OFFICIAL TRANSLATION OF

Fachspezifische Bestimmungen für den Studiengang „Data Science and Artificial Intelligence (M.Sc.)“

Vom 17. April 2024 und 26. Juni 2024

(Amtliche Bekanntmachung Nr. 56 vom 24. Juli 2024)

THIS TRANSLATION IS FOR INFORMATION ONLY – ONLY THE GERMAN VERSION SHALL BE LEGALLY VALID AND ENFORCEABLE!

Subject-Specific Provisions for the Master of Science in Data Science and Artificial Intelligence (MSc)

dated 17 April 2024 and 26 June2024

On 5 June 2024 and 16 June 2024 in accordance with Section 108 subsection 1 of the Hamburg higher education act (Hamburgisches Hochschulgesetz, HmbHG) the Executive University Board of the University of Hamburg ratified the Subject-Specific Provisions for the Master of Science in Data Science and Artificial Intelligence adopted on17 April 2024 and 26 June 2024 by the Faculty of Mathematics, Informatics and Natural Sciences in accordance with Section 91 subsection 2 no.1 HmbHG dated 18 July 2001 (HmbGVBl. p. 171) and amended 11 July 2023 (HmbGVBl. p. 250, 254).

Preamble

These Subject-Specific Provisions supplement the provisions of the Faculty of Mathematics, Informatics and Natural Sciences' Examination Regulations dated 20 October 2021 as amended governing Master of Science (MSc) degree programs and provide a description of the modules for the Data Science and Artificial Intelligence degree program.

I. Supplementary regulations

Section 1:
Program and examination objectives, academic degree, and implementation of the degree program

Section 1 subsection 1:

(1) The Master of Science in Data Science and Artificial Intelligence degree program is a consecutive and research-based degree program taught in English.

(2) The Master of Science in Data Science and Artificial Intelligence degree program follows the general program goals set out in Section 1 subsection 1 of the Master of Science examination regulations.

(3) The Master of Science in Data Science and Artificial Intelligence degree program consolidates students' abilities to independently apply computer science knowledge and skills in the field of data science and artificial intelligence. Graduates are able to act independently and apply scientific methods of computer science to their work, and act responsibly, especially with regard to the effects of technological change and social implications.

(4) Data Science and Artificial Intelligence degree program graduates acquire skills to collect, process, and analyze complex data using computer-aided methods. In particular, students are taught knowledge of data analysis, machine learning, artificial intelligence, and the handling and processing of large amounts of data.

(5) Graduates are able to analyze and process complex data in one or more fields of application, and can apply basic and advanced methods of artificial intelligence and adapt them to different challenges and areas of application. They are also able to develop new methods of artificial intelligence and machine learning which can be used in new areas of application.

(6) The Master of Science in Data Science and Artificial Intelligence degree program enhances students' abilities to conduct research-based scientific work. The Master's degree program prepares students for independent academic and research-oriented work and is a professional qualification for academic professions and doctoral studies.

Section 1 subsection 4:
This degree program is administered by the Faculty of Mathematics, Informatics and Natural Sciences.

Section 4
Program and examination structure
Modules and ECTS credits

Section 4 subsections 2 and 3:
(1) Detailed descriptions of all modules can be found in Appendix A to these Subject-Specific Provisions and in the module course catalog.

(2) The Data Science and Artificial Intelligence (M.Sc.) degree program consists of a required area (54 ECTS credits), a required elective area (24 ECTS credits), an advanced area (18 ECTS credits) and a domain area (24 ECTS credits).

(3) The required area Mandatory Modules in Data Science and Artificial Intelligence teaches mathematical and computer-aided principles for the analysis of data as well as the basics for legally compliant and ethically acceptable data use. The required area consists of the modules Foundations of Data Analytics (InfM-FDA, 6 ECTS credits), Epistemology, Ethics and Privacy (InfM-EEP, 6 ECTS credits), Seminar (InfM-Sem/DSAI, 3 ECTS credits), Project (InfM-Proj/DSAI, 9 ECTS credits) and the final module (30 ECTS credits) and thus has a scope of 54 ECTS credits.

(4) The required elective area Fundamentals of Data Science and Artificial Intelligence teaches basic knowledge in the areas of data analysis and processing as well as handling of large amounts of data and basic computer science knowledge in the areas of theoretical computer science and software engineering. The required elective area Fundamentals of Data Science and Artificial Intelligence comprises 24 ECTS credits. The required elective modules (Fundamentals) from which to choose are detailed in Appendix A to these Subject-Specific Provisions and in the module course catalog. An application to recognize other suitable modules for credit in addition to the required elective modules (Fundamentals) listed in Appendix A to these Subject-Specific Provisions and in the module course catalog may be submitted to the responsible examinations board.

(5) Advanced Topics in Data Science and Artificial Intelligence providing students with advanced knowledge in computer science-related subject areas from required and required elective areas. Advanced Topics in Data Science and Artificial Intelligence comprises 18 ECTS credits. The required elective modules (Fundamentals) from which to choose are detailed in Appendix A to these Subject-Specific Provisions and in the module course catalog. An application to recognize other suitable modules for credit in addition to the advanced modules listed in Appendix A to these Subject-Specific Provisions and in the module course catalog may be submitted to the responsible examinations board.

(6) Domain Knowledge in Data Science and Artificial Intelligence teaches basic knowledge in the respective application domains. The domain area comprises 24 ECTS credits. In the domain area, modules from at least two application domains with at least 6 ECTS credits per domain must be selected. The assignment of modules to a specialization is described in Annex A of these subject-specific provisions and in the module handbook. An application to recognize other suitable modules for credit in addition to the domain area modules listed in Appendix A to these Subject-Specific Provisions and in the module course catalog may be submitted to the responsible examinations board. Students also have the opportunity to choose up to 6 ECTS credits from the University of Hamburg's range of free elective area courses as part of the 24 ECTS credits. However, you can also fill the entire 24 ECTS credits with application domains. The examinations board may make recommendations for domain areas.

(7) The examinations board decides on a case by case basis whether work from a previous bachelor's degree program or a comparable master's degree program will be allowed credit. This decision is based in particular on whether prior work can be adapted to the qualification objectives of the master's degree program and must ensure students are unable to complete modules with the same or essentially identical content in a bachelor's degree program and then again in a master's degree program.

First subject semester	Foundations of Data Analytics (6 ECTS credits)	Epistemology, Ethics and Privacy (6 ECTS credits)	Required elective DSAI (9 ECTS credits)		Domains (9 ECTS credits)
Second subject semester	Seminar DSAI (3 ECTS credits)	Required elective DSAI (15 ECTS credits)		Advanced module DSAI (6 ECTS credits)	Domains (6 ECTS credits)
Third subject semester	Project DSAI (9 ECTS credits)		Advanced module DSAI (12 ECTS credits)		Domains (9 ECTS credits)
Fourth subject semester	Final Module (30 ECTS credits)				

Fig.: Curriculum Data Science and Artificial Intelligence (M.Sc.)

Section 5
Course types

Section 5 sentence 2:

(1) All course types pursuant to Section 5 of the Examination Regulations for Master of Science Degree Programs may be implemented.

(2) Modules generally consist of combinations of lectures and one seminar or exercise, or exclusively of lectures or seminars. Lectures may also include integrated exercises.

Section 5 sentences 3 and 4:

Attendance is compulsory for the following types of courses:

a) seminars, as these are generally aimed at improving students' abilities to handle criticism and to hold discussions
b) internships, as these are intended to guide students and enable them to resolve practical problems
c) projects, as these also serve to develop social skills (e.g., the ability to work in a team).
d) exercises, if the qualification objectives of the associated module cannot normally be fully achieved without them.

Compulsory attendance does not apply to admission to repeat examinations.

Section 5 sentence 5:
Courses are held in English. Some individual modules in the required elective area, specialization area, or domain area, may also be held in German. The ability to complete the program completely in English is guaranteed.

Section 13
Completed coursework and module examinations

Section 13 subsection 4:
As a rule written examinations last 120 minutes. Oral examinations last between 20 and 30 minutes. More information is contained in Appendix A. Any changes will be announced before registration for the module.

Section 13 subsection 6:
The examination shall be in English. Any changes will be announced prior to module registration. If the examiner and the student agree, the examination may also be taken in a language that is different from the language of the module.

Section 14
Master's thesis

Students who have completed the required modules Foundations of Data Analytics (InfM-FDA), Epistemology, Ethics and Privacy (InfM-EEP) and a total of at least 75 ECTS credits, including at least 6 ECTS credits in an application domain, can be admitted to the final module. The chair of the examinations board decides exceptions to this rule. A mandatory component of the final module is a colloquium consisting of a presentation and an academic discussion about the subject matter of the thesis. The lecture and discussion will last between 30 and 60 minutes. The presentation is one tenth of the grade for the final module, which must receive a passing grade of at least 4.0. The colloquium must be held no later than six weeks after submission of the thesis.

Section 14 subsection 4 sentence 2:
The master's thesis must be written in English.

Section 14 subsection 5:
The work required in the final module, comprised of a master's thesis and an oral examination amounts to 30 ECTS credits. The master's thesis must be completed within six months.

Section 14 subsection 7 sentence 1:
At least one assessor should be an authority in the discipline of informatics.

Section 15
Evaluation of examinations

Section 15 subsection 3 sentence 5:
If a module examination is comprised of multiple testing components, then the (overall) grade for the module is calculated on the basis of the average grades for respective performance weighted according to the ECTS credits assigned to each part. This does not apply to the final module. Calculation of the final module grade is governed by Section 14.

Section 15 subsection 3 sentences 10 and 11:
The overall grade earned for the master's degree program is calculated on the basis of the average of the grades from the modules weighted according to the ECTS credits assigned to them plus the grade from the final module and excluding ECTS credits that have been earned in the domain and free elective area.

Section 15 subsection 4:
The overall grade "pass with distinction" is awarded if a grade of 1.0 is awarded for the final module, the average overall grade is less than or equal to 1.3, and none of the module grades for the required, required elective, or advanced modules is greater than 2.0.

II. Module descriptions

Descriptions of all of the modules can be found in Appendix A to these Subject-Specific Provisions and in the module course catalog.

Section 23
Effective date

These Subject-Specific Provisions become effective on the day following official publication by the University of Hamburg. They first apply to students commencing their studies in Winter Semester 2024/25.

Hamburg, 24 July 2024
University of Hamburg

Appendix A to Subject-Specific Regulations for program M.Sc. Data Science and Artificial Intelligence 2024 – translation for information only – not legally binding

						Courses				Examinations			
Recommended Semester	**Frequency**	**Duration (1 oder 2 Semesters)**	**Required (R), required elective (RE) or elective (E)**	**Module ID**	**Prerequisites**	**Module**	**Course Title**	**Teaching format**	**Weekly Credit Hours**	**Examination Prerequisites**	**Exam Type(s)**	**Graded**	**ECTS Credits**
Mandatory modules													
The following modules must be taken: InfM-EEP, InfM-FDA, InfM-MA/DSAI, InfM-Proj/DSAI, InfM-Sem/DSAI													54
1	WiSe	1	R	InfM-EEP	none	**Epistemology, Ethics and Privacy**				none	Generally an Oral exam; Written exam as exception*	y	6
							Epistemology, Ethics and Privacy	VL	2				
							Epistemology, Ethics and Privacy	Ü	2				
Qualification targets: Students are familiar with the typical epistemological, ethical, legal and technical requirements for data collection, storage, processing and transfer with a focus on data science and artificial intelligence. They have the necessary methodological knowledge to formulate such requirements and to select, adapt and further develop organizational and technical measures for their implementation.													
1	WiSe	1	R	InfM-FDA	none	**Foundations of Data Analytics**				none	Generally a Written exam; Oral exam as exception*	y	6
							Foundations of Data Analytics	VL	2				
							Foundations of Data Analytics	Ü	2				
Qualification targets: Students have fundamental domain knowledge in the field of data analytics. This includes topics in linear algebra, multivariate stochastics, dimension reduction and clustering, with a view to machine learning.													
2	WiSe / SuSe	1	R	InfM-Sem/DSAI	Recommended: Individual seminars may recommend specific content requirements.	**Seminar Data Science and Artificial Intelligence**				Active participation	Presentation and written report	y	3
							Seminar	Sem	2				
Qualification targets: Students have the in-depth ability to independently develop specialist content in the fields of data science and/or artificial intelligence from the original literature and to present their own and others' problems and solutions in a presentation and in written form.													
3	WiSe	1	R	InfM-Proj/DSAI	Recommended: Individual projects may recommend specific content requirements.	**Project Data Science and Artificial Intelligence**				Active participation	Project completion	y	9
							Project	Proj	6				
Qualification targets: Students are able to grapple with new problems and to solve sophisticated challenges in Data Science and/or Artificial Intelligence using scientific methods (under supervision) in a team. They possess advanced abilities to present issues and solutions formulated themselves and by others both orally and in writing.													

4	WiSe / SuSe	s.b.	R	InfM-MA/DSAI	Required: See §14 MSc examination regulations MIN-Faculty and Supplementary Subject-Specific Provisions §14	**Final Module M.Sc. Data Science and Artificial Intelligence**			See Section 14 of Supple-mentary Subject-Specific Provisions	Master's thesis (90 %) and colloquium (10 %)	y	30
						Master's thesis and a presentation in a colloquium	-	-				
						For duration see § 14 MSc examination regulations of the MIN-Faculty and Supplementary Subject-Specific Provisions § 14.						

Qualification targets:

- Students possess the ability to work independently on a complex, scientific problem from the field of Data Science and Artificial Intelligence using scientific methods
- They possess advanced problem-solving skills and the ability to transfer the theoretical and methodological knowledge of Data Science and Artificial Intelligence to application domains
- They are able to scientifically evaluate and classify their own work against the background of current research work regarding the chosen topic
- They are able to document problem analyses, approaches to solutions, and empirical findings in accordance with scientific standards
- They are able to present, scientifically evaluate, and discuss the approaches to solutions both verbally and in writing.

Required elective area – Fundamentals of Data Science and Artificial Intelligence

Selection from the modules: InfM-ALG, InfM-DIS, InfM-ML, InfM-NN, InfM-STSP, InfM-SWA — 24

1	WiSe	1	RE	InfM-ALG	Required: Knowledge of algorithms and data structures as well as basic knowledge of the formal foundations of informatics	**Algorithms**			none	Generally a Written exam; Oral exam as exception*	y	9
						Algorithms	VL	4				
						Algorithms	Ü	2				

Qualification targets: Students have in-depth knowledge of advanced algorithms and data structures as well as methods to analyze their efficiency. They have developed problem-solving skills for difficult, formalizable problems primarily of combinatorial nature. Students are moreover able to develop algorithms for special problems themselves and to evaluate these in terms of their problem adequacy.

1	WiSe	1	RE	InfM-STSP	none	**Statistical Signal Processing**			none	Generally an Oral exam; Written exam as exception*	y	9
						Statistical Signal Processing	VL	4				
						Statistical Signal Processing	Ü	2				

Qualification targets: Students have fundamental domain knowledge of signal and system theory. The students have fundamental knowledge of the analysis and processing of stochastic and deterministic sensor data, signals and processes. Students master basic methods of stochastic modeling of sensor data, signals and random processes. Students are able to design and analyze simple signal processing systems.

1	WiSe	1	RE	InfM-SWA	Recommended: Programming skills in an object-oriented programming language	**Software Architecture**			none	Generally a Written exam (90 Min.); Oral exam as exception*	y	6
						Software Architecture	VL	2				
						Architecture-centric Software Development	Sem	2				

Qualification targets: Students have a sound understanding of the requirements for software architecture as a component in the development of complex systems. They possess fundamental knowledge of the methods, principles, techniques, and procedures involved in the development of software architectures.

2	SuSe	1	RE	InfM-DIS	Recommended: In-depth knowledge of the relational database model (ER modeling, normalization, relational algebra, SQL); basic knowledge of semi-structured data management (XML, XML schema, XML query languages); basic knowledge of formal logic (Horn clause logic,	**Databases and Information Systems**			none	Generally a Written exam; Oral exam as exception*	y	9

					predicate calculus)							
							Databases and Information Systems	VL	4			
							Databases and Information Systems	Ü/Sem	2			
Qualification targets: Students have in-depth knowledge of the basic principles, concepts, and methods of data management, data preparation, and data analysis. They are able to handle data and knowledge assets and to conceptualize and implement database and information systems and adapt database systems to specific application circumstances. They are moreover aware of the possibilities for integrating database solutions into complex software systems (data warehouses or web-based distributed information systems).												
2	SuSe	1	RE	InfM-ML	Recommended: Basic knowledge of linear algebra, stochastics, data mining, Python		**Machine Learning**			none	Generally a Written exam; Oral exam as exception*	y	9
							Machine Learning	VL	4			
							Machine Learning	Ü/Sem	2			
Qualification targets: Students have in-depth knowledge of the various approaches to learning from data, including their limitations. They are able to compare learning methods in terms of specific application conditions. They are able to systematically classify new procedures. They can design, implement, and evaluate a learning system for a given task. They can present empirical findings from the field of machine learning.												
2	SuSe	1	RE	InfM-NN	Recommended: Knowledge in bio-inspired artificial intelligence		**Neural Networks**			none	Generally an Oral exam; Written exam as exception*	y	6
							Neural Networks	VL	2			
							Neural Networks	Sem	2			
Qualification targets: Students have an in-depth understanding of artificial neural networks and their integration into informatics architectures. They can analyze and understand complex problems and develop adequate solutions for them.												
Advanced Topics in Data Science and Artificial Intelligence												
Selection from the modules: InfM-BAI, InfM-BKIM, InfM-CV 1, InfM-CV 2, InfM-IR, InfM-LT, InfM-NLP, InfM-OML, InfM-RT, InfM-SSV, InfM-WV												18
1/3	WiSe	1	RE	InfM-BAI	none		**Bio-Inspired Artificial Intelligence**			none	Generally an Oral exam; Written exam as exception*	y	6
							Bio-Inspired Artificial Intelligence	VL	2			
							Bio-Inspired Artificial Intelligence	Sem	2			
Qualification targets: Students are familiar with the scientific investigation and use of intelligent behavior in nature: They are acquainted with the principles of biological intelligent strategies. Students are able to critically analyze relevant characteristics and can implement these characteristics in computer models for intelligent systems and robots.												
1/3	WiSe, occ.	1	RE	InfM-BKIM	Recommended: Programming experience in Python, basic knowledge of (descriptive) statistics		**Biostatistics and Artificial Intelligence in Medicine**			none	Presentation and written report mit einer Gesamtnote (100 %)	y	6
							Biostatistics and Artificial Intelligence in Medicine	VL	2			
							Biostatistics and Artificial Intelligence in Medicine	Ü	2			
Qualification targets: Students are able to analyze OMICS data (genomics, transcriptomics, proteomics, and metabolomics) descriptively and extract phenotypic signatures (complex biomarkers for diseases or cellular development). They are familiar with methods of artificial intelligence and machine learning, especially for data protection and privacy relating to patient data. Students can assess the quality of AI and ML models learned from their computer programs and recognize their fundamental limitations. They are able to determine if and how advanced medical data analysis techniques can be applied to similar problems. They can successfully implement selected AI and ML tools in a programming language and adapt these to produce an AI and ML method that maximizes data protection and privacy "by design".												
1/3	WiSe	1	RE	InfM-CV 1	none		**Computer Vision I**			none	Generally a Written exam; Oral exam as exception*	y	6

							Computer Vision I	VL	2				
							Computer Vision I	Ü	2				
Qualification targets: Students know the basics of digital image processing and computer vision, reinforced through exercises.													
1/3	WiSe	1	RE	InfM-IR	Recommended: Basic knowledge of knowledge processing		**Intelligent Robotics**			none	Generally an Oral exam; Written exam as exception*	y	6
							Intelligent Robotics	VL	2				
							Intelligent Robotics	Sem	2				
Qualification targets: Students are familiar with the physical forms of perception in terms of their applications in robotics. They can apply sensor-based techniques in robotics and other technical systems. They master basic techniques of intelligent systems and understand their possible applications in technical systems. They will have an overview of application areas and implementation approaches for machine learning methods.													
1/3	SuSe	1	RE	InfM-LT	Recommended: Basic knowledge of automatic language processing; basic knowledge of machine learning		**Language Technology**			none	Generally a Written exam; Oral exam as exception*	y	6
							Language Technology	VL	2				
							Language Technology	Ü	2				
Qualification targets: Students gain in-depth knowledge in selected areas of the machine processing of natural language. They are able to assess the viability and transferability of methods of natural language processing and are familiar with and understand the latest research findings.													
1/3	WiSe	1	RE	InfM-NLP	Required: Programming in Java — Recommended: Knowledge in algorithmics and mathematics		**Natural Language Processing and the Web**			none	Generally a Written exam; Oral exam as exception*	y	6
							Natural Language Processing and the Web	VL	2				
							Natural Language Processing and the Web	Ü	2				
Qualification targets: Students are able to understand and differentiate between methods and approaches to processing unstructured texts; to reproduce and explain how Internet search engines work; to build sample applications of language processing on the web for themselves and analyze these; and to analyze and assess the potential of web content for improving language technology applications.													
1/3	WiSe	1	RE	InfM-OML	Recommended: InfM-ML, basic knowledge of linear algebra, analysis, Python		**Optimization for Machine Learning**			none	Generally a Written exam (90 Min.); Oral exam as exception*	y	6
							Optimization for Machine Learning	VL	2				
							Optimization for Machine Learning	Ü	2				
Qualification targets: Many problems in the field of machine learning and artificial intelligence require the solution of an optimization problem. This applies to both classical machine learning and modern deep learning methods. The theoretical foundations of optimization algorithms and their practical implementation in Python are covered with a special focus on machine learning problems. Students know and understand the theoretical guarantees/runtimes and limits of various optimization algorithms. They know which algorithm to choose for a specific machine learning problem and how to efficiently implement optimization algorithms for machine learning. They are aware of numerical robustness and rounding errors in optimization algorithms.													
1/3	WiSe	1	RE	InfM-WV	Recommended: Basic knowledge of knowledge processing and logic		**Knowledge Processing**			none	Generally an Oral exam; Written exam as exception*	y	6
							Knowledge Processing	VL	2				
							Knowledge Processing	Sem	2				
							Alternatively, teaching format may be lecture with 3 credit hours per week and seminar with 1 credit hour per week.						

Qualification targets: Student have an in-depth understanding of how to handle data, information, and knowledge for complex domains. They are able to analyze requirements and to select suitable, i.e. adequate and efficient, knowledge processing concepts. Moreover, they can comprehend complex problems and develop adequate solutions in the field of intelligent systems.

2	SuSe, at least every other year	1	RE	InfM-CV 2	Recommended: InfM-CV 1	**Computer Vision II**				none	Generally an Oral exam; Written exam as exception*	y	6
							Computer Vision II	VL	2				
							Computer Vision II	Ü/Sem	2				

Qualification targets: Students possess in-depth knowledge of current research topics regarding image processing and are able to independently apply this knowledge to their individual research in this area.

2	SuSe	1	RE	InfM-RT	Recommended: Basic knowledge of knowledge processing	**Robot Technology**				none	Generally an Oral exam; Written exam as exception*	y	6
							Robot Technology	VL	2				
							Robot Technology	Ü	1				
							Robot Practical Course	Prak	1				

Qualification targets: Students master the mathematical tools for describing robotic systems. They are able to apply and develop components for real robots.

2	SuSe	1	RE	InfM-SSV	Recommended: Basic knowledge in signal processing	**Speech Signal Processing**				none	Generally an Oral exam; Written exam as exception*	y	6
							Speech Signal Processing	VL	2				
							Speech Signal Processing	Ü	2				

Qualification targets: Students can explain the basics of speech production, perception, and analysis; understand the mathematical and information theoretic foundations of speech signal processing; and apply the methods learned and explain the functions of practical speech signal processing systems.

Domain Knowledge in Data Science and Artificial Intelligence

Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be acquired as free electives.

Domain Knowledge in Data Science and Artificial Intelligence: Biology

Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be acquired as free electives.
Modules offered in *Domain Knowledge in Data Science and Artificial Intelligence: Biology*: BBIO-WPW-22a, BBIO-WPW-37, Bio-2, i-MARSYS 1, MBIO-W-31, MBIO-W-38, MBIO-W-49, MoPS-01, MoPS-05

1/3	WiSe	1	RE	BBIO-WPW-22a	none	**Introduction to Behavioural Ecology**				none	Written exam	y	3
							Introduction to Behavioural Ecology	VL	1				

Qualification targets: Students deepen their understanding of evolutionary hypotheses and their verification through experiments. They are familiar with the application of the economy principle in behavioural science.

1/3	WiSe	1	RE	BBIO-WPW-37	Recommended: Knowledge in Ecology	**Numerical Modeling Basics in Biology**				Active par-ticipation	Paper	y	3
							Mathematische Beschreibung biologischer Prozesse	VL	1				
							Programmierung mit Matlab/Octave und Fortran	Sem	1				

ualification targets: The students have basic knowledge of the mathematical description of biological processes. The focus is on dynamic processes (e.g. population dynamics). They can apply this knowledge to numerically integrate the underlying differential equations with the help of computer models. The students can independently develop their own solution approaches for dynamic biological processes and implement them in a computer model.

1/3	WiSe	1	RE	Bio-2	none	**Evolutionary Biology**				none	Written exam	y	4

							Grundlagen der Evolutionsbiologie (Fundamentals in Evolutionary Biology)	VL	2				
							Biologische Fallstudien (Case Studies in Evolutionary Biology)	VL	1				
Qualification targets: The students gain an overview of the mechanisms, processes and concepts of evolution with evidence by experimental research. Selected case studies facilitate appreciation of overlaps between scientific disciplines, different approaches to elucidate biological questions in the light of evolutionary theory as well as their application.													
1/3	WiSe	1	RE	i-MARSYS 1	none		**Introduction to Biological Oceanography and Fisheries Science**			Presentatio	Generally an Oral exam; Written exam as exception*	y	6
							Introduction to Biological Oceanography and Fisheries Science	VL	3				
							Current Literature in Biological Oceanography and Fisheries Science	Sem	2				
Qualification targets: Students know and understand basic questions, methods and the current state of knowledge in the fields of Biological Oceanography and Fisheries Science.													
1/3	WiSe	1	RE	MBIO-W-31	none		**Digital Methods in Morphology**			Active participation	Oral exam	y	9
							Softwareübung zur organismischen Strukturanalyse	Ü	3				
							Praktikum zur organismischen Strukturanalyse	Prak	6				
Qualification targets: Students have an overview of the types and formats of digital data sets. They understand the steps to turn real objects into digital, editable objects. They learn, remember and understand the basics in the theoretical part. They acquire basic skills in various software packages to apply the basics to digital datasets, to assess them, to quantify if necessary. They are visualized in publication quality.													
1/3	WiSe	1	RE	MoPS-01	none		**Introduction to Molecular Plant Science**			Presentatio	Oral exam or written exam	y	6
							Introduction to Molecular Plant Science	VL	2				
							Case Studies	Sem	2				
Qualification targets: Students are familiar with current topics in molecular plant sciences, in particular plant physiology, developmental biology, plant genetics and infection biology.													
1/3	SuSe	1	RE	MoPS-05	none		**Ethics in Biology**			Active participation	Paper	y	6
							Ethics in Biology	VL	2				
							Ethics in Biology	Sem	2				
Qualification targets: Students are familiar with different ethical concepts as a key to understand, why people differ in evaluations of scientific and technical innovations. They are able to develop their own qualified position, to understand societal governance processes and ways to actively participate in societal decision making.													
2	SuSe	1	RE	MBIO-W-38	Recommended: Advanced knowlege in Plant Physiology and Ecology		**Modeling Vegetation in the Earth System**			Expercises completed	Paper	y	3
							Die Funktion der Vegetation im Erdsystem	VL	1				
							Prozessbasierte Modellierung von Vegetation	Ü	1				
Qualification targets: Students have basic knowledge of the effect of climate factors on vegetation functions (photosynthesis, water uptake, growth), and of the feedback effect of vegetation on climate. They can apply this knowledge to the quantitative determination of vegetation functions based on given climate data. Furthermore, they can independently develop their own model approaches for given vegetation processes. The students have basic knowledge of global computer models of the land surface.													
2	WiSe	1	RE	MBIO-W-49	Recommended: Advanced knowledge of evolutionary biology, animal and plant biodiversity, ecology and biostatistics		**Interactions of biota and global biogeochemical cycles from the geological past to the future**			Seminar participation successful	Presentation	y	3
							Interactions of biota and global biogeochemical cycles from the geological past to the future	Sem	2				

Qualification targets: The students have basic knowledge of the interactions between biota and the main relevant biogeochemical cycles of the Earth system (carbon, water, nitrogen, phosphorus, etc.). They are able to apply this knowledge to assess the importance of organisms for global climate on different time scales. The students can independently understand, summarize and analyze scientific publications on the topic, and discuss the results of their analyses in a presentation.

Domain Knowledge in Data Science and Artificial Intelligence: Chemistry

Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be acquired as free electives.

Modules offered in *Domain Knowledge in Data Science and Artificial Intelligence: Chemistry*: CHE 002 A, CHE 008, CHE 015 CIS, CHE 026 A, CHE 070 A, CHE 071, CHE 080 A, CHE 081 A, CHE 136, CHE 356, CHE 498 A, CHE-DSiC

1/3	WiSe	1	RE	CHE 498 A	Recommended: Introductory courses in biochemistry and cell biology	**Synthetic cell biology – Lecture and seminar module**				Seminar participation successful	Presentation in English (40 %) and oral or written examination in German or English (60 %).	y	3
							Synthetic cell biology	VL	1				
							Synthetic cell biology	Sem	1				

Qualification targets: The course is aimed at students from a wide range of disciplines who are interested in team-oriented and independent work on a scientific or medical research project. The necessary basics of synthetic biology are acquired and various research projects are developed in small working groups. The semester concludes with a graded presentation of the individual project ideas.

1/3	WiSe	1	RE	CHE 002 A	none	**Physical Chemistry I: Introduction into Physical Chemistry**				none	Written exam	y	4,5
							Physical Chemistry I: Introduction into Physical Chemistry	VL	2				
							Physical Chemistry I: Introduction into Physical Chemistry	Ü	1				

Qualification targets: Students understand the fundamental principles of classic thermodynamics and can describe thermodynamic processes. They are able to differentiate between processes and to understand the principle of circular processes. Students are familiar with the equations of state of ideal gases and mixtures. They are also able to describe chemical balances and to differentiate between reaction orders.

1/3	WiSe	1	RE	CHE 008	none	**Introduction to Biochemistry**				none	Written exam	y	3
							Introduction to Biochemistry	VL	2				

Qualification targets: Students have basic specialist knowledge in biochemistry and are able to describe cellular structures. They also have basic knowledge of the structure and properties of the basic macromolecules of cells such as proteins, nucleic acids, lipids, and sugars. They understand the cellular functions of biomolecules and can describe basic methods for their characterization. Students understand the fundamental principles of protein function, that is, the structural and catalytic functions, as well as nucleic acid functions as the main elements involved in the transfer of genetic information. They can build on the examples of biochemical processes to differentiate from these in more complex and branched biochemical pathways and identify the regulatory points of these.

Students moreover understand the biophysical properties of proteins and nucleic acids, and thus the fundamental aspects of biochemical methods for their characterization, and can implement and apply this knowledge in practice to identify and characterize cellular macromolecules.

1/3	WiSe	1	RE	CHE 015 CIS	Recommended: Knowledge of physical chemistry	**Theoretical Chemistry**				Expercises and project completed	Written exam	y	6
							Theoretical Chemistry	VL	1				
							Theoretical Chemistry	Ü	1				
							Theoretical Chemistry	Proj	2				

Qualification targets: Students are able to discuss general principles and models of theoretical chemistry. Based on this, they can differentiate between the various electronic structures of molecules and solids, and analyze and compare the differences. In the project, students apply the methods learned to computer programs.

1/3	WiSe	1	RE	CHE 080 A	none	**General and Inorganic Chemistry**				Expercises completed	Written exam	y	6
							General and Inorganic Chemistry	VL	4				
							General and Inorganic Chemistry	Ü	2				

Qualification targets: Students are able to explain the relationship between the properties of chemical elements or processes in linguistic descriptions and chemical formulas. They can work independently to prepare chemical reaction equations based on stoichiometric principles and the law of mass action, applying the necessary units of measurement correctly in the process. They are familiar with the structure of atoms and can distinguish between the properties of the atom nucleus and electron shell. They are able to understand the different types of chemical bonds based on fundamental knowledge of physics and chemistry and to develop judgments on which bond types exist in which compounds or elements. They understand the structure principle of the periodic table of the elements and can deduce simple properties of elements from it. Hence, they can name and explain important material cycles and reaction types.												
1/3	WiSe	1	RE	CHE 356	Recommended: Introductory courses in chemistry and biochemistry	**Introduction to medicinal chemistry**				none	Written exam	y	3
							Introduction to medicinal chemistry	VL	2				
Qualification targets: Students are familiar with and understand basic technical terms and problems in medical chemistry. They understand the fundamental principles that determine and influence the interaction of drugs with molecular targets in the human organism and can name and interpret examples from this field. Students know of various techniques that are used by medical chemists in drug development, particularly in the determination and optimization of lead compounds.													
2	SuSe	1	RE	CHE 026 A	Recommended: Introductory courses in physical chemistry	**Computer Chemistry – Lecture**				none	Written exam	y	6
							Molecular dynamics and machine learning	VL	2				
							Density functional theory and the chemical bond	VL	2				
Qualification targets: Students are able to explain and discuss the theory behind chemical simulations and data-based methods in chemistry, apply them to solve specific chemistry problems, and select appropriate model parameters and approximations for specific problems. They can also compare and evaluate various approximations in chemical simulations.													
2	SuSe	1	RE	CHE 070 A	Recommended: CHE 002 A	**Physical chemistry II: Introduction to quantum mechanics**				none	Written exam	y	4,5
							Physical chemistry II: Introduction to quantum mechanics	VL	2				
							Physical chemistry II: Introduction to quantum mechanics	Ü	1				
Qualification targets: The aim of this module is to provide basic knowledge of the general principles of quantum mechanics. Students will recognize their importance and necessity. They are familiar with the principle of wave-particle duality. Students are able to differentiate between operators and observables and can solve the Schrödinger equation to simple systems. Students are able to explain the particle-in-a-box model and apply their acquired knowledge to the quantum mechanical description of the hydrogen atom.													
2	SuSe	1	RE	CHE 071	Recommended: Introductory courses in physical chemistry	**Physical Chemistry III: Consolidation of central topics of physical chemistry**				none	Written exam	y	4,5
							Physical Chemistry III: Consolidation of central topics of physical chemistry	VL	2				
							Physical Chemistry III: Consolidation of central topics of physical chemistry	Ü	1				
Qualification targets: The module builds on important fundamentals in the areas of thermodynamics, kinetics, and electrochemistry. Students are able to describe mixed phases and interpret phase equilibria. They understand Faraday's laws and can apply these to atomic and molecular electrochemical processes. Students recognize the central importance of the Nernst equation and are able to apply it. They are familiar with central electrochemical methods such as cyclic voltammetry and are able to describe and interpret such measurement data.													
2	SuSe	1	RE	CHE 081 A	Recommended: CHE 080 A	**Organic Chemistry**				none	Written exam	y	6
							Organic Chemistry	VL	3				
							Organic Chemistry	Ü	2				

Qualification targets: Students have fundamental specialist knowledge in organic chemistry. They are able to recognize functional groups of complex molecules and to assign examples of compounds to the corresponding (natural) substance classes. They can name molecules according to the IUPAC nomenclature and correctly apply stereochemical terms. Students are moreover familiar with the main reactions of functional groups and can formulate and apply their syntheses and reaction modes, including the reaction mechanisms.

2	SuSe	1	RE	CHE 136	Recommended: Fundamentals of quantum mechanics and basic knowledge of Python	**Electronic Transport in Molecules and Nanoscopic Systems**				none	Generally a Presentation; Paper as exception*	y	3
							Electronic Transport in Molecules and Nanoscopic Systems	VL	2				

Qualification targets: The students are able to explain, discuss, and evaluate various models and mechanisms of electrical conductivity for different systems. They are capable of constructing numerical models and conducting simulations with them.

2	SuSe	1	RE	CHE-DSiC	none	**Data Science in Chemistry**				Practial course completed	Presentation	y	6
							Insight into research in chemistry	Prak	-				
							Research internship	Prak	-				

Qualification targets: Students develop the ability to work purposefully on scientific questions, to apply the methods they have learnt, and to link and present their results.

Domain Knowledge in Data Science and Artificial Intelligence: Earth System Sciences

Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be
acquired as free electives.
Modules offered in *Domain Knowledge in Data Science and Artificial Intelligence: Earth System Sciences*: GO-GEIN-G, GP-M-AS-APPVOLC, GP-M-AS-INV, GP-M-AS-MIG, GP-M-AS-MLG, GP-M-AS-MSEM, GP-M-AS-SEI, ICSS-M-1.2-PCS, ICSS-M-2.1-DLAI, ICSS-M-2.2.7, MET-KLIMA, MET-M-ACE-AP , MET-M-ACE-CM , MET-M-ACE-GWL , MET-M-ACE-NP, MET-M-ADYN, MET-
M-EXP-S, OZ-M-DL, OZ-M-IPO, OZ-M-MACH

1/3	WiSe	1	RE	GP-M-AS-INV	Recommended: Analyzing Earth System Data	**Inversion Problems**				As announced	Expercises completed	y	6
							Inversion Problems	VL	2				
							Inversion Problems	Ü	2				

Qualification targets: After completing the module, students are familiar with concepts, theory and limitations of linear and non-linear inversion methods and algorithms. They have inverted diverse data sets using self-written programs and gained experience in the application of established inversion methods. They are capable of solving inverse problems efficiently on their own. They are familiar with confidence intervals and the concept of errors and recognize instabilities and non-unique solutions.

1/3	WiSe	1	RE	GP-M-AS-MIG	Recommended: Analyzing Earth System Data	**Migration of seismic reflection data**					Written exam	y	6
							Migration of seismic reflection data	VL	2				
							Migration of seismic reflection data	Ü	2				

Qualification targets: After successful completion of the module, students are familiar with the foundations of subsurface imaging by depth conversion of poststack and prestack reflection seismic data.

1/3	WiSe	1	RE	GP-M-AS-MLG	Recommended: Analyzing Earth System Data	**Machine Learning in Geophysics**				Expercises completed	Paper	y	6
							Machine Learning in Geophysics	VL	2				
							Machine Learning in Geophysics	Ü	2				

Qualification targets: After successful completion of the module, students will have an overview of machine learning, including theory and specific applications in Geophysics. They have applied various machine learning techniques to geophysical problems using self-written programs but also get to know several open source machine learning frameworks. They learned how to evaluate the performance of their implemented algorithms.

1/2/3	WiSe o. SuSe, gen. ev. sem.	1	RE	GP-M-AS-MSEM	Recommended: Analyzing Earth System Data	**Seminar on Machine Learning in Geophysics**				As announced	Presentation and written report	n	3
							Seminar on Machine Learning in Geophysics	Sem	2				
Qualification targets: After successful completion of the module, students can familiarise themselves with an advanced geophysical topic. They can present their results in an oral lecture and lead a scientific discussion.													
1/3	WiSe	1	RE	GP-M-AS-SEI	Recommended: Generating Earth System Data	**Body and Surface Wave Seismology**				Expercises completed	Expercises completed	y	6
							Body and Surface Wave Seismology	VL	2				
							Body and Surface Wave Seismology	Ü	2				
Qualification targets: After completing the module, the students should understand the fundamental concepts of seismic wave propagation and put these concepts into practice. They will be familiar with the theory, analysis and application of surface waves. Through computer exercises, they will have some practical experience in the application of several seismological methods.													
1/3	WiSe	1	RE	ICSS-M-1.2-PCS	none	**Physics of the Climate System**					Oral exam or written exam	y	4,5
							Physics of the Climate System	VL	4				
Qualification targets: Students have a basic understanding of the meteorological and oceanographic processes relevant for the mean state and variability of the climate system.													
1/3	WiSe	1	RE	MET-KLIMA	none	**Fundamentals of Meteorology and Climate**					Written exam	y	4
							Fundamentals of Meteorology and Climate	VL	2				
							Fundamentals of Meteorology and Climate	Ü	2				
Qualification targets: Students know the basic concepts of meteorology and climate research. They are familiar with the most important phenomena and their physical foundations. They are capable of interdisciplinary cooperation.													
1/3	WiSe	1	RE	MET-M-ACE-AP	none	**Atmospheric Physics**					Oral exam	y	6
							Atmospheric Physics	VL	2				
							Atmospheric Physics	Ü	2				
Qualification targets: Students are familiar with basic concepts of atmospheric thermodynamics, fluid mechanics, and cloud microphysics as necessary to further study the role of these processes in weather and climate.													
1/3	WiSe	1	RE	MET-M-ACE-GWL	Recommended: Analyzing Earth System Data	**Geophysical Wave Lab**					Paper	y	6
							Geophysical Wave Lab	VL	2				
							Geophysical Wave Lab	Ü	2				
Qualification targets: The students gain an overview of basic wave concepts important for the atmospheric and ocean circulation, and hands-on experience in analyzing specific phenomena, such as the Rossby and inertia-gravity waves in the midlatitudes and in the tropics, geostrophic adjustment, barotropic instability, impact of orography on the flow, as well as practical skills in designing numerical experiments and describing their results in a written form.													
1/3	WiSe	1	RE	MET-M-ADYN	none	**Atmospheric Dynamics**					Oral exam	y	6
							Atmospheric Dynamics	VL	2				
							Atmospheric Dynamics	Ü	2				
Qualification targets: The course teaches atmospheric dynamics by systematically introducing equations and concepts of increasing complexity and their use for understanding outputs of complex weather and climate models. Students learn to interpret atmospheric phenomena in observations and numerical models in terms of concepts and simplified models that describe scales and dynamical regimes of interest and can be solved mathematically. These solutions provide physical understanding of processes otherwise difficult to grasp.													
1/3	WiSe	1	RE	OZ-M-IPO	none	**Introduction to Physical Oceanography**					Expercises completed	y	3
							Introduction to Physical Oceanography	VL	2				
Qualification targets: Students will be provided with the basic knowledge related to actual local measurements and learn how to connect this knowledge to understand the ocean system on larger spatial and temporal scales. By presenting an ocean-related topic to their peers, they will gain insight into reading, discussing and presenting scientific publications.													
1/3	WiSe	1	RE	OZ-M-MACH	Recommended: Analyzing Earth System Data	**Machine Learning in Climate Science**					Presentation and written report	y	3
							Machine Learning in Climate Science	Sem	2				

Qualification targets: Students will have an insight into the current state of the rapidly evolving field of machine learning in climate science; including an understanding of the basic terminology, potential applications, and the strengths, challenges and limitations of different approaches. In addition, students will have deep knowledge of a self-selected example study from the literature.

2	SuSe	1	RE	GO-GEIN-G	none	**Introduction to Geophysics**			As announced	Expercises completed	y	4
						Introduction to Geophysics	VL	3				
						Introduction to Geophysics	Ü	1				

Qualification targets: After successful completion of the module, students have an understanding of the most important phenomena and methods in geophysics and a general overview of the subject. They are familiar with measurement techniques, the principal function of measurement instruments and basic evaluation methods.

2	SuSe	1	RE	GP-M-AS-APPVOLC	Recommended: Generating Earth System Data, GP-M-AS-INV	**Applied Volcanology**			As announced	Paper	y	4
						Applied Volcanology	VL	2				
						Applied Volcanology	Ü	1				

Qualification targets: Upon successful completion, the students are familiar with the most abundant measurement devices used at volcanoes worldwide. They have identified the physical parameters, relevant to volcanological research and know how to retrieve them. They gained overview on the measurement principles and function of devices and their installation in the field. In addition, an introduction to general periphery (electronic and IT), power supply, data storage and transmission, as well as accurate timing of instruments will enable students to plan their own campaigns.

2	SuSe	1	RE	ICSS-M-2.1-DLAI	none	**Dynamics of land-atmosphere interactions**				Written exam	y	3
						Dynamics of land-atmosphere interactions	VL	2				

Qualification targets: Students understand key biophysical and biogeochemical land-atmosphere interactions that influence climate dynamics. They know basic mathematical and numerical concepts of how to represent the underlying terrestrial processes in land surface models.

2	SuSe	1	RE	ICSS-M-2.2.7	Recommended: Generating Earth System Data	**Sea ice physics, observations and modelling**				Written exam	y	6
						Sea ice physics, observations and modelling	VL	2				
						Sea ice physics, observations and modelling	Ü	2				

Qualification targets: Students have practical knowledge of the physics of sea ice and its interaction with the atmosphere and the ocean. They know the scientific methods used to study sea ice, including satellite remote sensing, scientific instruments and large-scale climate models.They know how the different methods can ideally be combined to gain robust insights into the functioning of sea ice and thus to use the sea ice as a proxy to gain experience in working as climate researchers.

2	SuSe	1	RE	MET-M-ACE-CM	Recommended: Generating Earth System Data	**Climate Modelling**				Expercises completed	y	6
						Climate Modelling	VL	2				
						Climate Modelling	Ü	2				

Qualification targets: Students will have a basic understanding of global coupled climate models: how they work, are developed and how they can advance our understanding of the climate system. Students will be able to discuss advantages as well as the limitations of different model setups and analyses.

2	SuSe	1	RE	MET-M-ACE-NP	Recommended: Generating Earth System Data	**Numerical Weather Prediction**				Expercises completed	y	6
						Numerical Weather Prediction	VL/int.Ü	4				

Qualification targets: Students know and understand atmospheric observations, a hierarchy of data assimilation methods, formulation of numerical prediction models, theoretical and intrinsic predictability, ensemble forecasting, and interpretation of outputs of forecast models. Students developed understanding of various components of the numerical prediction models and how they contribute to reliability of model forecasts.

2	SuSe	1	RE	MET-M-EXP-S	Recommended: Generating Earth System Data	**Experimental Meteorology**				Presentation and written report	y	3
						Experimental Meteorology	Sem	2				

Qualification targets: Students know how to design, conduct and analyze experiments in Atmospheric Science. They can analyze large, complex observational data sets to test theories in Atmospheric Science. They are able to assess the uncertainty of observational data.

2	SuSe	1	RE	OZ-M-DL	Recommended: Analyzing Earth System Data	**Practical Deep Learning with Climate Data**					Expercises completed	y	6
						Practical Deep Learning with Climate Data	VL/int.Ü	4					

Qualification targets: Students will have understood fundamental neural network approaches to classification and regression problems. They will have written programs implementing multiple neural network architectures and trained them on simulations and observations of the atmosphere and ocean. They will have hands-on experience in designing and executing a deep learning-based research project.

Domain Knowledge in Data Science and Artificial Intelligence: Informatics

Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be
acquired as free electives.
Modules offered in *Domain Knowledge in Data Science and Artificial Intelligence: Informatics*: InfM-ALG, InfM-ARA, InfM-BAI, InfM-BKIM, InfM-CV 1, InfM-CV 2, InfM-DIS, InfM-IR, InfM- LT, InfM-ML, InfM-NLP, InfM-NN, InfM-OML, InfM-RT, InfM-SSV, InfM-STSP, InfM-SWA, InfM-WV
Moduls potentially already taken in *Advanced Topics in Data Science and Artificial Intelligence* or *Domain Knowledge in Data Science and Artificial Intelligence* are not available.

1/3	WiSe	1	RE	InfM-ALG	Required: Knowledge of algorithms and data structures as well as basic knowledge of the formal foundations of informatics	**Algorithms**				none	Generally a Written exam; Oral exam as exception*	y	9
						Algorithms	VL	4					
						Algorithms	Ü	2					

Qualification targets: Students have in-depth knowledge of advanced algorithms and data structures as well as methods to analyze their efficiency. They have developed problem-solving skills for difficult, formalizable problems primarily of combinatorial nature. Students are moreover able to develop algorithms for special problems themselves and to evaluate these in terms of their problem adequacy.

1/3	WiSe	1	RE	InfM-ARA	Recommended: Knowledge of algorithms and mathematics	**Analysis of Randomized Algorithms**				none	Generally an Oral exam; Written exam as exception*	y	9
						Randomized Algorithms	VL/int.Ü	4					
						Randomized Algorithms	Sem	2					

Qualification targets: Students have the basic knowledge needed to analyze randomized algorithms and systems, and can use this to analyze randomized algorithms.

1/3	WiSe	1	RE	InfM-BAI	none	**Bio-Inspired Artificial Intelligence**				none	Generally an Oral exam; Written exam as exception*	y	6
						Bio-Inspired Artificial Intelligence	VL	2					
						Bio-Inspired Artificial Intelligence	Sem	2					

Qualification targets: Students are familiar with the scientific investigation and use of intelligent behavior in nature: They are acquainted with the principles of biological intelligent strategies. Students are able to critically analyze relevant characteristics and can implement these characteristics in computer models for intelligent systems and robots.

1/3	WiSe, occ.	1	RE	InfM-BKIM	Recommended: Programming experience in Python, basic knowledge of (descriptive) statistics	**Biostatistics and Artificial Intelligence in Medicine**				none	Presentation and written report mit einer Gesamtnote (100 %)	y	6
						Biostatistics and Artificial Intelligence in Medicine	VL	2					
						Biostatistics and Artificial Intelligence in Medicine	Ü	2					

Qualification targets: Students are able to analyze OMICS data (genomics, transcriptomics, proteomics, and metabolomics) descriptively and extract phenotypic signatures (complex biomarkers for diseases or cellular development). They are familiar with methods of artificial intelligence and machine learning, especially for data protection and privacy relating to patient data. Students can assess the quality of AI and ML models learned from their computer programs and recognize their fundamental limitations. They are able to determine if and how advanced medical data analysis techniques can be applied to similar problems. They can successfully implement selected AI and ML tools in a programming language and adapt these to produce an AI and ML method that maximizes data protection and privacy “by design”.

1/3	WiSe	1	RE	InfM-CV 1	none	**Computer Vision I**				none	Generally a Written exam; Oral exam as exception*	y	6
						Computer Vision I	VL	2					
						Computer Vision I	Ü	2					
Qualification targets: Students know the basics of digital image processing and computer vision, reinforced through exercises.													
1/3	WiSe	1	RE	InfM-IR	Recommended: Basic knowledge of knowledge processing	**Intelligent Robotics**				none	Generally an Oral exam; Written exam as exception*	y	6
						Intelligent Robotics	VL	2					
						Intelligent Robotics	Sem	2					
Qualification targets: Students are familiar with the physical forms of perception in terms of their applications in robotics. They can apply sensor-based techniques in robotics and other technical systems. They master basic techniques of intelligent systems and understand their possible applications in technical systems. They will have an overview of application areas and implementation approaches for machine learning methods.													
1/3	SuSe	1	RE	InfM-LT	Recommended: Basic knowledge of automatic language processing; basic knowledge of machine learning	**Language Technology**				none	Generally a Written exam; Oral exam as exception*	y	6
						Language Technology	VL	2					
						Language Technology	Ü	2					
Qualification targets: Students gain in-depth knowledge in selected areas of the machine processing of natural language. They are able to assess the viability and transferability of methods of natural language processing and are familiar with and understand the latest research findings.													
1/3	WiSe	1	RE	InfM-NLP	Required: Programming in Java — Recommended: Knowledge in algorithmics and mathematics	**Natural Language Processing and the Web**				none	Generally a Written exam; Oral exam as exception*	y	6
						Natural Language Processing and the Web	VL	2					
						Natural Language Processing and the Web	Ü	2					
Qualification targets: Students are able to understand and differentiate between methods and approaches to processing unstructured texts; to reproduce and explain how Internet search engines work; to build sample applications of language processing on the web for themselves and analyze these; and to analyze and assess the potential of web content for improving language technology applications.													
1/3	WiSe	1	RE	InfM-OML	Recommended: InfM-ML, basic knowledge of linear algebra, analysis, Python	**Optimization for Machine Learning**				none	Generally a Written exam (90 Min.); Oral exam as exception*	y	6
						Optimization for Machine Learning	VL	2					
						Optimization for Machine Learning	Ü	2					
Qualification targets: Many problems in the field of machine learning and artificial intelligence require the solution of an optimization problem. This applies to both classical machine learning and modern deep learning methods. The theoretical foundations of optimization algorithms and their practical implementation in Python are covered with a special focus on machine learning problems. Students know and understand the theoretical guarantees/runtimes and limits of various optimization algorithms. They know which algorithm to choose for a specific machine learning problem and how to efficiently implement optimization algorithms for machine learning. They are aware of numerical robustness and rounding errors in optimization algorithms.													
1/3	WiSe	1	RE	InfM-STSP	none	**Statistical Signal Processing**				none	Generally an Oral exam; Written exam as exception*	y	9
						Statistical Signal Processing	VL	4					
						Statistical Signal Processing	Ü	2					

Qualification targets: Students have fundamental domain knowledge of signal and system theory. The students have fundamental knowledge of the analysis and processing of stochastic and deterministic sensor data, signals and processes. Students master basic methods of stochastic modeling of sensor data, signals and random processes. Students are able to design and analyze simple signal processing systems.													
1/3	WiSe	1	RE	InfM-SWA	Recommended: Programming skills in an object-oriented programming language		**Software Architecture**			none	Generally a Written exam (90 Min.); Oral exam as exception*	y	6
							Software Architecture	VL	2				
							Architecture-centric Software Development	Sem	2				
Qualification targets: Students have a sound understanding of the requirements for software architecture as a component in the development of complex systems. They possess fundamental knowledge of the methods, principles, techniques, and procedures involved in the development of software architectures.													
1/3	WiSe	1	RE	InfM-WV	Recommended: Basic knowledge of knowledge processing and logic		**Knowledge Processing**			none	Generally an Oral exam; Written exam as exception*	y	6
							Knowledge Processing	VL	2				
							Knowledge Processing	Sem	2				
							Alternatively, teaching format may be lecture with 3 credit hours per week and seminar with 1 credit hour per week.						
Qualification targets: Student have an in-depth understanding of how to handle data, information, and knowledge for complex domains. They are able to analyze requirements and to select suitable, i.e. adequate and efficient, knowledge processing concepts. Moreover, they can comprehend complex problems and develop adequate solutions in the field of intelligent systems.													
2	SuSe, at least every other year	1	RE	InfM-CV 2	Recommended: InfM-CV 1		**Computer Vision II**			none	Generally an Oral exam; Written exam as exception*	y	6
							Computer Vision II	VL	2				
							Computer Vision II	Ü/Sem	2				
Qualification targets: Students possess in-depth knowledge of current research topics regarding image processing and are able to independently apply this knowledge to their individual research in this area.													
2	SuSe	1	RE	InfM-DIS	Recommended: In-depth knowledge of the relational database model (ER modeling, normalization, relational algebra, SQL); basic knowledge of semi-structured data management (XML, XML schema, XML query languages); basic knowledge of formal logic (Horn clause logic, predicate calculus)		**Databases and Information Systems**			none	Generally a Written exam; Oral exam as exception*	y	9
							Databases and Information Systems	VL	4				
							Databases and Information Systems	Ü/Sem	2				
Qualification targets: Students have in-depth knowledge of the basic principles, concepts, and methods of data management, data preparation, and data analysis. They are able to handle data and knowledge assets and to conceptualize and implement database and information systems and adapt database systems to specific application circumstances. They are moreover aware of the possibilities for integrating database solutions into complex software systems (data warehouses or web-based distributed information systems).													
2	SuSe	1	RE	InfM-ML	Recommended: Basic knowledge of linear algebra, stochastics, data mining, Python		**Machine Learning**			none	Generally a Written exam; Oral exam as exception*	y	9
							Machine Learning	VL	4				
							Machine Learning	Ü/Sem	2				

Qualification targets: Students have in-depth knowledge of the various approaches to learning from data, including their limitations. They are able to compare learning methods in terms of specific application conditions. They are able to systematically classify new procedures. They can design, implement, and evaluate a learning system for a given task. They can present empirical findings from the field of machine learning.														
2	SuSe	1	RE	InfM-NN	Recommended: Knowledge in bio-inspired artificial intelligence		**Neural Networks**			none	Generally an Oral exam; Written exam as exception*	y	6
							Neural Networks	VL	2				
							Neural Networks	Sem	2				
Qualification targets: Students have an in-depth understanding of artificial neural networks and their integration into informatics architectures. They can analyze and understand complex problems and develop adequate solutions for them.														
2	SuSe	1	RE	InfM-RT	Recommended: Basic knowledge of knowledge processing		**Robot Technology**			none	Generally an Oral exam; Written exam as exception*	y	6
							Robot Technology	VL	2				
							Robot Technology	Ü	1				
							Robot Practical Course	Prak	1				
Qualification targets: Students master the mathematical tools for describing robotic systems. They are able to apply and develop components for real robots.														
2	SuSe	1	RE	InfM-SSV	Recommended: Basic knowledge in signal processing		**Speech Signal Processing**			none	Generally an Oral exam; Written exam as exception*	y	6
							Speech Signal Processing	VL	2				
							Speech Signal Processing	Ü	2				
Qualification targets: Students can explain the basics of speech production, perception, and analysis; understand the mathematical and information theoretic foundations of speech signal processing; and apply the methods learned and explain the functions of practical speech signal processing systems.														
Domain Knowledge in Data Science and Artificial Intelligence: Mathematics														
Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be acquired as free electives. Modules offered in *Domain Knowledge in Data Science and Artificial Intelligence: Mathematics*: Ma-M-MSAT/DSAI-HDS2, Ma-M-S/DSAI-MDN, Ma-M-VMMOA/DSAI-AT12, Ma-M-VMMOA/DSAI-AT6, Ma-M-VMMOA/DSAI-MOML, Ma-M-VMMOA/DSAI-NSO, Ma-M-VMS/DSAI-HDS1, Ma-M-VMS/DSAI-VMS, Ma-M-WR/DSAI-MML, Ma-M-WR/DSAI-MoL													
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-S/DSAI-MDN	Recommended: Knowledge of linear algebra and analysis as well as prior knowledge of nonlinear optimization		**Modellierung und Datenanalyse auf großen Netzwerken**			none	Presentation	y	4
							Modellierung und Datenanalyse auf großen Netzwerken	Sem	2				
Qualification targets: Students gain an insight into modern methods and research topics in the field of big data, including theoretical foundations, and can apply these learning methods in a data science context.														
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-VMMOA/DSAI-AT6	Recommended: Knowledge of linear algebra and analysis as well as prior knowledge of nonlinear optimization		**Selected Topics in Optimization and Approximation**			Expercises completed	Oral exam	y	6

							Selected Topics in Optimization and Approximation	VL	2				
							Selected Topics in Optimization and Approximation	Ü	1				
Qualification targets: The students acquire deepened knowledge of the state of research in an area of optimisation or approximation pertaining to the research areas of the department of mathematics and are then capable of applying advanced scientific methods relevant to the research areas. They take insight into the scientific literature and pratice to handle it.													
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-VMMOA/DSAI-AT12	none		**Selected Topics in Optimization and Approximation**			Expercises completed	Oral exam	y	12
							Selected Topics in Optimization and Approximation	VL	4				
							Selected Topics in Optimization and Approximation	Ü	2				
Qualification targets: The students acquire deepened knowledge of the state of research in an area of optimisation or approximation pertaining to the research areas of the department of mathematics and are then capable of applying advanced scientific methods relevant to the research areas. They take insight into the scientific literature and pratice to handle it.													
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-VMMOA/DSAI-MOML	Recommended: Knowledge of analysis and linear algebra, previous knowledge of (non-linear or non-smooth) optimization		**Mathematical Optimization in Machine Learning**			Expercises completed	Oral exam	y	6
							Mathematical Optimization in Machine Learning	VL	2				
							Mathematical Optimization in Machine Learning	Ü	1				
Qualification targets: Students have gained an insight into machine learning from an optimization perspective. They are familiar with various machine learning problems and know the mathematical optimization methods that can be used in this context and have become familiar with their properties.													
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-VMMOA/DSAI-NSO	Recommended: Knowledge in linear algebra and analysis		**Non-smooth optimization**			Expercises completed	Oral exam	y	6
							Non-smooth optimization	VL	2				
							Non-smooth optimization	Ü	1				
Qualification targets: Students have acquired basic knowledge of mathematical analysis and numerical methods in convex non-smooth optimization. The students • are able to reproduce basic concepts of convex analysis and apply them to simple problems. • know solution methods for convex non-smooth optimization problems and can classify the advantages and disadvantages of the methods. • know techniques for mathematical convergence analysis of these methods and can reproduce them.													
1/3	WiSe o. SuSe, occ.	1	RE	Ma-M-VMS/DSAI-HDS1	none		**High-dimensional statistics I**			none	Oral exam	y	8
							High-dimensional statistics I	VL	2				
							High-dimensional statistics I	Ü	2				
Qualification targets: Students understand the basic principles underlying high-dimensional statistics and common frameworks for applying these principles. They derive key mathematical results and implement estimators.													
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-VMS/DSAI-VMS	Recommended: Knowledge to the extent of the Bachelor's modules Analysis, Mathematical Stochastics, Mathematical Statistics, Measure Theoretical Concepts of Stochastics		**Advanced Mathematical Statistics**			Expercises completed	Oral exam	y	4
							Advanced Mathematical Statistics	VL	2				
							Advanced Mathematical Statistics	Ü	1				
Qualification targets: Qualification targets: Students have an in-depth understanding of the questions, basic principles and results of a sub-area of mathematical statistics and are proficient in the statistical methods used.													
1/2/3	WiSe o. SuSe, occ.	1	RE	Ma-M-WR/DSAI-MoL	Required: Good knowledge in Analysis and linear algebra — Recommended: Basic knowledge in numerical mathematics, optimization, stochastics		**Mathematics of Learning**			Expercises completed	Oral exam	y	6
							Mathematics of Learning	VL	2				

							Mathematics of Learning	Ü	1				
Qualification targets: Students have basic theoretical knowledge of learning methods in data science and can apply these learning methods in a data science context.														
2	SuSe	1	RE	Ma-M-MSAT/DSAI-HDS2	none		**High-dimensional statistics II**			none	Oral exam	y	8
							High-dimensional statistics II	VL	2				
							High-dimensional statistics II	Ü	2				
Qualification targets: Students understand adavanced principles underlying high-dimensional statistics and common frameworks for applying these principles. They derive key mathematical results and implement estimators.														
2	SuSe, occ.	1	RE	Ma-M-WR/DSAI-MML	Required: Basic knowledge of mathematics, especially analysis and linear algebra — Recommended: Knowledge of mathematical stochastics and numerical mathematics		**Mathematical Machine Learning**			Active participation	Team project work (50 %) and Oral Exam (50 %)	y	6
							Mathematical Machine Learning	VL	2				
							Mathematical Machine Learning	Proj	1				
Qualification targets: Students understand the basic principles, techniques and algorithms of machine learning. They can confidently deal with important terms and fundamental results and apply basic concepts to selected applications.														
Domain Knowledge in Data Science and Artificial Intelligence: Physics														
Modules can be elected as offered, with a minimum of 24 ECTS in domains and free electives overall, including at least 6 ECTs from at least two different domains. Up to 6 ECTS can be acquired as free electives. Modules offered in *Domain Knowledge in Data Science and Artificial Intelligence: Physics*: PHY-DAPA, PHY-MV-BP-E07, PHY-MV-LP-T14														-
1/3	WiSe	1	-	PHY-DAPA	Recommended: Basic knowledge of Python, basic knowledge of machine learning and data		**Modern data challenges and algorithms in particle physics and astronomy**			none	Expercises completed	n	5
							Modern data challenges and algorithms in particle physics and astronomy	VL	2				
							Modern data challenges and algorithms in particle physics and astronomy	Ü	2				
Qualification targets: Students have an understanding of current issues in physics research and the use of AI methods to solve them.														
2	SuSe	1	-	PHY-MV-BP-E07	none		**Artificial Intelligence for Biomedical Imaging**			none	Presentation and written report with an overall grade (100 %)	y	3
							Artificial Intelligence for Biomedical Imaging	Sem	2				
Qualification targets: The students • have an overview of current techniques and methods of machine learning (especially deep learning) and artificial intelligence (AI). • have in-depth knowledge and insights into current areas of application of AI in the field of medical and biomedical imaging and analysis. Current research topics and selected research areas of the Department of Physics and the UKE are presented.Students are able to discuss the respective topics and methods in a reflective manner and successfully complete a Master's thesis in this area.														
2	SuSe	1	-	PHY-MV-LP-T14	Required: Quantum mechanics — Recommended: Fundamentals of quantum optics		**Quantum Metrology and Quantum Sensing**			none	Written exam or Oral exam	y	5
							Quantum Metrology and Quantum Sensing	VL	2				
							Quantum Metrology and Quantum Sensing	Ü	2				

Qualification targets: Students will learn about a (quantum) information-theoretical approach to the calculation of inaccuracies in precision measurements. They will learn about the importance of entanglement for the improvement of measurement precision and they will get to know some applications of modern methods of data analysis.

Note:

The prerequisites for participation in a module are divided into:

- compulsory prerequisites—other modules that must be completed before being allowed to start that module, that is, students have passed the respective examination(s)
- recommended prerequisites—prerequisites that do not necessarily need to be completed before commencement of the module

Key

Lab = laboratory
course
Proj = project
Sem = (integrated) seminar
PC = practical course / Int. PC =
integrated practical course
L = lecture
WiSe = winter semester
SoSe = summer semester
MIN-PO = Examination Regulations for the Bachelor of Science (BSc) and Master of Science (MSc) degree programs of the MIN Faculty at the University of Hamburg
FSB = subject-specific provisions MSc Data Science and Artificial Intelligence
Generally an oral examination; written examination as exception* = type of examination will be announced prior to module registration.
Generally a written examination; oral examination as exception* = type of examination will be announced prior to module registration.
Presentation (possibly with written elaboration) or term paper* = type of examination will be announced before module registration