEA-E 543	Environmental Management	
SPEA-E 560	Environmental Risk Analysis	
SPEA-P 539	Management Science for Public Affairs	
SPEA-P 541	Benefit Cost Analysis	
SPEA-R 512	Climate Law and Policy	
SPEA-R 521	Domestic Environmental Policy	
SPEA-R 531	Water Law	
SPEA-R 532	Water Policy and Economics	
SPEA-R 533	Public Natural Resources Law	
SPEA-R 625	Environmental Economics and Policy	**P: V517**
SPEA-R 535	International Environmental Policy	
SPEA-R 643	Natural Resource Management and Policy	
SPEA-R 645	Environmental Law	
SPEA-R 674	Energy Economics and Policy	**P: V517**
SPEA-S 596	Sustainable Development	**P: V517** or equivalent coursework
SPEA-V 517	Public Management Economics	
SPEA-V 550	Energy Law and Policy	
SPEA-X 511	Human Behavior and Energy Consumption	Cross-listed with SPEA-E 501

ISE Core – Required: (4 credit hours)
Take the following two courses.

		P=Prerequisite, C=Corequisite, & R=Recommendations
ENGR-E 500	Introduction to Intelligent Systems Engineering (1 cr.)	
SPEA-E 552	Environmental Engineering	

Continued on next page

ISE Core – Choose List: (3 credit hours)
Take one of the following courses.

		P=Prerequisite, C=Corequisite, & R=Recommendations
ENGR-E 501	Intro to Computer Engineering	
ENGR-E 502	Intro to Cyberphysical Systems	
ENGR-E 503	Intro to Intelligent Systems	
ENGR-E 504	Intro to Bioengineering	
ENGR-E 505	Intro to Nanoengineering	
ENGR-E 506	Intro to Neuroengineering	

ISE Computing Tools Requirement: (3 credit hours)
Familiarity with multiple computing languages and the ability to learn to operate across them is a requisite skillset in this field. Students may apply for a Computing Tools Waiver based on previously completed coursework or existing expertise, in which case these 3 credits would be replaced by an ENGR course with instructor approval. Other courses may be approved by advisor.

		P=Prerequisite, C=Corequisite, & R=Recommendations
INFO-D 590	Data Science Onramp	Variable topics, take for 1-3 credits
SPEA-E 555	Intro to Coding for Environment and Policy (1 cr.)	
SPEA-E 555	Python Programming for Environment and Policy (1 cr.)	
SPEA-E 555	Using R for Environment and Policy (1 cr.)	
ENGR-E 501	Intro to Computer Engineering	
ENGR-E 502	Intro to Cyberphysical Systems	
ENGR-E 503	Intro to Intelligent Systems	
ENGR-E 511	Machine Learning and Signal Processing	
ENGR-E 516	Engineering and Cloud Computing	
ENGR-E 517	High Performance Computing	
ENGR-E 533	Deep Learning Systems	

Continued on next page

Dual Environmental Science – ISE Concentration: (At least 20 credit hours)
Courses taken for the concentration allow schools to acquire competency in tools, skills, methods, and approaches used in environmental science and intelligent systems engineering. Courses taken to fulfill requirements cannot be "double counted."

At least 6 credits must be selected from SPEA Environmental Science Electives (listing SPEA-E) and 11 credits from ISE Electives (listing ENGR), including courses listed in the Core requirements and in the following sections.

SPEA Environmental Science Electives (At least 6 credit hours)

		P=Prerequisite, C=Corequisite, & R=Recommendations
SPEA-E 514	Changing Landscape of Toxic-Chemical Regulation	
SPEA-E 517	BMP Design for Healthy Urban Watersheds	
SPEA-E 518	Vector-based GIS	
SPEA-E 520	Environmental Toxicology	
SPEA-E 529	Application of GIS	
SPEA-E 534	Restoration Ecology	**P: E527** or **E540**
SPEA-E 540	Wetlands Ecology and Management	
SPEA-E 542	Hazardous Materials	
SPEA-E 545	Lake and Watershed Management	
SPEA-E 546	Stream Ecology	**P: E556**
SPEA-E 554	Groundwater Flow Modeling	
SPEA-E 555	Intro to Coding for Environment and Policy (1 cr.)	
SPEA-E 555	Python Programming for Environment and Policy (1 cr.)	**P: E555 Intro to Coding**
SPEA-E 555	Using R for Environment and Policy (1 cr.)	**P: E555 Intro to Coding**
SPEA-E 556	Limnology (4 cr.)	
SPEA-E 560	Environmental Risk Analysis	**P: E538**, **V506**, or consent of instructor. A firm foundation in math and/or science is useful.
SPEA-E 562	Solid and Hazardous Waste Management	
SPEA-E 591	Climate-Change Impacts on Natural Resources	**P: Requires an upper division or grad class in ecology, environmental management, or environmental policy**

Continued on next page

Dual Environmental Science – ISE Concentration: (continued)

ISE Electives (At least 11 credit hours)

		P=Prerequisite, C=Corequisite, & R=Recommendations
ENGR-E 501	Intro to Computer Engineering	
ENGR-E 502	Intro to Cyberphysical Systems	
ENGR-E 503	Intro to Intelligent Systems	
ENGR-E 504	Intro to Bioengineering	
ENGR-E 505	Intro to Nanoengineering	
ENGR-E 506	Intro to Neuroengineering	
ENGR-E 510	Engineering Distributed Systems	
ENGR-E 511	Machine Learning and Signal Processing	
ENGR-E 512	Advanced Computer Architecture	
ENGR-E 513	Engineering Compilers	
ENGR-E 514	Embedded Systems	
ENGR-E 516	Engineering and Cloud Computing	
ENGR-E 517	High Performance Computing	
ENGR-E 518	Engineering Networks	
ENGR-E 519	Engineering Operating Systems	
ENGR-E 522	Sensors and Remote Sensing	
ENGR-E 523	Internet of Things	
ENGR-E 525	Robotics	
ENGR-E 531	Physical Optimization	
ENGR-E 532	Systems Engineering	
ENGR-E 533	Deep Learning Systems	
ENGR-E 534	Big Data Applications	
ENGR-E 537	Rapid Prototyping for Engineering	
ENGR-E 540	Computational Methods for 3-D Biomaterials	
ENGR-E 541	Simulating Cancer as an Intelligent System	
ENGR-E 551	Nanoscale Simulation and Engineering Applications	
ENGR-E 565	Image Processing for Medical Applications	
ENGR-E 583	Information Visualization	

Continued on next page

Dual Environmental Science – ISE Concentration: (continued)

ISE Electives (At least 11 credit hours)

		P=Prerequisite, C=Corequisite, & R=Recommendations
ENGR-E 584	Scientific Visualization	
ENGR-E 599	Topics in Engineering	**Topics include:** • Microfluidics and Nanofluidics • Program Optimization • High Performance Big Data Systems • Digital Design with FPGAS • Computational Bioengineering • Computational Modeling Methods • Network Systems • Advanced Bioengineering • Robotics II • Communication and Coordination in Multicellular Systems • Biomedical Sensors and Devices • Advanced Signal Processing in Medical Devices

Additional electives that may be used to meet the required total credit hours for the dual degree include any courses listed above not used to satisfy a degree requirement. Additional approved electives are included below from closely related disciplines. Courses not listed may be approved by an advisor with justification.

SPEA non-E Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
SPEA-I 516	Public Management Information Systems	
SPEA-I 519	Database Management Systems	
SPEA-I 611	Design of Information Systems	**P: I516, I519**
SPEA-I 613	Implementation of Information Systems	**P: I611**
SPEA-P 507	Data Analysis and Modeling for Public Affairs	

Geography Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
GEOG-G 532	Physical Climatology	
GEOG-G 538	Geographic Information Systems	
GEOG-G 588	Applied Spatial Statistics	

Continued on next page

Dual Environmental Science – ISE Concentration: (continued)

Earth and Atmospheric Sciences Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
EAS-G 514	Geophysical Signal Analysis	
EAS-G 534	Dynamic Meteorology: Synoptic to Global Scale	
EAS-G 538	Air Pollution Meteorology	
EAS-G 540	Physical Meteorology and Climatology	
EAS-G 547	Instrumentation for Atmospheric Science	
EAS-G 548	Sustainable Energy Systems	
EAS-G 559	Earth Surface Processes	
EAS-G 564	Dynamic Meteorology: Boundary-layer Meteorology	
EAS-G 576	Climate Change	
EAS-G 594	Numerical Weather Prediction	
EAS-G 612	Inverse Methods in Geophysics (2 cr.)	
EAS-G 690	Mathematical Modeling in the Geosciences	
EAS-G 690	Fluvial Processes and Sediment Transport	

Biology/Biotech Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
BIOL-B 572	Photobiology	**P: S305** or **L367** or **CHEM-C 483** or equivalent.
BIOL-L 510	Introduction to the Research Laboratory	
BIOL-L 519	Bioinformatics: Theory and Application	
BIOL-L 522	Advanced Eukaryotic Molecular Genetics	**P: Consent of instructor**
BIOL-L 523	Critical Analysis of the Scientific Literature (1-6 cr.)	
BIOL-L 560	Physiological Ecology	
BIOL-L 572	Microbial Ecology	

Continued on next page

Dual Environmental Science – ISE Concentration: (continued)

Biology/Biotech Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
BIOL-L 575	Ecosystem Structure and Function	**P: L473** and **L474** (or equivalent) or instructor's consent.
BIOL-L 577	Theoretical Ecology	
BIOL-M 511	Molecular Biology of Prokaryotes	**P: CHEM-C 584**

Informatics Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
INFO-D 590	Data Science Onramp	Variable topics, take for 1-3 credits
INFO-I 590	Environmental Policy, Health & Design	
INFO-I 590	Smart Cities	

Information and Library Science Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
ILS-Z 503	Representation and Organization	
ILS-Z 510	Intro to Information Studies	
ILS-Z 511	Database Design	
ILS-Z 512	Information Systems Design	

Mathematics Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
MATH-M 511/M512	Real Variable I & II	
MATH-M 513/M514	Complex Variables I & II	
MATH-M 540/M541	PDEs I & II	
MATH-M 544/M545	ODEs I & II	
MATH-M 571/M572	Numerical Methods I & II	
MATH-M 671/M672	Numerical Differential and Integral Equations I & II	

Continued on next page

Dual Environmental Science – ISE Concentration: (continued)

Physics Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
PHYS-P 555	Quantum Computation and Information	
PHYS-P 582	Biological and Artificial Neural Networks	
PHYS-P 583	Signal Processing and Information Theory in Biology	
PHYS-P 609	Computational Physics	
PHYS-P 610	Computational Physics II	

Statistics Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
STAT-S 501	Statistical Methods I	
STAT-S 503	Statistical Methods II	
STAT-S 520	Introduction to Statistics	
STAT-S 611	Statistical Computing	

Chemistry Courses

		P=Prerequisite, C=Corequisite, & R=Recommendations
CHEM-C 501	Chemical Instrumentation	
CHEM-C 503	Methods of Structure Determination	
CHEM-C 540	Advanced Organic Chemistry	
CHEM-C 565	Nuclear Chemistry	
CHEM-C 566	Spectroscopy	
CHEM-C 567	Statistical Mechanics	
CHEM-C 572	Computational Chemistry and Molecular Modeling	
CHEM-C 611	Electroanalytical Chemistry (1.5-3 cr.)	
CHEM-C 612	Spectrochemical Methods of Analysis	
CHEM-C 613	Mass Spectrometry (1.5-3 cr.)	
CHEM-C 614	Chromatography (1.5-3 cr.)	
CHEM-C 616	Surface Analysis and Surface Chemistry (1.5 cr.)	
CHEM-C 633	Inorganic Chemistry of Main Group Elements	
CHEM-C 634	Transition Metal Chemistry	

Continued on next page

Capstone Requirement: (3 credits hours)

Each candidate for the MS-ES/ISE dual degree program should take a 3-credit hour course during which they participate in a team to carry out an integrative project that addresses a multidisciplinary problem, or the candidate should conduct a graduate-level research project that culminates in a publication or thesis. Capstone course credit may be double-counted in either Concentration or Tool Skill requirements.

The capstone requirement may be met by one of the following courses or with an approved course of a similar format:

		P=Prerequisite, C=Corequisite, & R=Recommendations
SPEA-V 600	Capstone in Public and Environmental Affairs	*Sections with an environmental focus.*
SPEA-E 517	BMP Design for Healthy Urban Watersheds	
SPEA-E 546	Stream Ecology	
SPEA-E 560	Environmental Risk Analysis	**P: E538**, **V506**, or consent of instructor. A firm foundation in math and/or science is useful.
ENGR-E 790	Capstone Design I	
ENGR-E 791	Capstone Design II	

Experiential Requirement: (0-3 credit hours)

Each candidate for the MS-ES/ISE dual degree program must obtain professionally relevant experience through one of the following options:

1. Approved Internship **SPEA-E 589** or **ENGR-E 591** (0-3 credit hours): The student will work with either the O'Neill Career Hub or the Luddy School's Career Services Office to arrange for a suitable internship. Internships vary greatly according to the expectations and requirements of the sponsor. Students are expected to give careful attention in the selection of an internship suitable to their professional goals. Typically, students do not use credit hours for the internship, and as a result, have minimal fees for the experience. However, students who want the additional credit hours can receive up to 3 credit hours for an internship involving the appropriate amount of work; these students will owe fees for the 3 credit hours.

2. Professional Experience (3 credit hours): Students who have had significant environmental management, computing, technical or design work experience in the past may receive a 3-credit hour reduction and a waiver of the Experiential Requirement. To receive 3 credit hours, a student must have a minimum of one year's work experience. Under no circumstances will prior professional experience credit and transfer credit total more than 12 credit hours. Students receiving prior professional experience credit should carefully plan the balance of their program with their faculty advisors.