Programme descriptions

Annex to the Education and Examination Regulations 2019-2020
Graduate School of Natural Sciences

Version 1.0, 15 May 2019

Contents

Artificial Intelligence

Admission to the degree in Artificial Intelligence

Applicants should possess solid basic knowledge of at least the following two topics:

- logic as used in artificial intelligence, in particular propositional and predicate logic;
- programming languages as used in artificial intelligence, in particular logic, imperative and/or object-oriented languages, and skills to develop and analyze programmes in these languages.

In addition, applicants should possess solid basic knowledge of at least one of the following five topics

- artificial intelligence;
- mathematics as used in artificial intelligence;
- cognitive psychology;
- formal linguistics and natural language processing;
- philosophy of cognitive science.

Applicants holding one of the following bachelor degrees satisfy these requirements:

- A BSc in Artificial Intelligence from a Dutch University which is organized in KION (Kunstmatige Intelligentie Opleidingen Nederland)
- A BSc in Artificial Intelligence or Computer Science from Utrecht University

Finally, applicants should have the ability to communicate facts and findings verbally and in writing, also using information and communication technology and audio-visual means.

Degrees in all probability meeting the above requirements are:

- A BSc with a major in Artificial Intelligence
- A BSc with a major in Computer Science
- A BSc with a major in one of the following subjects, with some Computer-Science or AI-related courses:
    - Cognitive Science
    - Linguistics
    - Philosophy
    - Psychology
- A Dutch HBO diploma in Computer Science with a suitable programme

In case the student has not taken one of the above mentioned subjects, it can be taken as part of the MSc programme to remedy this deficiency (at most 7.5 EC, which counts as a secondary elective). The programme coordinator will decide which topics need to be followed. One course of the following Bachelor-level courses can be taken as deficiency course which is specifically mentioned in the student's Admission conditions. Each of the courses below is 7.5 EC, and note that they may be given in the Dutch language:

- Logica voor Informatica (INFOB1LI)
- Wiskunde voor KI (KIV13005)
- Inleiding Logica (KIV13001)
- Logica voor AI (INFOLAI)
- Intelligente Systemen (INFOB3IS)
- Computationele Intelligentie (INFOB3CI)
- Modelleren en programmeren voor KI (KI1V13009)
- Imperatief Programmeren (INFOIMP)
- Databases (INFODB)

- Datastructuren (INFODS)
- Inleiding tot de Cognitiewetenschap (201800004)
- Experimentele methoden en statistiek (KI3V14002)
- Inleiding Taalkunde for KI (KI1V13004)
- Computationele Linguïstiek (KI2V13007)
- Logische Complexiteit (KI3V12013)

Premaster's programme

A premaster's programme of at most 30 EC is possible (for Dutch speaking students) and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed) before entry into the Artificial Intelligence programme is allowed.

Learning outcomes

The graduate of the master's programme in artificial intelligence:

Knowledge and understanding
K1. Has mastery of artificial intelligence at an advanced academic level. This means mastery of a number of advanced general subjects in the areas of agents, cognitive processing and reasoning, and in depth-knowledge and ability in at least one advanced subject (such as agent design, multi-agent communication, multi-agent learning, cognition and language, psychology of perception, natural language processing, advanced machine learning, logic and computation, logic and language, or argumentation). Mastery of the necessary logical, computational and experimental tools; K2. Has thorough experience with research in (pure or applied) artificial intelligence and complete awareness of the applicability of research in technological developments and organizational contexts; K3. Is able to read research articles in artificial intelligence.
Applying knowledge and understanding
A1. Is capable of understanding a wide variety of different research problems in artificial intelligence and being able to formulate these at an abstract level. To see, from the abstract level, the relation between diverse problems and to contribute creatively to their solution focused on practical applications; A2. Is able to point at solutions for identified problems using the most advanced techniques from artificial intelligence; A3. Is capable of creating innovative software and information system designs, taking account of feasibility issues; A4. Has mastery of the necessary skills in theoretical analysis, modeling and experimentation. A5. Understands the potential dilemmas related to scientific integrity in his/her research field.
Making judgements
M1. Is capable of assessing and discussing research results and of taking part in discussions within the research group; M2. Is able to evaluate research results in the context of similar research on artificial intelligence. Is capable of assessing the practical feasibility and usefulness of artificially intelligent designs; M3. Is capable of reflecting on his/her own activities as a researcher and being aware of social and ethical responsibilities concerning application of research
Communication
C1. Is capable of presenting one's own research in both written and spoken English to diverse audiences. Is able to adapt to the background and interest of the audience;

C2. Is capable of working in a (possibly interdisciplinary) team of experts performing the aforementioned activities and communicating easily in both written and oral English.
Learning skills
L1. Is capable of working independently and of taking initiatives where necessary; is capable of identifying areas where expertise is lacking and remedying the situation; L2. Is capable of writing a research proposal and independently carrying out research in an area of technical artificial intelligence; L3. Has the qualification to obtain a PhD position in the area of specialization or a key position outside of academia in the area of specialization. This includes but is not limited to working at R&D departments, working in (software) industry, consultancy, and government institutions. L4. Has a realistic idea of the career opportunities after graduating, and of the skills that he/she needs to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: 540 hours for the whole programme excluding the research part, which is 12 hours per week. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	16 EC
Primary electives	30 EC
Secondary electives	30 EC
Research part	44 EC
Total	**120 EC**

Mandatory courses

- Methods in AI Research (INFOMAIR) (7.5 EC)
- Philosophy of AI (WBMV05003) (7.5 EC)
- Introducing Natural Sciences (INTRO-GSNS) (0.5 EC)
- Dilemmas of the scientist (FI-MHPSDIL) (0.5 EC)

Primary electives

Four courses from the following twelve courses have to be chosen, each 7.5 EC:

- Intelligent Agents (INFOIAG)
- Multi-Agent Systems (INFOMAS)
- Multi-agent Learning (INFOMAL)
- Social Simulation (INFOMSOSI)
- Advanced Machine Learning (INFOMAML)
- Natural Language Processing (INFOMNLP)
- Cognitive Modeling (INFOMCM)
- Experimentation in Psychology, Linguistics, and AI (INFOMEPL)
- Machine learning for human vision and language (INFOMLHVL)
- Logic and Language (TLMV13020)
- Computational Argumentation (INFOMCARG)
- Logic and Computation (WBMV13005)

Secondary electives

- Choice of all primary electives
- Research internship 7.5 EC (INFOMRIAI) or 15 EC (INFOMRIAI1)
- Free choice of courses from the UU master's programmes Neuroscience and Cognition, Computing Science, Game and Media Technology (as far as their courses are open for students of other master programmes).
- The following courses from the UU research master programme Philosophy: Digital ethics (FRRMV16017) and Topics in Epistemology and Philosophy of Science (FRRMV16011).
- The following courses from the UU research master programme Linguistics: "Reasoning about Meaning in Linguistic Communication" (TLRMV19103), "Cognitive and Computational Aspects of Word Meaning" (TLRMV19109), "Foundations of Sound Patterns" (TLRMV16105), "Individual Assignment RMA: NLP (GWMIND1900)". The individual assignment is only available when taken in tandem with one of the other three courses.
- The following ten courses from the UU master's programme Business Informatics: Data Science & Society (INFOMDSS), Adaptive Interactive Systems (INFOMAIS), ICT Advisory (INFOMICTA), Multimedia discourse interaction (INFOMMDI), Natural Language Generation (INFOMNLG), Method Engineering (INFOME), Software Architecture (INFOMSWA), Business Intelligence (INFOMBIN), Requirements Engineering (INFOMRE), and ICT Entrepeneurship (INFOIE).
- The course 'Applied Cognitive Psychology II (201800484) from the faculty of social sciences'.
- Choice of other master courses within or outside the UU, subject to approval by the coordinator; see also art. 3.7, lid 2

Deficiency courses

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

In the research part the student carries out a research project under the responsibility of a scientific staff member of Utrecht University. Both the research project and the supervisor should be approved by the programme coordinator. The research part is split into the following courses:

- Artificial intelligence MSc thesis Part I (INFOMAI1; 14 EC)
- Artificial intelligence MSc thesis Part II (INFOMAI2;30 EC)

The research project should be done on a topic related to primary electives. The project is normally performed within the research group of the supervising staff member but can also be done in a research-and-development department of a company or institution. Students who have not yet passed all primary electives or who have more than 15 EC still open can only start with the research part after approval by the programme coordinator.

Part II of the Thesis project can only be started when Part I results in an approval to continue with Part II.

Cum Laude

The minimum grade required for the research part (INFOMAI2) to obtain a cum laude degree qualification is 8.5. Please note that additional requirements need to be met to obtain this qualification (see OER main document).

Labour market perspectives and scientific integrity

Scientific integrity is addressed in the mandatory course Dilemmas of the scientist and in the research part.
The student can become familiar with labour market perspectives through a research internship (7.5 or 15 EC), and through the final thesis project when done externally.

Profiles (Educational/Applied Data Science/Complex Systems)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with an educational, 'applied data science' , or `complex systems' profile. The contents and further description of these profiles, including entry requirements to specific courses, are described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to succesfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Mandatory courses	16	EC
Primary electives	30	EC
Secondary electives	0	EC
Research part	44	EC
Total	**90**	**EC**

Special provisions for students who enrolled in the programme Artificial Intelligence in the year 2015-2016 and earlier

1- The courses Introducing Natural Sciences (GSNS-intro; 0.5 EC), Dilemmas of the scientist (FI-MHPSDIL; 0,5 EC) and the thesis split components INFOMAI1 and INFOMAI2 are not mandatory for students that have started their Research part prior to 1 September 2018 and were already exempted from the split.

2- The following substitute courses may be used:
   - Cognitive Modeling (INFOMCM) may be replaced by Cognitive Systems (201300049)
   - Experimentation in Psychology, Linguistics and AI '[may] be replaced by either Experimentation in Psychology and Linguistics (INFOMEPL) or by Linguistics Modeling and Experimental Research (TLMV13021).
   - Machine learning for human vision and language may be replaced by Advanced Topics in Cognitive Science (INFOMATCS) or Advanced Topics in Cognitive Science (201300050)

Special provision for students who enrolled before September 2018 and have already passed Methods in Artificial Intelligence Research (INFOMAIR) for 15 EC

These students can count INFOMAIR as the mandatory INFOMAIR course of 7.5 EC plus a primary elective of 7.5 EC.

Special provision for students who enrolled before September 2019

Students that have taken one of the following three courses from Business Informatics as a secondary elective can count these as secondary elective.

- Software Product Management (INFOMSPM)
- Enterprise Architecture (INFOEAR)
- Seminar Software Ecosystems (INFOMSSE)

Computer Science

Computing Science

Admission to the degree in Computer Science

Applicants should posses

- solid basic knowledge of computer science and logic;
- the ability to analyze and model computer science problems;
- the ability to communicate facts and findings verbally and in writing, also using information and communication technology and audio-visual means.

Degrees in all probability meeting these requirements are:

- a BSc in Computer Science or Artificial Intelligence,
- a BSc with a major in Computer Science or Artificial Intelligence,
- a BSc with a science major and (a) a minor in Computer Science or (b) a minor in Technical Artificial Intelligence or (c) a comparable use of the non-major part ('profileringsruimte') of the bachelor programme,
- a HBO-diploma 'Hogere Informatica Opleiding' (HIO) or (Technical) Computer Science.

In addition, applications should meet either the requirements of the Computing Science programme or the Game and Media Technology programme.

Admission to the programme Computing Science

Students qualify for admission to the programme Computing Science if they possess the following skills and knowledge (in addition to the criteria for the degree programme Computer Science):

- have a reasonable experience in the use of several programming languages (amongst which functional and object-oriented languages);
- have a basic knowledge of modern software construction;
- have a basic knowledge of algorithms and data structures, their design and analysis
- have adequate knowledge of the working of computer systems and information networks;
- have a basic knowledge of computer science and logic ;
- be able to reason formally;
- be able to communicate facts and findings verbally and in writing, including using information and communication technology and audio-visual means.

BSc degrees in Informatics (Computer Science) at many regular universities in the Netherlands and abroad are nowadays equivalent to the extent that is needed for entry in this master's programme `Computing Science'. Suitable standards must be achieved in basic backgrounds, as in the UU major, in the domains of programming (Java, C#, Haskell, software engineering) and algorithmic and formal methods (data structures, discrete mathematical methods, complexity). *Other* BSc programmes that likely satisfy the entrance requirements include:

- a BSc in Mathematics (with a minor in informatics) or Artificial Intelligence
- a HBO-bachelor in the `HBO-opleiding Informatica',
- a HBO-bachelor in Informatics/Information Technology other than the `HBO-opleiding Informatica',

in all cases depending on the particular programme followed.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed) before entry into this Computing Science programme is allowed.

With HBO's whose bachelor programme(s) in informatics do not meet the entrance requirements fully as a rule, a premaster's package can be agreed, which students can embed in their individual HBO study programme if they wish to qualify for entrance beforehand.

Learning outcomes

The graduate of the master's programme in Computing Science:

Knowledge and understanding
K1. Can use his or her knowledge of computer science to make a substantial contribution to the development and/or application of scientific concepts and methods, often in a research context.
K2. Is capable of understanding important recent developments in computer science, and of indicating their implications for society and the research field.
K3. Is capable of interpreting and using specialized literature in the field of computing science.
K4. Has insight into integrity related issues in computer science.
Applying knowledge and understanding
A1. Is capable of translating a problem from the area of computer science or an application into a research question that is relevant to and suited for scientific development, product development or education.
A2. Is capable of translating this research question into an appropriate research plan in accordance with the required scientific and methodological standards.
A3. Is capable of independently performing this research with the required care and ethical responsibility and to process, interpret and evaluate the empirical data and other outcomes thus obtained in the appropriate manner.
Making judgments
M1. Is capable of discussing the outcomes of empirical and theoretical research and to relate them to the current scientific state-of-the-art and literature.
M2. Is capable of indicating the relevance of this research to the solution of problems in the area of computer science, also from the viewpoint of society wherever possible.
M3. Has the capability to reflect critically on his or her own efforts as a researcher in the area of computer science from the viewpoint of society.
Communication skills
C1. Is capable of clearly communicating the results of research, in writing as well as orally, to an audience of specialists and laymen, in an international context.
C2. Is capable of functioning effectively in a research team of possibly multi-disciplinary composition.
Learning skills
L1. Has the capability to evaluate his or her own learning- and development process during the study, and if necessary to motivate and adjust his- or herself.
L2. Has acquired an effective and result driven way of working that allows him or her to function independently in a competitive labor market.
L3. Has the qualification to obtain a PhD position as well as a job in business and industry.
L4. Has insight into employment opportunities and on the skills needed to make a successful start in the job market.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is 400 hours, or 8 hours per week, for the whole programme excluding the research part.

Contents

Mandatory courses	23.5 EC
Primary electives	22.5 EC
Secondary electives	30 EC
Research part	44 EC
Total	**120 EC**

Study paths

Students follow "study paths". A study path is a coherent set of courses tailored towards a general topic within the master's programme. The following study paths (listed below) are pre-defined and set the standard for the programme.

- Programming technology
- Algorithm design and analysis
- Advanced planning and decision making
- Algorithmic data analysis

Alternatively, an individual study path can be composed, under approval of the programme director. The courses that belong to each of the above study paths are listed in the "Primary electives" section below.

Mandatory courses

Algorithms for decision support (INFOMADS) (7.5 EC)
Concepts of programming language design (INFOMCPD) (7.5 EC)
Big data (INFOMBD) (7.5 EC)
Introducing Natural Sciences (GSNS-intro) (0.5 EC)
Dilemmas of the scientist (FI-MHPSDIL) (0.5 EC).

Primary electives

The primary electives consist of at least three courses from the choice of four core courses defined by the study path chosen by the student. For each of these study paths, their corresponding courses (all are 7.5 EC) are listed below.

Programming technology, courses:
Advanced functional programming (INFOAFP)
Automatic program analysis (INFOAPA)
Program semantics and verification (INFOMPSM)
Technologies for learning. (INFOMTFL)

Algorithm design and analysis, courses:
Geometric algorithms (INFOGA)
Algorithms and networks (INFOAN)
Scheduling and time-tabling (INFOSTT)
Crowd Simulation (INFOMCRWS)
Network science (INFOMNWSC)

Advanced planning and decision making, courses:
Probabilistic reasoning (INFOPROB)
Algorithms and networks (INFOAN)
Evolutionary computing (INFOEA)
Scheduling and time-tabling (INFOSTT)

Algorithmic data analysis, courses:
Data mining (INFOMDM)
Multimedia retrieval (INFOMR)
Pattern recognition (INFOMPR)
Pattern set mining (INFOMPSM)

Secondary electives

To be chosen in agreement with the chosen study path from the following list:

Any course from the above "Primary Electives" list.
An experimentation project of either 7.5 or 15 EC.
A literature study under supervision of a CS staff member (capita selecta) of 7.5 EC.
Any MSc course from the Computer Science curriculum
Any MSc course offered by Universiteit Utrecht: a student may take up to 15 EC worth of relevant courses outside of the regular Computer Science curriculum upon approval in advance of the programme director. Of these, 7.5 EC worth of course can be chosen outside the Faculty of Science.

Deficiency courses

Up to two courses (15 EC) of the following Bachelor-level courses can be taken as deficiency courses which are specifically mentioned in the student Admission's conditions (as stated in his/her Admission Letter). Each of the courses below is 7.5 EC, and note that they are only given in the Dutch language:

Logica voor informatica	(INFOB1LI)
Databases	(INFODB)
Datastructuren	(INFODS)
Functioneel programmeren	(INFOFP)
Modelleren en systeemontwikkeling	(INFOMSO)
Onderzoeksmethoden voor informatica	(INFOB3OMI)
Onderzoeksmethoden voor gametech	(INFOB3OMG)
Optimalisering en complexiteit	(INFOOPT)
Talen en compilers	(INFOB3TC)
Algoritmiek	(INFOAL)
Software testing en verificatie	(INFOB3STV)
Data-analyse en retrieval	(INFOB3DAR)

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

Research can be done in the following directions: all subjects related to the research programmes of the Software Technology chair, the Algorithmic Data Analysis chair, the Algorithmic Systems chair, or the Decision Support Systems chair (internally or externally). In particular, all subjects related to the list of Primary Elective courses.

The overall research part is split into the following parts:

- Thesis project Part I (15 EC)
- Thesis project Part II (25 EC)
- The Computing Science colloquium (4 EC)

Part I of a thesis project can only be started when the student has done enough mandatory courses, primary electives, and secondary electives with a total of at least 67.5 EC. Part II of the thesis project can only be started when Part I results in an approval to continue with Part II.

Cum laude

To obtain a *cum laude* degree qualification, the minimum grade for the Part II of a thesis project is 8.5. Please note that additional requirements need to be met to obtain this qualification as listed in the main text of the OER.

Labour market perspectives and scientific integrity

Scientific integrity is a part of the Computing Science colloquium and consists of two sessions: one at the start of the programme during the GSNS-Intro and one during the programme (FI-MHPSDIL, Dilemmas of the scientist (0.5 EC). A wide variety of activities related to labour market perspectives are offered by Career Services to the Computing Science students.

Profile (Complex Systems/Education/Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme's Secondary Elective space with a Complex Systems, Education, or Applied Data Science "profile". The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master’s programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to succesfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Special provisions for students who enrolled before September 2019

Students enrolled into this programme prior to 1 September 2019 who have taken the course Compiler construction (INFOMCCO) should not take the course Automatic program analysis (INFOAPA) due to their overlapping content.

Computer Science

Game and Media Technology

Admission to the degree in Computer Science

Applicants should posses

- Solid basic knowledge of computer science and logic;
- The ability to analyze and model computer science problems;
- The ability to communicate facts and findings verbally and in writing, also using information and communication technology and audio-visual means.

Degrees in all probability meeting these requirements are:

- A BSc in Computer Science or Artificial Intelligence
- A BSc with a major in Computer Science or Artificial Intelligence
- A BSc with a science major and (a) a minor in Computer Science or (b) a minor in Technical Artificial Intelligence or (c) a comparable use of the non-major part ('profileringsruimte') of the bachelor programme
- A HBO-diploma 'Hogere Informatica Opleiding' (HIO) or (Technical) Computer Science;

In addition, applications should meet either the requirements of the Computing Science programme or the Game and Media Technology programme.

Admission to the programme Game and Media Technology

Students qualify for admission to the programme Game and Media Technology if they possess the following skills and knowledge (in addition to the criteria for the degree programme Computer Science):

- the ability to make a computer programme of reasonable complexity and size, in an object-oriented programming language such as Java, C++ or C#;
- knowledge of data structures, algorithms and related concepts of reasonable complexity, such as sorting algorithms, O(..)-notation, balanced binary search trees, etc.;
- knowledge of mathematics, notably calculus, logic, linear algebra, probability and statistics
- knowledge of basic computer-graphics techniques;
- have a good level of English understanding, speaking and writing.

Bachelor programmes that in all probability satisfy those knowledge and skill requirements are:

- BSc programmes with a major in computer science;
- BSc with a major in science and a minor (or comparable) in computer science;
- A HBO BSc programme in HIO or technical computer science. In this case, an average grade of at least 7/10 for the core courses is required next to the already mentioned skills and knowledge.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed) before entry into the **Game and Media Technology** programme is allowed.

Learning outcomes

The graduate of the master's programme in Game and Media Technology:

Knowledge and understanding
K1. Can use his or her knowledge of computer science and its applications in the field of game and media technology to make a substantial contribution to the development and/or application of scientific concepts and methods, often in a research context.
K2. Is capable of understanding important recent developments in computer science and its applications in the field of game and media technology, and of indicating their implications for society and the research field.
K3. Is capable of interpreting and using specialized literature in the field of game and media technology.
K4. Has insight in the integrity dilemmas that play a role in the field of game and media technology.
Applying knowledge and understanding
A1. Is capable of translating a problem from the area of computer science and its applications in the field of game and media technology or an application into a research question that is relevant to and suited for scientific development, product development or education.
A2. Is capable of translating this research question into an appropriate research plan in accordance with the required scientific and methodological standards.
A3. Is capable of independently performing this research with the required care and ethical responsibility and to process, interpret and evaluate the empirical data and other outcomes thus obtained in the appropriate manner.
Making judgments
M1. Is capable of discussing the outcomes of empirical and theoretical research and to relate them to the current scientific state-of-the-art and literature.
M2. Is capable of indicating the relevance of this research to the solution of problems in the area of computer science and its applications in the field of game and media technology, also from the viewpoint of society wherever possible.
M3. Has the capability to reflect critically on his or her own efforts as a researcher in the area of computer science, and its applications in the field of game and media technology from the viewpoint of society.
Communication skills
C1. Is capable of clearly communicating the results of research, in writing as well as orally, to an audience of specialists and laymen, in an international context.
C2. Is capable of functioning effectively in a research team of possibly multi-disciplinary composition.
Learning skills
L1. Has the capability to evaluate his or her own learning- and development process during the study, and if necessary to motivate and adjust him- or herself.
L2. Has acquired an effective and result driven way of working that allows him or her to function independently in a competitive labor market.
L3. Has the qualification to obtain a PhD position as well as a job in business and industry.
L4. Has a good overview of the opportunities and necessary skills to make a successful transition to the labour market.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: **400** hours for the whole programme excluding the research part. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	16 EC
Primary electives	45 EC
Secondary electives	15 EC
Research part	44 EC
Total	**120 EC**

Mandatory courses

INFOMCV Computer Vision (7.5 EC),
INFOMSCIP Scientific Perspectives on GMT (7.5 EC),
GSNS-INTRO Introducing Natural Sciences (0.5 EC),
FI-MHPSDIL Dilemmas of the Scientist (0.5 EC)

Primary electives

Select out of the following list of courses, amounting to a total of 45 EC:

INFOMAIGT AI for game technology (7.5 EC)
INFOGA Geometric Algorithms (7.5 EC),
INFOMAGR Advanced Graphics (7.5 EC),
INFOMCANIM Computer Animation (7.5 EC),
INFOMGP Game Physics (7.5 EC),
INFOMMMI Multimodal Interaction (7.5 EC),
INFOMMOB Mobile Interaction (7.5 EC),
INFOMOMA Motion and Manipulation (7.5 EC),
INFOMOV Optimization and Vectorization (7.5 EC),
INFOMCRWS Crowd Simulation (7.5 EC),
INFOMR Multimedia Retrieval (7.5 EC),
INFOMSMT Sound and Music Technology (7.5 EC),
INFOMPR Pattern Recognition (7.5 EC),
INFOMSPGMT Small Project GMT (15 EC)

Secondary electives

- Any master's course offered by the UU (including the not chosen primary electives), or master's courses from another university in or outside the Netherlands, subject to approval by the programme coordinator.
- At most one capita selecta (INFOCSM, 7.5 EC) on an approved subject.

Deficiency courses

Courses that remove deficiencies, as recommended by the programme coordinator.
Examples of common deficiency courses include:

- INFOIBV Beeldverwerking (Image Processing) (7.5 EC),
- INFOB3APGA Applied Games (7.5 EC),
- INFOAL Algoritmiek (algorithms) (7.5 EC),
- INFOB3IT Interactietechnologie (Interaction Technology) (7.5 EC),
- INFODDM Driedimensionaal Modelleren (Three-Dimensional Modelling) (7.5 EC)

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

The research part is split into the following courses:

INFOMGMT1	Game and Media Technology Project Proposal (15 EC)
INFOMGMT2	Game and Media Technology MSc Thesis (25 EC)
INFOMCGM4	Colloquium (4 EC)

Part I of a thesis project can only be started when the student has completed enough of the mandatory, primary and secondary electives with a total of at least 67.5 EC. Part II of the thesis project can only be started when Part I results in an approval to continue with Part II.

Successfully completing the course INFOMGMT1 is a mandatory prerequisite to continue with the course INFOMGMT2.

Cum laude

The minimum grade for the course INFOMGMT2 a student needs to obtain a *cum laude* degree qualification is 8.5. Please note that additional requirements (as listed in the maintext of the OER) need to be met to obtain this qualification.

Labour market perspectives and Scientific Integrity

Scientific Integrity is a part of the colloquium (INFOMCGM4), the Master's Introduction (GSNS-INTRO, 0.5 EC) and the course Dilemmas of the Scientist (FI-MHPSDIL, 0.5 EC). A wide variety of activities related to labour market perspectives is offered by Career Services to the GMT students.

Profile (Educational, Complex Systems, Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with a profile such as the Educational, Complex Systems or the Applied Data Science profile. The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to succesfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Four courses (7.5 EC each) should be selected out of the primary electives. The small project cannot be selected. The mandatory courses (16 EC) and the research part (44 EC) do not change.

Mandatory courses	16 EC
Primary electives	30 EC
Secondary electives	0 EC
Research part	44 EC
Total	**90 EC**

Special provisions for students who enrolled in the programme Game and Media Technology in the year 2017-2018 and earlier
For these students, the course *Scientific Perspectives on GMT* is not mandatory. However, the course *Motion and Manipulation* is mandatory. For students who started September 2017, *Motion and Manipulation* is mandatory and *Scientific Perspectives on GMT* is not allowed (unless special permission is given). Students who have enrolled in February 2018, can either choose *Scientific Perspectives on GMT* or *Motion and Manipulation* as a mandatory course.

Information Science

Human Computer Interaction

Admission to the degree in Information Science

Applicants should possess the following:

- basic knowledge in the field of information science (including data and process models, organization science, and coding paradigms);
- basic knowledge of research methods;
- basic knowledge of cognitive and communication science;
- basic knowledge of interactive information systems design methods and modeling;
- the ability to communicate facts and findings verbally and in writing, also using information and communication technology and audio-visual means.

In addition, applications should meet either the requirements of the Business Informatics programme or the Human Computer Interaction programme.

Degrees meeting these requirements are (see remarks on HBO below):

- a BSc in Information Science

Other bachelor degrees that are likely to satisfy these requirements, but, probably require a deficiency course(s) or a premaster's programme:

- Innovation Management, Liberal Arts and Science, Management Science, Artificial Intelligence, Psychology, or Industrial Design with a minor in Information Science;
- a BSc (other than the ones mentioned above) with a major in Information Science;
- a BSc in Computer Science (or another information technology bachelor, e.g. Information Engineering);
- a BSc in Mathematics, Physics, Biomedical Sciences with courses in programming, statistics and data management

Similar BSc programmes to the ones mentioned may also satisfy most, if not all, entrance requirements. Students with such a BSc degree are invited to contact the program coordinator for further information.

Students with a HBO-background need an average score of at least 7.5 for their professional bachelor programme and a score of at least 7.5 for their thesis project. The bachelor course on Scientific Research Methods is a deficiency course for HBO students whose degree did not contain research methods, and is taught in the master's programme.

Admission to the programme Human Computer Interaction

Students qualify for admission to the programme Human Computer Interaction if they possess the following skills and knowledge (in addition to the criteria for the degree programme Information Science):

- Basic knowledge of user-centered design and evaluation methods
- A clear interest in Human Computer Interaction as judged from the motivation letter

In case not all requirements are met, either a deficiency course (7.5 EC) needs to be followed, which replaces a secondary elective course, or a tailored premaster's programme will be defined.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed), before entry into the HCI programme is allowed.

Learning outcomes

The graduate of the master's programme in Human-Computer Interaction (HCI):

Knowledge and understanding K1. is capable of making an essential contribution to the development and/or application of scientific concepts and methods, predominantly in relation to research in HCI; K2. is capable of considering recent developments within HCI (e.g., novel sensor-based interfaces) and of specifying the implications of those developments for the discipline; K3. is capable of appropriately utilising and interpreting specialist professional literature relevant to HCI, using systematic reviews (e.g., PRISMA); K4. understands the potential dilemmas related to ethics (scientific integrity, privacy and security) in the research field of HCI. K5. understands the psychological aspects underlying human behaviour that are relevant to HCI K6. understands the computing and information science aspects underlying system behaviour that are relevant to HCI K7. is capable of explaining and advocating where and how human-centred design and user experience research fits within organizations, and how it needs to consider and influence organizational and business strategies.
Applying knowledge and understanding A1. is capable of critically analysing, defining, and using a problem within the HCI domain and use this to formulate relevant appropriate research questions for either HCI educational, scientific, or engineering purposes; A2. is capable of formulating a research design, which is appropriate for that research question and is in line with the HCI methodological and scientific standards, A3. is capable of conducting that research with the prerequisite degree of care and ethical responsibility, and to process, analyse, interpret and evaluate empirical data or other findings obtained in the process appropriately; A4. is capable of analysing the computing and information science aspects underlying system behaviour and apply these in HCI research and design; A5. is capable of analysing the psychological aspects underlying human behaviour and apply these in HCI research and design; A6. is capable of analysing possible future HCI designs and methods, critically analyse their pros and cons, conduct a requirement analysis, and suggest implementation strategies, taking the latest HCI developments in consideration.
Making judgements M1. is capable of discussing the findings of HCI research, relating it to the state of the art and relevant literature, and participating critically and constructively in the scientific debate; M2. is capable of specifying the relevance of such research for the resolution of questions and problems in the field of HCI, both from a research and a societal point of view; M3. is capable of critically reflecting on their own efforts as a researcher in the field of HCI and that of others from a societal perspective, including ethical perspectives such as privacy, scientific integrity, and information security.

Communication
C1. is able to clearly communicate research findings in both written and oral form to an audience of specialists as well as people other than professional experts within an international context;
C2. is able to function effectively and creatively as part of possibly multidisciplinary teams, lead such teams, and communicate effectively with clients, end-users and other stakeholders (e.g., engineers);
C3. is able to showcase a portfolio of industrial and research projects in which their competencies have been applied;
C4. is able to implement prototype systems that support effective and efficient communication of HCI solutions.

Learning skills
L1. has the skills to evaluate their own learning and development process, and to motivate and correct themselves during their studies where necessary;
L2. has developed their own effective, performance-oriented methodology to enable them to perform independently in the field of Interaction Technology;
L3. has the qualifications to enroll in a PhD programme in the field of Information Science;
L4. Is qualified to acquire a position as a professional in the field of Information Technology;
L5. has a realistic idea of the career opportunities after graduating, and of the skills that they need to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme is **400** hours, or **8** hours per week, for the whole programme excluding the research part.

Contents

Mandatory courses	32.0	EC
Primary electives	22.5	EC
Secondary electives	22.5	EC
Research part	43.0	EC
Total	**120.0**	**EC**

In case deficiency courses need to be followed to fill in gaps in the knowledge of students, the course credits obtained by these courses are additional to the 120 EC of the master HCI courses.

For students who follow one of the two available profiles (i.e., education and applied data science), one of the primary electives is waived in favor of the profile of 30 EC.

Mandatory courses

- Introducing Natural Sciences (GSNS-intro 0.5 EC)
- Dilemmas of the scientist (FI-MHPSDIL 0.5 EC)
- Introduction to HCI (INFOMIHCI 1.0 EC)
- Advanced Cognitive and Social Psychology for HCI (INFOMCSP 7.5 EC)
- Advanced HCI Qualitative Research Methods (INFOMQLM 7.5 EC)
- Interaction Technology Innovation (INFOMITI 7.5 EC)
- Advanced HCI Quantitative Research Methods (INFOMQNM 7.5 EC)

Primary electives

- Adaptive Interactive Systems (INFOMAIS 7.5 EC)
- Natural Language Generation (INFOMNLG 7.5 EC)
- Multimodal Interaction (INFOMMMI 7.5 EC)
- Mobile Interaction (INFOMMOB 7.5 EC)
- Seminar Multimedia Discourse Interaction (INFOMMDI 7.5 EC)
- Cognitive Modeling (INFOMCM 7.5 EC)
- Seminar Serious Gaming (INFOMSEGA 7.5 EC)
- Sound and Music Technology (INFOMSTM 7.5 EC)
- Technology for Learning (INFOMTFL 7.5 EC)

Secondary electives

- Remaining primary electives
- Courses of the master programmes Artificial Intelligence, Computing Science, Game and Media Technology, and Business Informatics
- Educational profile (30 EC)
- Applied Data Science profile (30 EC)
- Other master courses within or outside UU (*permission required*)
- One or two deficiency courses (*permission required*)

Deficiency courses

Example deficiency courses include:
-INFOB1CODE Computational Thinking,
-INFOB2SOM Software Ontwikkelings Methoden,
-INFOB3CE Cognitie en Emotie,
-INFOUE Usability Engineering and User Experience,
-INFOWO Research Methods,
-INFOB3PET Persuasive Technology.

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

- Thesis Human-Computer Interaction, part 1 (INFOMHC1 15.0 EC)
- Thesis Human-Computer Interaction, part 2 (INFOMHC2 25.0 EC)
- Colloquium HCI (INFOMCHCI 3.0 EC)

Part I of the thesis project (INFOMHC1) can start as soon as the student has completed the mandatory, primary, and secondary electives, with a total of at least 67.5 EC. Part II of the thesis project can only be started when Part I results in an approval to continue with Part II.

Cum Laude

The minimum grade for Part II of the thesis project (INFOMHC2) a student needs to obtain a *cum laude* degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Labour market perspectives and scientific integrity

Career Services offers HCI students a variety of activities related to labour market perspectives. In addition, via guest lectures, course assignments, and the two thesis parts, HCI students become acquainted with the labour market.

Scientific integrity is part of the research master HCI. In particular, it is part of Dilemmas of the scientist (FI-MHPSDIL), Advanced HCI Qualitative Research Methods (INFOMQLM), Advanced HCI Quantitative Research Methods (INFOMQNM), Colloquium HCI (INFOMCHCI), Thesis Human-Computer Interaction, part 1 (INFOMHC1), and Thesis Human-Computer Interaction, part 2 (INFOMHC2).

Profile (Applied Data Science/Educational Profile)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with an **Applied Data Science** or **Educational Profile** profile. The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described above. Note that if the student fails to successfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Information Science

Business Informatics

Admission to the degree in Information Science

Applicants should possess the following:

- basic knowledge in the field of information science (including data and process models, organization science, and coding paradigms);
- basic knowledge of research methods;
- basic knowledge of cognitive and communication science;
- basic knowledge of interactive information systems design methods and modeling;
- the ability to communicate facts and findings verbally and in writing, also using information and communication technology and audio-visual means.

In addition, applications should meet either the requirements of the Business Informatics programme or the Human Computer Interaction programme.

Degrees meeting these requirements are (see remarks on HBO below):

- a BSc in Information Science

Other bachelor degrees that are likely to satisfy these requirements, but, probably require a deficiency course(s) or a premaster's programme:

- Innovation Management, Liberal Arts and Science, Management Science, Artificial Intelligence, Psychology, or Industrial Design with a minor in Information Science;
- a BSc (other than the ones mentioned above) with a major in Information Science;
- a BSc in Computer Science (or another information technology bachelor, e.g. Information Engineering);
- a BSc in Mathematics, Physics, Biomedical Sciences with courses in programming, statistics and data management

Similar BSc programmes to the ones mentioned may also satisfy most, if not all, entrance requirements. Students with such a BSc degree are invited to contact the program coordinator for further information.

Students with a HBO-background need an average score of at least 7.5 for their professional bachelor programme and a score of at least 7.5 for their thesis project. The bachelor course on Scientific Research Methods is a deficiency course for HBO students whose degree did not contain research methods, and is taught in the master's programme.

Admission to the programme Business Informatics

Students qualify for admission to the programme Business Informatics if they possess the following skills and knowledge (in addition to the criteria for the degree programme Information Science):

- basic knowledge of organization science (including organizational structure, strategy, and culture);
- knowledge of product software development, delivery, implementation and use;
- basic knowledge of data science and data analytics;
- programming skills in an object oriented programming language;
- basic knowledge of formal logic and modeling.

Students with a University bachelor entering the admissions process:
-before September 1, 2020, need an average score of at least 6.5 for courses that match the Information Science and Business Informatics requirements.

-on or after September 1, 2020, need an average score of at least 7.0 for courses that match the Information Science and Business Informatics requirements.

Students need to have finished their bachelor program within a maximum of n + 1 years, where n where n is the nominal length of the bachelor programme (in years).

As part of his/her application, a candidate can indicate if and explain why his/her grades, scores, or study path would not be an adequate indication of his/her actual academic potential.

Premaster's programme
A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme consists of courses from the bachelor in Information Science. The premaster's programme should be finished (i.e. all courses passed) before entry into the Business Informatics programme is allowed.

The possible premaster's courses are:

-Mobiel Programmeren	(INFOB1MOP),
-Datamodelleren	(INFOB1DM),
-Imperatief Programmeren	(INFOIMP),
-Mens, Maatschappij, en ICT	(INFOB1IMM),
-Modelleren en Systeemontwikkeling	(INFOMSO),
-Wetenschappelijke Onderzoeksmethoden	(INFOWO),
-Data Analytics	(INFOB3DA),
-Informatieuitwisseling	(INFOB1IUW),
-Product Software	(INFOB3PS),
-Databases	(INFODB),
-Interactietechnologie	(INFOB3IT),
-Ontwerpen van Interactieve Systemen	(INFOB1OIS),
-Organisaties en ICT	(INFOB1OICT),
-Persuasive Technologies	(INFOB3PET),
-Strategisch Management van Organisaties en ICT	(INFOB3SMI),
-Webtechnologie	(INFOB2WT),
-E-Business	(INFOEBU),
-Informatiesystemen	(INFOB1ISY),
-Kennisisystemen	(INFOB3KSY),
-Usability Engineering	(INFOUE)
-Computational Thinking	(INFOMCTH).

Learning outcomes
The graduate of the Master's programme in Business Informatics:

Knowledge and understanding
K1. Has theoretical and practical knowledge of advanced general subjects such as methodology of development, implementation and adoption of software products, and ICT entrepreneurship.
K2. Is able with this knowledge to contribute to scientific research in these areas using an appropriate method.
K3. Is aware of important recent developments on subjects such as methodology of development, implementation and adoption of software products, and ICT entrepreneurship.
K4. Understands the relevance of these developments for his/her scientific discipline.
K5. Has the skills to understand the specialized literature on at least one area in the field of: software product development methodology; implementation and adoption of systems; ICT entrepreneurship.
K6. Has the skills to relate this literature to his/her own research.
K7. Has insight into the integrity dilemmas that occur in the domain.
Applying knowledge and understanding
A1. Is able to formulate together with the supervisor an original research question in the field of Business Informatics.
A2. Is able to design, under the supervision of a member of the scientific staff, a research plan that addresses a research question and that conforms to the methodological and scientific standards of the discipline.
A3. Is able to carry out this research plan under the supervision of a member of the scientific staff according to the rules of good experimental practice and ethics and is able to analyze and interpret the acquired materials and/or data according to scientific standards.
A4. Is able to create a plan for the implementation of an academic artifact in society and valorize the artifact.
Making judgements
M1. Is able to participate critically and constructively in the scientific debate.
M2. Is able to indicate the relevance of his/her research to solve problems and issues in the field of Business Informatics, both from a scientific and a societal point of view.
M3. Is able to reflect critically upon his/her own research contribution and that of the student's peers from a societal point of view, including ethical perspectives such as privacy, scientific integrity, and information security.
Communication
C1. Has the skills to communicate research results, both in written and spoken English, to an audience of specialists or non-specialists.
C2. Is able to function effectively in a possibly multidisciplinary team of experts working in the field of Business Informatics.
Learning skills
L1. Has the skills to evaluate his/her own learning and development process and to adjust this process if necessary.
L2. Has a result oriented working attitude that enables him/her to work as a professional in the field of information technology.
L3. Has the qualifications to enroll in a PhD programme in the field of Information Science.
L4. Is qualified to acquire a position as a professional in the field of information technology.

Contact hours
The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: 400 hours for the whole programme excluding the research part. This number is based on an average of 8 contact hours per week during

normal education periods, times 50 weeks, as students follow 5 periods of 10 weeks. The number will be higher for students who follow more than the required number of courses.

The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	32 EC
Primary electives	22.5-45 EC
Deficiency course*	0-7.5 EC
Secondary electives	0-15 EC
Research	43 EC
Total**	**120 EC**

* Deficiency courses are courses that fill in gaps in the knowledge of students, typically from the Information Science Bachelor program.
** The total always has to add up to at least 120EC.

Mandatory courses

- Advanced Research Methods (INFOARM)
- Method Engineering (INFOME)
- Data Science and Society (INFOMDSS)
- Business Process Management (INFOMBPM)
- Introduction to MBI (INFOSPMBI): 1 EC
- Introducing Natural Sciences (GSNS-intro, 0.5 EC)
- Dilemmas of the scientist (FI-MHPSDIL; 0.5 EC)

Primary electives

- Software Production (INFOMSPR)
- Business Intelligence (INFOMBIN)
- ICT Startups (INFOMSTART)
- ICT Advisory (INFOMICTA)
- Data Mining (INFOMDM)
- Technologies for Learning (INFOMTFL)
- Adaptive Interactive Systems (INFOMAIS)
- Software Ecosystems (INFOMSSE)
- Data Analysis and Visualization (201600038)
- Pattern Recognition (INFOMPR)
- Enterprise Architecture (INFOEAR)
- Software Architecture (INFOMSWA)
- Natural Language Generation (INFOMNLG)
- Big Data (INFOMBD)
- ICT Entrepreneurship (INFOIE)
- Requirements Engineering (INFOMRE)
- Mobile Interaction (INFOMMOB)

Primary electives (Seminars, max 2 per program)

- Seminar Multimedia Discourse Interaction (INFOMMDI)
- Seminar Medical Informatics (INFOMSMI)
- Seminar Software Production (INFOMSPR)
- Seminar Foundations of Information Science (INFOMFIS)
- Seminar Process Mining (INFOMPROM)

Secondary electives

- Any MSc course from the Computer Science curriculum.
- Any MSc course from the Information Science curriculum.
- Any related MSc course offered by Utrecht University when approved in advance by the programme coordinator.
- Capita Selecta (INFOISM): 7,5 EC. A Capita Selecta is not a standard course option and needs to be agreed to by a supervisor before admission to the course.

Deficiency Courses

Possible deficiencies (at most 7.5 EC), deficiency courses are defined by the programme coordinator:

- The possible deficiency courses are:
- Mobiel Programmeren (INFOB1MOP),
- Datamodelleren (INFOB1DM),
- Imperatief Programmeren (INFOIMP),
- Mens, Maarschappij, en ICT (INFOB1IMM),
- Modelleren en Systeemontwikkeling (INFOMSO),
- Wetenschappelijke Onderzoeksmethoden (INFOWO),
- Data Analytics (INFOB3DA),
- Informatieuitwisseling (INFOB1IUW),
- Product Software (INFOB3PS),
- Databases (INFODB),
- Interactietechnologie (INFOB3IT),
- Ontwerpen van Interactieve Systemen (INFOB1OIS),
- Organisaties en ICT (INFOB1OICT),
- Persuasive Technologies (INFOB3PET),
- Strategisch Management van Organisaties en ICT (INFOB3SMI),
- Webtechnologie (INFOB2WT),
- E-Business (INFOEBU),
- Informatiesystemen (INFOB1ISY),
- Kennisisystemen (INFOB3KSY),
- Usability Engineering (INFOUE)
- Computational Thinking (INFOMCTH).

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Limitations

- Only two seminars can be followed in one MBI programme.
- Bachelor courses are not allowed in the Master's programme, unless they are deficiency courses, prescribed during the admission process.

Research part

The research part consists of the following:

- Thesis Project Part 1: 14EC
- Thesis Project Part 2: 25EC
- MBI Colloquium (INFOCQMBI4):4EC

The thesis project can be started when all primary electives, secondary electives, and deficiency courses have been completed. Exceptions need to be approved by the program coordinator.

The Research Part or Thesis Project includes participation in the bi-weekly MBI Colloquium (at the end of the Master's programme).

Research can be done on all subjects related to the list of courses or related to the interests of the staff of the department staff, with a focus on information science, after agreement with a supervisor within the department.

Cum Laude

When a student desires to obtain a cum laude, the minimum grade for the course **"Thesis Project Part 2"** is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Course Organization, Content, and Assessment

The MBI programme employs different methods for assessment, such as group work, projects, presentations and pitches, exams, and essays. For each course, at least 20% needs to be assessed on an individual basis. Furthermore, for each course at most 15% of each assessment part of a course can be judged based on language, layout, and document quality.

All primary elective courses with more than 50 students in the previous year are taught by at least two lecturers, unless the lecturer volunteers to teach the course alone. At least one of the lecturers must be in possession of the basic teaching qualification.

Labor Market Perspectives

To support students in entering the labor market effectively, the following tools are used:

- Empirical data gathered during company visits in courses such as Enterprise Architecture and Method Engineering
- Guest lectures in many of the courses
- The research of the research group and its Master students requires empirical data, which is typically gathered by collaborating with large organizations, such as technology companies and consultancy firms ("Society is our Lab")
- The courses of ICT-Advisory, ICT-Entrepreneurship, and ICT Startups also train students in professional activities and prepare them for running their own business
- Students are stimulated to use Career Services made available by the university

Students are actively discouraged from working while following the MBI programme as it is a fulltime programme.

Scientific Integrity

Scientific integrity is supported and ensured by using the following instruments:

- In the introduction to Business Informatics course the topic of scientific integrity is discussed
- Students have to hand in project work with a cover page stating that this is their original work
- Students collaborate with senior staff on research projects
- The course of Advanced Research Methods spends two lectures on research integrity and ethics in research
- Students follow the course Scientific Integrity (0.5EC)
- Staff uses plagiarism detection tools

Profiles (Educational/Complex Systems/Applied Data Sciences)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with one *profile.* The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the Master's programme, the remaining 90EC must be filled in as described below. Note that if the student fails to succesfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120EC) programme structure.

Students must request participation in a profile from the programme coordinator.

Mandatory courses	32 EC
Primary electives	7.5-15 EC
Deficiency course*	0-7.5 EC
Profile courses and projects	30 EC
Research	43 EC
Total**	**120 EC**

* Deficiency courses are courses that fill in gaps in the knowledge of students, typically from the information science bachelor program.
** The total always has to add up to at least 120EC.

Special provisions

Students who enrolled in 2017-2018 or earlier can have Knowledge Management (INFOKMT) as a mandatory course.
Students who enrolled in 2018-2019 can have Knowledge Management (INFOKMT) and/or Data Science and Society (INFOMDSS) as a mandatory course.

Students who enrolled before 2019-2020 are allowed to submit only three mandatory courses plus one additional primary elective.

Chemical Sciences

Nanomaterials Science

Admission to the degree in Chemical Sciences and the programme Nanomaterials Science

Applicants should possess:

- a sound basic knowledge and practical skills in physical, inorganic and/or organic chemistry and necessary mathematical skills; in particular skills and knowledge of at least three out of the following subjects is needed: Physical Chemistry (classical and statistical thermodynamics), Inorganic and Solid State Chemistry, Spectroscopy and structural analysis, Advanced organic chemistry and/or organometallic chemistry combined with practical skills and Quantum Chemistry or Applied Density Functional Theory.
- the ability to work independently as well as in groups on solving chemical problems, present the results of solving problems and to read (English) chemistry literature at the level of graduate textbooks;
- the ability of writing a research report in English, such as a bachelor thesis, is a prerequisite. The report and the work must be assessed with good grades. In case of doubt a personal interview may be part of the admission procedure.

Degrees in all probability meeting these requirements are:

- A BSc degree with a major in chemistry or chemical engineering
- A major in science with a strong component in chemistry.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed) before entry into the **Nanomaterials Science** programme is allowed.
Typically, students from a dutch applied science university (so called HBO institutions) follow this programme. Theoretical skills that will be trained in this programme are mathematics, physical and inorganic chemistry, quantum chemistry and spectroscopic analysis techniques. It is strongly advised to follow this programme as a minor within the third or fourth year of the HBO-degree programme. These courses could be combined i.e. with the HBO "afstudeerstage" in one of the Debye research groups.
The premaster's student will follow courses together with bachelor students of the chemistry programme. Bachelor courses at the level of a first and second year bachelor's programme are taught in Dutch at Utrecht. Students could also opt to remedy their deficiencies at another university of which the content and level of the courses will be examined by the board of examiners of the Graduate School of Natural Sciences. A premasters programme can also be followed by students with an academic background with deficiencies of more than 15 EC. A specific programme will be tailored to their needs.

Learning outcomes

The graduate of the master's programme:

Knowledge and understanding
K1. Has knowledge of and insight into nanomaterials with an emphasis on colloids, catalysts, and condensed matter; K2. Is able with this knowledge to contribute to scientific research in these areas using appropriate methods and instrumentation;

K3. Is aware of recent developments in the research of colloids, catalysis and/or condensed matter and understands the relevance of these developments for the chosen field of specialization and society. K4. Has the skills to understand the professional literature in the area of colloids, catalysis, and condensed matter and to relate this to his/her own research. K5. Has insight in the potential dilemmas related to scientific integrity in his/her research field.
Applying knowledge and understanding
A1. Is able to formulate an original research question for the synthesis of nanomaterials, or for obtaining new knowledge of the chemical or physical properties of such materials;
A2. Is able to design a research plan that addresses this research question and that conforms to the methodological and scientific standards of the discipline;
A3. Is able to analyze and interpret the acquired materials and/or data according to the rules of good experimental practice and ethics.
Making judgments
M1. Is able to discuss and relate the obtained results with the actual state of the chosen research specialization and literature;
M2. Is able to indicate the relevance of his/her research topic for the solutions and problems in the field of nanomaterials science, where possible from a societal point of view.
M3. Is able to reflect critically upon his/her own contribution as a researcher in the field of nanomaterials research from a societal perspective.
Communication
C1. Has the skills to discuss, both in spoken and written English, the obtained results of own research, including the underlying knowledge and background for a group of specialists and non-specialists in an international context; C2. Is able to participate critically and constructively in the scientific debate in the research group; C3. Is able to function effectively in a possibly multidisciplinary team of experts working in the area of chemistry and/or physics of nanomaterials.
Learning skills
L1. Has the skills to evaluate his/her own learning and development process and to adjust this process if necessary; L2. Displays a professional and academic work attitude that enables him/her to work independently in a highly competitive labor market; L3. Has the qualifications to enroll in a PhD programme or to acquire a (research) position in a (semi) public or commercial organization; L4. Has a realistic idea of the career opportunities after graduating, and of the skills that he/she needs to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is **320** hours, or **16** hours per week, for the whole programme excluding the research part (52.5 EC) and the internship (30 EC). In the case that a student opts for 60 EC course work, the scheduled hours amount to **640** hours or 16h/w (excluding the research project of 52.5 EC).

Contents

Mandatory courses	15 EC
Primary electives	22.5 EC
Secondary electives	30 EC
Research part	52.5 EC
Total	**120 EC**

Mandatory courses

Academic Context Course (SK-MACCO): 6.5 EC
Introducing natural sciences (GSNS-INTRO):0.5 EC
Dilemmas of the scientist (FI-MHPSDIL): 0.5 EC
Advanced Spectroscopy (SK-MSPEC): 7.5 EC

Primary electives

There are four chemistry research groups participating in the Debye Institute for Nanomaterials Science. Each group requires one basic course to be taken by their students.

Research group	**Course (7.5 EC)**
Condensed Matter and Interfaces	-
Inorganic Chemistry and Catalysis	Adsorption, Kinetics and Catalysis (SK-MAKC)
Organic Chemistry and Catalysis	Organometallic Chemistry and Homogeneous Catalysis (SK-MOCHC)
Physical and Colloid Chemistry	Colloid Science (SK-MCS)

Before choosing the remaining courses, students should first check the course requirements of the research groups which are stated in the course guide of this programme.

Advanced Microscopy (NS-EX423M)
Colloid Science (SK-MCS)
Experimental Quantum Physics (NS-EX401M)
Organometallic Chemistry and Homogeneous Catalysis (SK-MOCHC)
Advanced Organic Chemistry (SK-MOSS)
Photon Physics (NS-EX418M)
Modelling and Simulation (NS-TP432M)
Soft Condensed Matter Theory (NS-TP453M)
Photovoltaic Solar Energy Physics (GEO4-2513)
Solids & Surfaces (SK-MSOLS)
Synthesis of Catalytic Nanomaterials (SK-MSYNA)
Toy Models (SK-MTOYM)

Secondary electives

For the remaining 30 EC, several options are possible.

Option one: any MSc course offered by the Graduate School of Natural Sciences including the remaining primary elective courses, or courses offered by the Graduate School of Life Sciences. Other courses can be taken with permission from the Board of Examiners who will take a decision based on the programme director’s advice.

The second option is to take a 15 up to 30 EC internship outside Utrecht University. Internships can only start as soon as the mandatory, primary elective courses and the research project of 52.5 EC have been finished.

The third option provided is to follow **one** of the following 3rd year bachelor's courses:

- *Advanced Physical Chemistry* (SK-BFYC3) or
- *The Origin of the Natural Sciences* (BETA-B2NW) or
- *Kwantummaterie (NS-371B).*

Note that prescribed deficiency courses (at most 15 EC) are deducted from the total credits of the secondary elective credits. When two deficiency courses are prescribed, option three is no longer valid.

Deficiency courses

Students that do not fully comply to the above enumerated skills and with a deficiency not exceeding more than 15 EC can be conditionally admitted by taking one or two courses out of the following list as secondary elective during the course of their study:

- Fysische chemie 2 (7.5 EC; SK-BFYCH)
- Anorganische en Vaste Stof Chemie (Inorganic Chemistry and Solid Sate Chemistry) (7.5 EC; SK-BANVA13)
- Advanced Organic Chemistry (7.5 EC, SK-BORC3)
- Toegepaste Density Funtional Theory (Applied Density Functional Theory) (7.5 EC; SK-BTDFT)
- Advanced Super Structures Scattering and Microscopy (7.5 EC; SK-BASSM)

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

The research part is split into the following courses:

Part 1, *Introduction to the research project* (15 EC, SK-MRES1): Introduction to research and initiating the research project

Part 2, *Research and thesis project* (37.5 EC, SK-MRES2): Finalizing the Research project and writing a thesis on the research topic

Successfully completing Part 1 *Introduction to the research project* is a mandatory prerequisite to continue with Part 2. Both parts are supervised by the same staff members.

The entire research project of 52.5 EC will be performed at one of the research groups of the Debye Institute including those belonging to the physics department (i.e. Soft Condensed Matter and Biophysics group) or, with the permission of the programme director, in a closely related research lab, provided that a staff member of the Debye Institute is willing to act as the primary responsible supervisor and first examiner. The student may start with his/her research project before the completion of the mandatory courses and the primary elective courses with the permission of the programme director. Research group specific requirements including the choice of certain primary elective courses, or other activities, are noted on the Research Project Application Form before the start of the project.

Cum laude

The minimum grade for the course SK-MRES2 a student needs to obtain a *cum laude* degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Labour market perspectives and scientific integrity

The **Introducing Natural Science** course initiates master's students in both topics. The master's programme elaborates further on these subjects in:

1. The mandatory **Academic Context Course**;
2. The **Internship** of 30 EC;
3. The course **Teaching in the Academia** of 1 EC (on top of the regular 120 EC programme);

Scientific Integrity will be tested in two courses: in the **Dilemmas of the scientist** (FI-MHPSDIL; 0.5 EC) and in a specific module (1.5 EC) as part of the **Academic Context Course**. Scientific Integrity will further be practiced during the research project.

Profile (Educational/Complex Systems/Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with a **educational** , **complex systems**, or **applied data science** profile. The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to succesfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Mandatory courses	15 EC
Primary electives	22.5 EC
Secondary electives	0 EC
Research part	52.5 EC
Total	**90 EC**

Courses that are taken in the complex systems profile and who also appear in the list of the primary elective courses within this programme, can only be taken as either a primary elective course or either a complex systems profile course.

Special provisions for students enrolled before September 2018

The mandatory course for the cohorts enrolled into this programme before September 2018 remains the *Adsorption Kinetics and Catalysis* course (SK-MAKC). This provision ends on August 31, 2020.

Mathematical Sciences

Admission to the degree in Mathematical Sciences

Applicants should possess:

- A solid basic knowledge of mathematics at the bachelor level, including single-variable and multi-variable real analysis, linear algebra (theory and applications), basic knowledge of probability and statistics and advanced knowledge of at least four of the following eight subjects: differential equations, complex analysis, probability theory and statistics, numerical mathematics, geometry and topology, algebra and number theory, discrete mathematics, optimization and decision theory;
- The ability to analyze mathematical problems;
- The ability to communicate findings verbally and in writing, in an appropriate mathematical manner.

In principle, the bachelor qualifications that meet these criteria are:

- A BSc with a major in Mathematics
- A BSc with a major in Physics, Computer Science or in Science with a strong component in Mathematics, which is comparable with the major part of the Utrecht University Bachelor in mathematics.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed) before entry into the Mathematical Sciences programme is allowed.

Learning outcomes

The graduate of the master's programme in Mathematical Sciences has:

Knowledge and understanding
K1. a theoretical and practical understanding of advanced general concepts, principles and techniques of fundamental and/or applied mathematics; K2. an overview of the area of scientific research and development in question; K3. in-depth knowledge of at least one area in the field of fundamental or applied mathematics at a sufficient level that international research literature can be understood; K4. an overview of the role of dilemmas of integrity in scientific research.
Applying knowledge and understanding
A1. the ability to independently identify, formulate, analyse and suggest possible solutions to problems in the field of mathematical sciences; A2. the ability to assimilate complex mathematical ideas and arguments; A3. the ability to conduct research in the field of mathematical sciences and report on it in a manner that meets the standards of the discipline (including correct referencing, appropriate layout and style)
Making judgements
M1. a theoretical and practical knowledge of advanced general concepts, principles and techniques of fundamental and applied mathematics, sufficient to evaluate one's own research and the research of others in a broad perspective.
Communication skills
C1. the ability to cooperate in a, possibly interdisciplinary, team of experts; C2. the ability to communicate results in English, both orally and in writing, including the underlying ideas, grounds and considerations, to an audience composed of specialists or non-specialists.

Learning skills
L1. the ability to reflect on one's own research and on research of others; L2. the ability to enroll in a PhD programme in mathematics, or to embark on a professional career as a mathematician, including having an overview of his/her career options; L3. has a realistic idea of the career opportunities as a mathematician after graduating, and of the skills that he/she needs to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is 480 hours for the whole programme excluding the research part. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	15 EC
Primary electives	45 EC
Secondary electives	15 EC
Research part	45 EC
Total	**120** EC

Mandatory courses

- Orientation on Mathematical Research (WISM102, 7.5 EC)
- Mathematical Colloquium (WISM103, 2.5 EC)
- Mathematics for Industry (WISM104, 4 EC)
- Master introduction (INTRO-GSNS, 0.5 EC)
- Dilemmas of the scientist (FI-MHPSDIL, 0.5 EC)

Primary Electives

Students make a tailor made course plan in consultation with their tutor so as to create a coherent course load in one of the six specializations. The programme director has to give approval to the selected courses. The six specializations are:

- Algebraic Geometry and Number Theory
- Differential Geometry, Topology, and Lie Theory
- Logic
- Differential Equations and Dynamical Systems
- Probability and Statistics
- Applied Mathematics, Complex Systems and Scientific Computing

Students must follow an advanced seminar in Mathematics (of at least 7.5 EC) in which they themselves have to give oral presentations. If approved by the programme director, the student can follow a seminar in Theoretical Physics. This seminar can also be followed while the student is working on the research project.

All other primary elective courses are chosen from the course list given below or, if approved by the executive panel of Mathematical Sciences of the board of examiners from other mathematics courses given at a university in the Netherlands.

Secondary Electives

The secondary elective courses can be any course from the course list below or other courses on the master level or an internship of 15 EC, if approved by the programme director.

Deficiency courses

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Special characteristic of the specialization Applied Mathematics, Complex Systems and Scientific Computing (AM)

A special characteristic of the specialization Applied Mathematics, Complex Systems and Scientific Computing (AM) is the freedom to choose up to 30 EC of courses in other disciplines, provided mathematics is applicable there. A list of courses outside of mathematics that fit the 30 EC ofcourses in other disciplines is published on the students.uu.nl webpage of Mathematical Sciences.

A minimum of 30 EC of mathematics courses must be taken from the courses that are labeled as an AM-course in the course list below.

Research part

The research part is split into the following parts:

- Research project: Proposal (15 EC, WISM105)
- Research project: Thesis (30 EC, WISM109)

For students that started the master before September 2016 the research part is split into:

- Research project: Proposal (15 EC, WISM105)
- Research project: Thesis (32 EC, WISM106).

Succesfully completing the part Research project:Proposal is a mandatory prerequisite to continue with the Research project: Thesis.

The research part is under the main guidance of a researcher of the Mathematical Institute. This work can also be done as an internship. The student can start with the research project when 45 EC of the mandatory courses or primary electives is completed, or if approved by the programme director.

Students can participate in the PhD Research training (WISM111, 7.5 EC; a course of the Honours programme Utrecht Geometry Centre). The credit points do not contribute to the 120 EC of the masters programme.

Cum laude

The minimum grade for the *Research project: Thesis* a student needs to obtain a *cum laude* degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Course list

The course list is made up of local courses, courses that are part of the national Mastermath Programme, selected courses that are part of the Master Industrial and

Applied Mathematics (IAM) of the Eindhoven University of Technology and courses that are part of Stochastics and Financial Mathematics (SFM) Programme, which is jointly offered by the University of Amsterdam (UvA), the Free University (VU) and the Utrecht University (UU). The courses that are part of the national Mastermath programme, as listed on https://elo.mastermath.nl, form the core part of the master's programme Mathematical Sciences. Examination takes place according to general rules of Mathermath, to be found at https://elo.mastermath.nl.

Mastermath courses 2019-2020

Fall 2019

Systems and Control	(WISL201; 6 EC)
Continuous Optimization	(WISL103; 6 EC, AM)
Discrete Optimization	(WISL101; 6 EC, AM)
Random Walks	(WISL610; 8 EC)
Probabilistic and Extremal Combinatorics	(WISL561; 8 EC)
Category Theory and Topos Theory	(WISL322; 8 EC)
Set Theory	(WISL316; 8 EC)
Forensic Probability and Statistics	(WISL716; 8 EC)
Machine Learning Theory	(WISL712; 8 EC)
Dynamical Systems	(WISL404; 8 EC)
Algebraic Geometry 1	(WISL509; 8 EC)
Mathematical Biology	(WISL411; 8 EC)
Partial Differential Equations	(WISL402; 8 EC)
Commutative Algebra	(WISL526; 8 EC)
Differential Geometry	(WISL503; 8 EC)
Algebraic Topology 1	(WISL508; 8 EC)
Asymptotic Statistics	(WISL702; 8 EC)
Measure Theoretic Probability	(WISL701; 8 EC)
Parallel Algorithms	(WISL603; 8 EC, AM)
Numerical Linear Algebra	(WISL601; 8 EC, AM)
Functional Analysis	(WISL401; 8 EC)
Poisson Geometry	(WISL564; 8 EC)
Lie Groups	(WISL519; 8 EC)
Algebraic Number Theory	(WISL305; 8 EC)
Advanced Algebraic Geometry	(WISL525; 8 EC)
Diophantine Approximation	(WISL302; 8 EC)
Cryptology	(WISL309; 5 EC)

Spring 2020

Inverse Problems in Imaging	(WISL430; 6 EC, AM)
Nonparametric Statistics	(WISL717; 6 EC)
Applied Finite Elements	(WISL204; 6 EC)
Scheduling	(WISL107; 6 EC)
Advanced Linear Programming	(WISL105; 6 EC, AM)
Queueing Theory	(WISL109; 6 EC)
Quantum Computing	(WISL117; 8 EC)
Quantum Information Theory	(WISL119; 8 EC)
Additive Combinatorics	(WISL330; 8 EC)
Percolation: from Introduction to Frontiers of Current Research	(WISL715; 8 EC)
Semidefinite Optimization	(WISL113; 8 EC)
Complex Networks	(WISL115; 8 EC)
Modular Forms	(WISL308; 8 EC)
Selected Areas in Cryptology	(WISL534; 8 EC)
Elliptic Curves	(WISL303; 8EC)
Operator Algebras	(WISL517; 8 EC)
Statistics for Stochastic Processes	(WISL116; 8 EC)

Stochastic Processes (WISL703; 8 EC)
Calculus of Variations (WISL607; 8 EC)
Introduction to Numerical Bifurcation Analysis of ODEs and Maps (WISL606; 8 EC, AM)
Topological Data Analysis (WISL608; 8 EC)
Topos Theory (WISL328; 8 EC)
Algebraic Geometry 2 (WISL539; 8 EC)
Symplectic Geometry (WISL516; 8 EC)
Lie Algebras (WISL609; 8 EC)
Algebraic Topology 2 (WISL541; 8 EC)
Geschiedenis (WISLEER903, 6 EC) (The course 'Geschiedenis' is in Dutch and organised by mastermath for teachers, Mathematical Sciences students can follow the course with an extra assignment)

0T**Local courses 2019-2020**

Fall 2019:
Introduction to Complex Systems (WISM484; 7.5 EC, AM)
Crash Course Deep Learning with Applications in Biology (WISM480; 3 EC, AM)
Orientation on Mathematical Research (WISM102; 7.5 EC, not open for students that have followed WISM556 in 2015-2016)

Spring 2020:
Seminar Number Theory (WISM559; 7.5 EC)
Seminar Algebraic Topology (WISM565; 7.5 EC)
Seminar on Logic (WISM550; 7.5 EC)
Seminar Machine Learning (WISM485; 7.5 EC, AM)
Seminar Applications of Mathematics in Radiation Research (WISM409; 7.5 EC, AM)
Laboratory Class Scientific Computing (WISM454; 7.5 EC, AM)
Seminar Differential Geometry (WISM501; 7.5 EC)
Applying Mathematics in Finance (WISM410; 7.5 EC, AM)
Seminar Brownian Motion and Financial Mathematics (WISM467; 7.5 EC)
Mathematical Colloquium (WISM103; 2.5 EC)
Mathematics for Industry (WISM104; 4 EC)

Stochastics and Financial Mathematics (SFM) courses 2019-2020
Computational Finance (5284COFI6Y; 6 EC)
Interest Rate Models (5374INRM6Y; 6 EC)
Portfolio Theory (5374POTS6Y; 6 EC)
Stochastic Processes for Finance (X_400352; 6 EC)
Simulation Methods in Statistics (5374SIMS6Y; 6 EC)
Statistical Models (53348STM6Y; 6 EC)
Stochastic Optimization (53748SOP6Y; 6 EC)
Stochastic Simulation (5334STSI6Y; 6 EC)
Statistics for Networks (53748STF6Y; 6 EC)

0T**Industrial and Applied Mathematics (IAM) courses 2019-2020**
Q1 :
Cryptology (2MMC10; 5 EC)
Q2 :
Applied Cryptography (2DMI10; 5 EC)
Multilinear Algebra and Applications (2MMD20; 5 EC)
Introduction to Molecular Modeling and Simulation (2MMN40; 5 EC)
Q3 :
Stochastic Networks (2MMS40; 5 EC
Cryptographic Protocols (2DMI00; 5 EC)
Graphs and Algorithms (2MMD30; 5 EC)
Q4 :

Algebraic Combinatorics (2MMD50; 5 EC)
Random Graphs (2MMS60; 5 EC)

Labour market perspectives and Scientific Integrity

- Scientific Integrity is included in Research project, the Introduction programme of the Graduate School of Natural Sciences and in Dilemmas of the scientist.
- Labour market perspectives is the focus of Mathematics for Industry (WISM104) and of the Career Orientation event of Mathematical Sciences.

Profiles (Educational/Complex Systems/Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with a Complex Systems, Educational or Applied Data Science *profile*. The contents and further description of these profiles, including entry requirements to specific courses, is described in the respective sections of this annex.. In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to successfully complete the profile, the curriculum conditions for the student revert to the regular (120 EC) programme structure.

Mandatory courses	15 EC
Primary electives	45 EC
Secondary electives	0 EC
Research part	30 EC
Total	**90 EC**

For students that have started before September 2016:

Mandatory courses	0 EC
Primary electives	52.5 EC
Secondary electives	7.5 EC
Research part	30 EC
Total	**90 EC**

The research part is split into the following parts:
- Research project: Proposal (10 EC, WISM105)
- Research project: Thesis (20 EC, WISM106)

Successfully completing the course Research project: Proposal is a mandatory prerequisite to continue with the Research project: Thesis.

Special provisions for students who enrolled in the programme Mathematical Sciences in the year 2016-2017 and earlier

For students who enrolled into the programme prior to 1 September 2016 the courses1T 1T*Introducing Natural Sciences* (INTRO-GSNS)1T, *Dilemmas of the scientist* (FI-MHPSDIL), *Orientation on Mathematical Research* (WISM102), *Mathematical Colloquium* (WISM103) and *Mathematics for Industry* (WISM104) are not mandatory. The research project for this group of students is 47 EC in total (15 EC proposal, 32 EC thesis).

For students who enrolled in the academic year 2016-2017 in the programme the courses *Orientation on Mathematical Research* (WISM102), *Mathematical Colloquium* (WISM100) and *Mathematics for Industry* (WISM101) are mandatory. For this group of students the courses *Introducing Natural Sciences* (INTRO-GSNS), *Dilemmas of the scientist* (FI-MHPSDIL) are part of the research part and the Research part: Proposal is 14 EC, or combined with a profile, the proposal is 9 EC.

Honours programme Utrecht Geometry Centre

Description

This programme, which is an extension of the master's programme Mathematical Sciences, prepares students for a PhD-position in Geometry and related fields.

Admission to the honours programme

The applicant should satisfy the admission criteria for the master's programme Mathematical Sciences. Additionally to this, the applicant will be reviewed by the selection committee of the Utrecht Geometry Centre. The selection committee will base its decision on previous study results, motivation and the CV of the applicant.

Learning outcomes

In addition to the learning outcomes of the masters programme Mathematical Sciences the student is able to write a research proposal for a PhD-position in geometry and related fields.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: 530 hours for the whole programme excluding the research part. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	15 EC
Primary electives	45 EC
Secondary electives	15 EC
PhD Research training (WISM 111)	7.5 EC
Research part	45 EC
Total EC	**127.5 EC**

For students that have started before September 2016

Mandatory courses	7.5 EC
Primary electives	50.5 EC
Secondary electives	15 EC
PhD Research training	7.5 EC
Research part	47 EC
Total EC	**127.5 EC**

Mandatory Courses

See the appendix of Mathematical Sciences.

Primary Electives

Students must follow two advanced seminars in Mathematics in which they themselves have to give oral presentations. All other primary elective courses are chosen from the course list given in the appendix of Mathematical Sciences.

Secondary Electives

See the appendix of Mathematical Sciences.

Research part

See the appendix of Mathematical Sciences. In addition to the research part of the masters programme Mathematical Sciences the participants of the Honours programme UGC will follow a training in writing a graduate research proposal and write a full PhD proposal under the supervision of a staff member of the Mathematical Institute (PhD Research Training, WISM111, 7.5 EC). The PhD Research Training will be graded on a pass/fail basis. The student participates for at least a semester in the weekly research seminar of the UGC.

Mid-term reviews of honours students

The progress of honours students will be reviewed by the selection committee after year 1 of study. Honours students should have obtained a minimum of 45 EC after 1. Students who do not meet theses criteria may be denied from the honours programme by the selection committee.

History and Philosophy of Science

Admission to the degree in History and Philosophy of Science

Applicants should posses

- A university Bachelor's degree;
- solid basic knowledge in one academic discipline with demonstrable interest in history and/or philosophy of the sciences and/or the humanities, for instance demonstrated by successfully completed courses in HPS of 10-15 EC and a motivation letter;
- the ability to work independently in writing a thesis as well as in groups during the courses;
- the skills to write essays and a thesis in English on an academic level (as demonstrated by a writing sample).

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e. all courses passed) before entry into the History and Philosophy of Science programme is allowed.

Learning outcomes

The graduate of the master's programme in History and Philosophy of Sciences:

Knowledge and understanding
K1. Has a basic knowledge and understanding of the main issues in history and philosophy of the sciences and the humanities. K2. Has detailed knowledge of one of the areas of history and/or philosophy of the sciences and the humanities. K3. Is able to contribute to scientific research in one of these areas using an appropriate methodology. K4. Has demonstrated to be able to compare and assess the applicability and relevance of various ways of knowing;
K5. Is aware of important recent developments in one of these areas and understands the relevance of these developments for his/her scientific discipline. K6. Understands the possible social relevance of these developments.
K7. Has the skills to understand the specialized literature on at least one of these areas and has the skills to use and interpret this literature adequately. K8. Understands the potential dilemmas related to scientific integrity in his/her research field.
Applying knowledge and understanding
A1. Is able to formulate an original research question in one of these areas relevant for scientific development, education, or public understanding.
A2. Is able to formulate a fitting research plan in accordance with scientific and methodological standards. A3. Is able to apply his/her understanding to current issues in science and academia, and to relate this to social, cultural and political developments.

A4. Is aware of the possibilities and pitfalls in applying his/her knowledge to social questions, and can relate this to his/her own work.
A5. Is able to carry out a research plan according to the rules of good practice and ethics.
Making judgements
M1. Is able to participate critically and constructively in scientific debates.
M2. Is able to assess the scientific and possible social relevance of his/her research.
M3. Is able to reflect critically upon his/her own historiographical or philosophical position within the chosen area, also from a social and cultural perspective.
Communication
C1. Has the skills to conceive papers for international peer-reviewed journals. Is able to present his/her work orally on an academic level.
C2. Is able to cooperate effectively with fellow researchers. C3. Is able to present complex issues in a clear way, both written and orally.
Learning skills
L1. Has the skills to work self-reliantly, to evaluate his/her own learning and development process and to adjust this process if necessary.
L2. Is able to write, with the help of a senior researcher, a grant proposal. L3. Is qualified to compete for a position for which an academic training in one of the areas of history and/or philosophy of the sciences and the humanities is required or useful.
L4. Has the qualifications to enroll in a PhD programme in the field of history and philosophy of science and is qualified to acquire a position as a professional in the field of history and philosophy of science, or e.g. science publishing, science communication, public policy, science management, or science museums. L5. Has a realistic idea of the career opportunities after graduating, and of the skills that he/she needs to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: 412 hours, or approximately 9 hours per week, for the whole programme excluding the research part. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	30 EC
Primary electives	22.5 EC
Secondary electives	15 EC
Research part	52.5 EC
Total	**120 EC**

Mandatory courses and primary electives reflect the body of knowledge in which a student must be sufficiently prepared to successfully engage in research. A secondary elective can be used for further specialization.

Mandatory courses

- History of the Natural Sciences (FI-MHPSHNS , 7.5EC)
- Philosophy of Science (FI-MHPSPS , 7.5EC)
- History of the Humanities (GKRMV18001, 7.5EC)
- Research Seminar (FI-MHPSSR , 6.5EC), consisting of:
  - reading group (history, philosophy or philosophy of physics)
  - colloquium attendance (a minimum of 20)
- Introducing Natural Sciences (GSNS-intro , 0.5EC)
- Dilemmas of the scientist (FI-MHPSDIL, 0.5EC)

Primary electives

At least 22.5 EC, to be chosen out of the following list:

Offered yearly:	***EC***	***code***
20th century German Philosophy	5	FRRMV16015
Art, Material Culture, and Technology	5 or 10	GKRMV16051
Geschiedenis en Filosofie van de Biologie	7.5	B-B3GESB05
History and Philosophy of Objectivity	5	FRRMV16014
History of Medicine	7.5	BMB507812
History of the Early Modern Book	5	GKRMV17007
History of the Humanities	7.5	GKRMV18001
History of the Natural Sciences	7.5	FI-MHPSHNS
Investigative Journalism	7.5	FI-MHPSIJ
Law as an Academic Discipline	7.5	RGMURWOM08
Logic of Computation	7.5	WBMV13005
Making Modern Science	7.5	SK-B3MAMO
Pharmaceutical Humanities	7.5	FA-MA214
Philosophy of Artificial Intelligence	7.5	WBMV05003
Philosophy of Science	7.5	FI-MHPSPS
Philosophy of the Social Sciences	7.5	201600160
Professional Skills and Identity	5	FI-MSECPSI
Science and the Dilemmas of Modernity	7.5	FI-MHPSDM
Science and the Public	7.5	FI-MHPSSP
Science in Society	5	FI-MSECSIS
Space and time: an introduction	5	FI-MHPSST
Special Topic #1	2.5	FI-MHPSTOP
Special Topic #2	2.5	FI-MHPSTOP
The Quantum World	5	FI-MHPSQW
Tutorial HPS	7.5	FI-MHPSTUT
Tutorial Philosophy	5	FRRMV17009, FRRMV17010
Offered every other year:		
* History of the Modern Life Sciences	7.5	FI-MHPSHLS
Foundations of Quantum Mechanics	5	FI-MHPSQM
* Philosophy of Relativity and Spacetime	5	FI-MHPSRS
* Research Seminar History of Mathematics	7.5	WISM481

*	Topics in Early Modern Philosophy	5	FRRMV16010
*	Topics in Epistemology and Philosophy of Science	5	FRRMV16011
	Topics in German Idealism	5	FRRMV17006
*	Topics in Metaphysics	5	FRRMV16008
*	Topics in Moral Psychology	5	FRRMV16013
	Topics in Philosophy of Language and Logic	5	FRRMV17003
	Topics in Philosophy of Mind	5	FRRMV17007

* these courses are not offered in 2019-20; offering in 2020-21 may be subject to changes.

The curriculum can contain no more than 15 EC of tutorials (FI-MHPSTUT, FI-MHPSTU2, OFRM16006, OFRM16007), and no more than 15 EC of Bachelor-level courses.

Secondary electives

Any master level course offered by Utrecht University, up to 15 EC.

Deficiency courses

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

The research part consists of:
- FI-MHPSRPP Research Project: proposal (15 EC)

And:
- FI-MHPSRP Research Project: thesis (22.5 or 37.5 EC, or 45 in case of a double degree programme)

And, in case of a 22.5 EC thesis:
- FI-MHPSINT Internship (15 ects)

or:
- extra courses (15 EC), preferably abroad, subject to approval of the Board of Examiners.

Successfully completing FI-MHPSRPP is a mandatory prerequisite to continue with FI-MHPSRP.

The subjects of the thesis and the internship have to be approved by the programme director. One of the supervisors of the thesis has to be a member of the Descartes Centre for the History and Philosophy of the Sciences and Humanities. Students can only start with the research project after finishing the mandatory courses, with the exception of the research seminar FI-MHPSSR.

Cum laude

The minimum grade for the thesis (FI-MHPSRP) a student needs to obtain a *cum laude* degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Labour market perspectives and scientific integrity

Scientific integrity: reflection on the values of science, both in theory and in practice, is a key part of this programme. Students are encouraged to discuss values and practices in historical and philosophical contexts, and to relate this to their own research. These issues are included in the assessment criteria for the research project. They are also addressed in the required course Dilemmas of the scientist.

Labour market perspectives are discussed in various settings:

- The research project and the research seminar are part of the preparation for an academic research career.
- Students are encouraged to do an internship outside academia.
- The course FI-MHPSPSI focuses on labour market orientation.
- Personal counseling by the tutor.
- UU Career Services.

Profiles

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with an ***educational profile****,* aimed at obtaining a teacher degree (subject to teaching degree requirements).

The profiles ***Complex Systems*** and ***Applied Data Science*** can also be followed as part of the HPS programme, but this requires permission of the Board of Examiners.

The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix.

In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to successfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Mandatory courses	30 EC
Primary electives	22.5 EC
Secondary electives	0 EC
Research part: thesis proposal and small thesis	37.5 EC
Total	**90 EC**

Physics

Climate Physics

Admission to the degree Physics

Applicants should possess:

- Solid knowledge of basic physics and mathematics at undergraduate level that is necessary to complete the degree programme (for details see admission criteria of the master's programmes);
- The ability to work independently as well as in groups on solving physical problems and presenting the results and to read (English) physics literature at the level of graduate textbooks;
- The ability to write a research report in English, such as a bachelor thesis.

In addition, applications should meet the requirements of either:
- the Climate Physics programme or
- the Theoretical Physics programme, or
- the Experimental Physics programme.

Degrees that most probably meet these requirements are
- A BSc degree in Physics,
- A BSc degree in Physics and Astronomy,
- A BSc degree with a major in Physics,
- A major in Science with a strong component in physics.

Admission to the programme Climate Physics

Students qualify for admission to the programme Climate Physics if they possess the following skills and knowledge (in addition to the criteria for the degree programme Physics):

1. Solid basic knowledge in classical physics, especially fluid dynamics, as well as in the mathematics required for the study of such topics at an advanced level.
2. The ability to work independently as well as in groups on solving physical problems, present the results of solving problems and to read (English) physics literature at the level of graduate textbooks.
3. Intermediate problem-solving skills in the main fields of physics and/or their applications.

Applicants with a BSc and background in related fields like chemistry, earth sciences, geophysics, mathematics can be admitted if their background level in physics and mathematics is sufficient.

In case the student has not taken one of the above mentioned subjects, it can be taken as part of the MSc programme to remedy this deficiency (at most 15 EC). The programme director will decide which topics need to be followed.

Premaster’s programme

A premaster’s programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student’s prior knowledge. The premaster’s programme must be completed (i.e. all courses passed) before entry into the Climate Physics programme is allowed.

Learning outcomes

The graduate of the master's programme in Climate Physics:

Knowledge and understanding
K1. has in-depth knowledge of and insight into the physics of the climate system, i.e. the dynamics of atmosphere, ocean and climate; K2. is aware of recent developments in the field of global climate models and of process-oriented models, and is able to state the relevance of these developments for the research field and society; K3. can read and understand the professional literature in the field of at least one of the five research themes of the programme, and is able to relate this to his/her own research. K4. understands the potential dilemmas related to scientific integrity in his/her research field.
Applying knowledge and understanding
A1. is able to define, under the supervision of a staff member, a scientific problem in Climate Physics; to formulate a research question, and to design a basic strategy to solve this problem; A2. is able to carry out this research plan under supervision of a scientific staff member according to the rules of good experimental practice and ethics, and report on it in a manner that meets the customary standards of the discipline; A3. is able to analyse and interpret, under the supervision of a staff member, the acquired results, materials and/or data according to scientific standards.
Making Judgements
M1. is able to participate critically and constructively in the scientific debate in the research group; M2. is able to indicate the relevance of his/her research for the advancement of physics; M3. is able to critically reflect on his/her own results, as well as on published scientific literature in the field of climate dynamics.
Communication
C1. is able to transfer knowledge and results of scientific research in the field of climate physics to both a specialised and a more broadly interested audience, both in oral and written form; C2. is able to professionally act in a (possibly multi-disciplinary and international) research team.
Learning skills
L1. has the skills to reflect upon his/her learning process and, if necessary, adjust this process; has acquired sufficient scientific knowledge and skills to conduct independent scientific research, or to conduct other discipline-related work; L2. is able to apply knowledge and insight in a way that demonstrates a professional approach to his or her work or profession; L3. has the qualifications to enroll in a PhD programme in Climate Physics; is qualified to acquire a position as a professional in a (semi) public or commercial organisation. L4. Has a realistic idea of the career opportunities after graduating, and of the skills that he/she needs to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: **900** hours for the whole programme excluding the research part. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	38.5 EC
Primary Electives	22.5-37.5 EC
Secondary Electives	0-15 EC
Research part	44 EC
Total	**120 EC**

Mandatory courses

- Dynamical Oceanography (NS-MO401M, 7.5 EC)
- Dynamical Meteorology (NS-MO402M, 7.5 EC)
- Atmospheric Composition and Chemical Processes (NS-MO405M, 7.5 EC)
- Simulation of Ocean, Atmosphere and Climate[a] (NS-MO501M, 7.5 EC)
- Making, Analysing and Interpreting Observations[a] (NS-MO502M, 7.5 EC)
- Graduate school's master introduction (GSNS-INTRO, 0.5 EC)
- Dilemmas of the scientist (FI-MHPSDIL, 0.5 EC)

Primary Electives

At least 22,5 EC has to be chosen from the following list of courses

- Ocean Waves (NS-MO428M, 7.5 EC)
- Ice and Climate (NS-MO427M, 7.5 EC)
- Current Themes in Climate Change (NS-MO434M, 7.5 EC)
- Boundary layers, Transport and Mixing (NS-MO408M, 7.5 EC)
- Marine Masters Summer Course (NS-MO446M, 3.75 EC)
- Turbulence in Fluids[b] (NS-376B, 7.5 EC)
- Wave Attractors (NS-MO477M, 7.5 EC)
- One of the following courses:
  - Morphodynamics of Tidal Systems (GEO4-4435, 7.5 EC)
  - Morphodynamics of Wave-Dominated Coasts (GEO4-4434, 7.5 EC)

[a] Students participating in the (coordinated) exchange with the master programmes "Integrated Climate System Studies" (ICSS), "Ocean and Climate Physics" (OCP) or "Meteorologie" at the Universität Hamburg are allowed to replace, after approval of the programme director or programme coordinator, either NS-MO501M or NS-MO502M by a course, followed during this exchange within the programmes listed above, that includes a clear numerical (NS-MO501M) or observational (NS-MO502M) component.

[b] Selection of this course requires permission of the programme director.

Secondary electives

- At most 15 EC may be chosen from all MSc courses offered by the Graduate School of Natural Sciences.
- For other master courses approval by the programme director is required.
- The following bachelor courses may be selected after approval by the programme director:
    a. Geophysical Fluid Dynamics (NS-353B)
    b. Mathematical modeling (WISB357)
- Secondary electives may be used for courses required to fulfill the admission requirements in the case of deficiencies.

Deficiency courses

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

Students who lack in total more than 15 ECTS of mandatory courses, primary and secondary electives can only start with the research part after approval by the programme director or the programme coordinator.
Before starting the research project a meeting with the programme coordinator is mandatory to check the (planned) study program.

The research part is split as follows:
Thesis project part 1 (NS-MO551M): 14 EC,
Thesis project part 2 (NS-MO552M): 30 EC.

Research is done under the supervision of a staff member of the Institute for Marine and Atmospheric Research. This research is concluded with a written master´s thesis.

Research can be done in the following directions:

- Ice and Climate;
- Ocean Circulation and Climate;
- Atmospheric Physics and Chemistry;
- Atmospheric Dynamics and the Hydrological Cycle;
- Coastal and Shelf Sea Dynamics.

Cum laude

The minimum grade for the course Thesis project part 2 a student needs to obtain a cum laude degree qualification is 9.0. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Labour market perspectives and scientific integrity

Both aspects are discussed during the master introduction days. Besides, students attend two additional mandatory sessions on scientific integrity in their first and second year. Information about labour market perspectives is also given in several courses, as well as during sessions between student and programme coordinator and during research projects and internships.

Profiles (Educational/Complex Systems/Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with a *profile*. The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the

remaining 90 EC must be filled in as described below. Note that if the student fails to successfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Mandatory courses	38.5 EC
Primary electives	22.5 EC
Secondary electives	0 EC
Research part	29 EC
Total	**90 EC**

The research partis split into thesis part 1 (NS-MO551M, 14 EC) and thesis part 2 (NS-MO552M, 15 EC).

Remark: in this programme it is permitted to combine the research part of the profile Complex Systems (15 EC) with the research part (29 EC) in the table above, but the two research parts will be separately assessed.

Special provisions for students who enrolled in the programme Climate Physics in the year 2017-2018 and earlier

The minimum grade for the Thesis to obtain a cum laude degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Physics

Experimental Physics

Admission to the degree Physics

Applicants should possess:

- Solid knowledge of basic physics and mathematics at undergraduate level that is necessary to complete the degree programme (for details see admission criteria of the master's programmes);
- The ability to work independently as well as in groups on solving physical problems and presenting the results and to read (English) physics literature at the level of graduate textbooks;
- The ability to write a research report in English, such as a bachelor thesis.

In addition, applications should meet the requirements of either:
- the Climate Physics programme or
- the Theoretical Physics programme, or
- the Experimental Physics programme.

Degrees that most probably meet these requirements are
- A BSc degree in Physics,
- A BSc degree in Physics and Astronomy,
- A BSc degree with a major in Physics,
- A major in Science with a strong component in physics.

Admission to the programme Experimental Physics

Students qualify for admission to the programme **Experimental** Physics if they possess the following skills and knowledge (in addition to the criteria for the degree programme Physics):

-skills and knowledge in Quantum Mechanics, Statistical Physics at an advanced bachelor level, and
-general knowledge on the subject of Subatomic Physics, Solid State Physics/Condensed Matter Physics, and in Soft Condensed Matter Physics.

Degrees mentioned in the paragraph *Admission to the degree of Physics* normally satisfy these conditions.

In case the student has not taken one of the above mentioned subjects, it can be taken as part of the MSc programme to remedy this deficiency (at most 15 EC). The programme director will decide which topic need to be followed.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme must be completed (i.e. all courses passed) before entry into the Experimental Physics programme is allowed.

Learning outcomes

The graduate of the master's programme in Experimental Physics:

Knowledge and understanding
K1. has in-depth knowledge of and insight into modern experimental physics with an emphasis on at least two of the following topics: Particle Physics (PP), Atomic, Molecular and Optical (AMO) physics, Soft Condensed Matter & Biophysics (SCMB);is aware of recent developments in experimental and data analysis techniques in at least one of the following fields: Particle Physics, Atomic, Molecular and Optical physics, Soft Condensed Matter & Biophysics, and is able to state the relevance of these developments for the research field and society; K2. is aware of recent developments in experimental physics, and is able to state the relevance of these developments for the research field and society; K3. can read and understand the professional literature in the field of at least one of the following topics: Particle Physics, Atomic, Molecular and Optical Physics, Soft Condensed Matter & Biophysics; and to relate this to his/her own research; K4. understands the potential dilemmas related to scientific integrity in his/her research field.
Applying knowledge and understanding
A1. is able to define, under the supervision of a staff member, a scientific problem in Particle Physics, Atomic, Molecular and Optical physics or Soft Condensed Matter & Biophysics, formulate a research question, and design a basic strategy to solve this problem; A2. is able to carry out this research plan under supervision of a scientific staff member according to the rules of good experimental practice and ethics, and report on it in a manner that meets the customary standards of the discipline; A3. is able to analyse and interpret, under the supervision of a staff member, the acquired results, materials and/or data according to scientific standards;
Making judgements
M1. is able to participate critically and constructively in the scientific debate in the research group; M2. is able to indicate the relevance of his/her research for the advancement of physics; M3. is able to reflect critically upon his/her own contribution to the research in the selected field (Particle Physics, Atomic, Molecular and Optical physics, or Soft Condensed Matter Physics & Biophysics), and that of others.
Communication
C1. has the skills to present and discuss, in spoken and written English, the results of research, including the underlying knowledge and background, to a target group composed of specialists or non-specialists. C2. is able to work together in a constructive and critical way in an international (possibly interdisciplinary) team of experts and use modern means of scientific communication.
Learning skills
L1. has the skills to evaluate his/her own learning and development process and to adjust this process if necessary; has the skills to work independently and take initiatives where necessary; L2. is able to apply knowledge and insight in a way that demonstrates a professional approach to his or her work or profession; L3. has the qualifications to enrol in a PhD programme in at least one of the following fields: Particle Physics, Atomic, Molecular and Optical physics, Soft Condensed Matter

& Biophysics; is qualified to acquire a position as a professional in a (semi) public or commercial organisation.
L4. Has a realistic idea of the career opportunities after graduating, and of the skills that he/she needs to successfully start a career.

Contact hours

The average number of contact hours for a student of the programme (number of scheduled contact hours for the different courses and, in addition, the scheduled or standardised supervision time) is: **750** hours for the whole programme excluding the research part. The number of contact hours for a student in the research part of the programme is specified in individual application forms.

Contents

Mandatory courses	23.5 EC
Primary electives	21.5 EC*
Secondary electives	15 EC*
Research part	60 EC
Total	**120 EC**

* The total credits for elective courses has to be 36.5 EC, with at least 21.5 EC from the list of primary electives. In addition to the courses, it is possible to combine 15 EC of primary electives and 15 EC of secondary electives to carry out a 30 EC internship. For this, permission of the Board of Examiners is required before the start of the internship. Internships can only start after the mandatory courses and primary elective courses have been finished, unless explicit permission to start earlier is given by the programme director.

Mandatory courses

There are five mandatory courses in total, three of which are the same for all students:

Graduate school's master introduction GSNS-INTRO, 0.5 EC
Dilemmas of the scientist FI-MHPSDIL, 0.5 EC
Experiment Design NS-EX422M, 7.5 EC

and two courses chosen from the following four:

Particle Physics 1 NS-EX416M, 7.5 EC
Photon Physics NS-EX418M, 7.5 EC
Experimental Quantum Physics NS-EX401M, 7.5 EC
Soft Condensed Matter Theory NS-TP453M, 7.5 EC

If a student follows more than five mandatory courses, the additional courses will be counted as primary electives.

Primary electives

A choice from the following list of courses:
For research in either of the three specialisations (PP: Particle Physics, AMO: Atomic and Molecular Physics, SCMB: Soft Condensed Matter& Biophysics) it is strongly recommended to choose 21.5 EC from the corresponding column in the table below.

Advisory Path		PP	AMO	SCMB
Course				
Additional Mandatory Courses				
Particle Physics I, NS-EX416M, 7.5 EC		☐		
Photon Physics, NS-EX418M, 7.5 EC			☐	
Experimental Quantum Physics, NS-EX401M, 7.5 EC		☐	☐	
Soft Condensed Matter Theory, NS-TP453M, 7.5 EC				☐
Utrecht Courses:				
Advanced Microscopy, NS-EX423M, 7.5 EC			☐	☐
Modelling and Simulation, NS-TP432M, 7.5 EC		☐	☐	☐
Quantum Field Theory, NS-TP401M, 10 EC		☐	☐	
Statistical Field Theory, NS-TP402M, 10 EC		☐	☐	☐
Advanced Spectroscopy, SK-MSPEC, 7.5 EC				☐
Colloid Science, SK-MCS, 7.5 EC				☐
Shared NIKHEF Master Courses:				
NS-EX404M Particle Physics 2	6 EC	☐		
NS-EX410M Beyond the standard model	3 EC	☐		
NS-EX415M Flavour Physics and CP violation	3 EC	☐		
NS-EX413M Programming C++	3 EC	☐	☐	☐
NS-EX405M Computational Methods	6 EC	☐	☐	☐
NS-EX407M Astroparticle Physics	6 EC	☐		
NS-EX414M Statistical Data Analysis	6 EC	☐	☐	☐
NS-EX406M CERN Summer Student Programme	6 EC	☐		

Secondary electives

For the remaining 15 EC, several options are possible: any remaining course from the list of primary electives, any other course offered by the Graduate Schools of Natural and Life Sciences; the course GEO4-2513 Solar Energy Physics; other courses with permission from Board of Examiners; or an internship of 15 EC outside Utrecht University (note also the possibility of a 30 EC internship, as described under 'Contents'). Selection of courses should be discussed with the programme director. Internships can start as soon as all mandatory courses and primary elective courses, as well as the research part have been finished, or sooner with permission of the programme director.

Deficiency courses

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

Before starting the research project, a meeting with the programme coordinator is mandatory to check the (planned) study program.
Students can only start with the research part after approval by the programme director or the programme coordinator.

The research part is split as follows:
- Thesis project part 1 (NS-EX551M): 15 EC;
- Thesis project part 2 (NS-EX552M): 45 EC.

Successfully completing part 1 of the Thesis project is a mandatory prerequisite to continue with part 2 of the Thesis project. Explicit permission is given to reuse data and written material graded in research part 1 for research part 2.

Research is done at either the Particle Physics section or at one of the research groups of the Debye Institute including those belonging to the chemistry department (Condensed Matter & Interfaces, Physical & Colloid Chemistry) or, with the permission of the programme director, in a closely related research lab, provided that a staff member of the department of physics is willing to act as the primary responsible supervisor and as a second examiner. The student may start with his/her research project before the completion of mandatory courses and the primary elective courses only with the permission of the programme director. Research group specific requirements, including the choice of certain primary elective courses or other activities, are noted on the Research Project Application Form before the start of the project.

Cum laude

The minimum grade for the course Thesis project part 2 a student needs to obtain a cum laude degree qualification is 9.0. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Labour market perspectives and scientific integrity

Both aspects are discussed during the master introduction days. Besides, students attend two additional mandatory sessions on scientific integrity in their first and second year. Labour market perspectives are also discussed during sessions between student and programme coordinator and during research projects and internships.

Profiles (Educational/Complex Systems/Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30 EC of the regular programme with a *profile*. The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the remaining 90 EC must be filled in as described below. Note that if the student fails to successfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120 EC) programme structure.

Mandatory courses	23.5 EC
Primary electives	21.5 EC
Secondary electives	0 EC
Research part	45 EC
Total	**90 EC**

The research is split into thesis part 1 (NS-EX551M, 15 EC) and thesis part 2 (NS-EX552M, 30 EC).
Remark: in this master's programme it is permitted to combine the research part of the profiles Complex Systems and Data Science (15 EC) with the research part (45 EC) in the table above, but the two research parts will be separately assessed.

Special provisions for students who enrolled in the programme Experimental Physics in the year 2017-2018 and earlier

The minimum grade for the Thesis to obtain a cum laude degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Honours programme Q-Biology

Description

This honoursprogramme is open to all natural and life science students. Extended information about admission, dead-lines, selection procedure, content of this programme can be found at: http://theory.bio.uu.nl/qbio/honours.html or in the Education and Examination regulations (OER in dutch) of the Graduate School of Life Sciences.

Admission to the programme

The pre-selection will be done by the coordinators of the QBio program, and will be based on the following criteria:

a. a letter of motivation expressing interest in interdisciplinary Life Sciences research,
b. evaluation from supervisors of current disciplinary Master's programme,
c. grades and the particular selection of relevant courses in the Bachelor's programme, and
d. grades and track chosen during the high school education (e.g. choice of math courses).

Beginning of January every year the applicants will be notified whether or not they fulfill the pre-selection criteria and that they can take part in the first part of Qbio honors programme (max. 25 students).

The students that are pre-selected for Qbio programme will join the monthly journal club meetings from January to June. The aim of this journal club is to learn to read interdisciplinary papers and to develop current overview of Quantitative Biology. In June the students will take the Qbio course and **their performance in this course is the final selection criteria** for the Qbio honors programme. The students will present a paper and make a pitch on interdisciplinary projects they are involved in. To prepare them for these presentations, there will be regular meetings between January till June on obtaining interdisciplinary skills.

Learning outcomes

Discoveries in the biological and biomedical sciences increasingly require combining sophisticated technologies, quantitative measurements, and theoretical approaches such as bioinformatics, mathematical modelling and computer simulations. Hence, modern Life Sciences research faces the challenge to integrate different scientific disciplines and foster collaborative projects between biologists, chemists, physicists, computer scientists and mathematicians to make biology a quantitative natural science.

Therefore, the most important learning outcomes of this honors program is:

- Student is able to work in interdisciplinary teams.
- Student gains the basic information on life sciences to be able to talk with life sciences researchers.
- Student can communicate his/her disciplinary work to an interdisciplinary audience.
- Student can critically read papers outside of his own discipline and can search for the possibilities of integrating his own discipline to resolve the biological research question.

Contents

The programme has the following components:

- **Attending Monthly** journal club : The students that are pre-selected for Qbio programme will join the monthly journal club meetings from January to June. The aim of this journal club is to learn to read interdisciplinary papers and to develop current overview of Quantitative Biology.

- **Three week** QBio course (4.5 EC). This course is an extended version of the master course Systems Biology (May 28- June 15, 2018, program is in preparation) for honour students (max 25 participants). The aim of this course is to learn about interdisciplinary research in life sciences.
    - Perform at least **one interdisciplinary research project** within the institute of Bioinformatics and Biocomplexity (IBB) or any other groups associated with Qbio honors programme (see http://tbb.bio.uu.nl/qbio/honours.html) during their Master.
- In the second year of Qbio honours programme, the students will organize a **one day symposium** on Quantitave Biology and continue to attend monthly journal clubs.
- **Writing own PhD proposal** as final literature thesis. Students are free to choose their own research topic, and by which group they would prefer to be supervised (7.5 EC). The supervisor may decide to submit your PhD proposal to NWO.

Physics

Theoretical Physics

Admission to the degree in Physics

Applicants should possess:

- Solid knowledge of basic physics and mathematics at undergraduate level that is necessary to complete the degree programme (for details see admission criteria of the master's programmes).
- The ability to work independently as well as in groups on solving physical problems and presenting the results and to read (English) physics literature at the level of graduate textbooks.
- The ability to write a research report in English, such as a bachelor thesis.

In addition, applications should meet the requirements of either:
- the Climate Physics programme or
- the Theoretical Physics programme, or
- the Experimental Physics programme.

Degrees that, in all probability, meet these requirements are:
- a BSc degree in physics,
- a BSc degree in physics and astronomy,
- a BSc degree with a major in physics,
- a major in Science with a strong component in physics.

Admission to the programme Theoretical Physics

Students qualify for admission to the programme **Theoretical** Physics if they (in addition to the criteria for the degree programme Physics) possess advanced knowledge of:
- quantum mechanics,
- statistical physics,
- classical field theory,
- electrodynamics.

Typically, "advanced" implies the second course on these topics in a physics curriculum. The students have preferably also successfully completed a course on solid-state or condensed-matter physics, e.g., quantum matter. Students who did not pass these courses with high grades (above average) are advised not to choose the **Theoretical Physics** programme.

Premaster's programme

A premaster's programme of at most 30 EC is possible and will be tailored by the Board of Admissions depending on the student's prior knowledge. The premaster's programme should be finished (i.e., all courses passed) before entry into the **Theoretical Physics** programme is allowed.

Learning outcomes

The graduate of the master's programme in **Theoretical Physics**:

Knowledge and understanding
K1. has in-depth knowledge of and insight into field-theoretic and mathematical methods in theoretical physics and its use in high-energy physics and/or condensed matter physics and/or statistical physics; K2. is aware of recent developments in theoretical physics, and can state the relevance of these developments for the research field and society; K3. can read and understand the professional literature in the field of at least one of the following topics: high energy physics, condensed matter physics, statistical physics, and to relate this to the graduate's own research; K4. understands the potential dilemmas related to scientific integrity in the graduate's research field.
Applying knowledge and understanding
A1. can define, under the supervision of a staff member, a scientific problem in modern theoretical physics, formulate a research question, and design a basic strategy to solve this problem; A2. can carry out this research plan under supervision of a scientific staff member according to the rules of good scientific practice and ethics, and report on it in a manner that meets the customary standards of the discipline; A3. can analyse and interpret, under the supervision of a staff member, the acquired results, materials and/or data according to scientific standards;
Making judgements
M1. can participate critically and constructively in the scientific debate in the research group; M2. can indicate the relevance of the graduate's research for the advancement of physics; M3. can critically reflect on this theoretical-physics research.
Communication
C1. can explain the results of this research to an audience of specialists as well as fellow students, both orally and in writing, in English; C2. can conduct a theoretical-physics research project, supervised by a staff member, possibly as part of a (multidisciplinary) research team.
Learning skills
L1. has the skills to evaluate the graduates's own learning and development process and to adjust this process if necessary; has obtained the ability to study independently; L2. can apply knowledge and insight in a way that demonstrates a professional approach to graduate's own work or profession; L3. is qualified to be admitted to a PhD research project in the field of theoretical physics, physics in general, and/or mathematics; is qualified to acquire a research position in a (semi) public or commercial organization. L4. has a good idea of the employment possibilities and the skills needed to make a successful start in the labour market.

Contact hours

The average number of contact hours for a student of the programme is **950** hours for the whole programme excluding the research part.

Contents

Mandatory courses	29.5 EC
Primary electives	25.5 EC
Secondary electives	15.0 EC
Research part	50.0 EC
Total	**120.0 EC**

Note: The requirements for the primary electives may be minimally met within the curriculum by taking three 6.0 EC courses and one 7.5 EC course, including one suitable mathematics course. However, the student is free to go beyond the requisite amount.

Mandatory courses

- Quantum Field Theory (NS-TP401M; 10.0 EC)
- Statistical Field Theory (NS-TP402M; 10.0 EC)
- Dilemmas of the Scientist (FI-MHPSDIL; 0.5 EC)
- Graduate School's Master Introduction (GSNS-INTRO; 0.5 EC)
- Student Seminar in Theoretical Physics (NS-TP504M; 7.5 EC)
- Theoretical Physics Colloquium* (NS-TP505M; 1.0 EC)

* To be awarded the 1.0 EC for the Theoretical Physics Colloquium, participation in at least 18 sessions is required, the student must have attended 3 talks by alumni of our **Theoretical Physics** programme and has to present proof of attendance to a career orientation activity involving non-academic representatives, e.g., the Astronomy & Physics Master's Career Day or FYSICA.

Primary electives

At least 19.5 EC to choose out of the following list:

- Advanced Topics in Theoretical Physics Spring (NS-TP434M; 6.0 EC)
- Advanced Topics in Theoretical Physics Fall (NS-TP534M; 6.0 EC)
- Cosmology (NS-TP430M; 7.5 EC)
- Field Theory in Condensed Matter (NS-TP457M; 7.5 EC)
- Field Theory in Particle Physics (NS-TP529M; 7.5 EC)
- General Relativity (NS-TP428M; 7.5 EC)
- Modelling and Simulation (NS-TP432M; 7.5 EC)
- Soft Condensed Matter Theory (NS-TP453M; 7.5 EC)
- String Theory (NS-TP526M; 7.5 EC)
- Theory for Technology* (NS-TP531M; 7.5 EC)

In this master's programme the course Modeling and Simulation (NS-TP432M) is labelled as Complex Systems course.

* In collaboration with the TU/Eindhoven

At least 6.0 EC to choose from any master level course in mathematics, or alternatively one third-year course of the bachelor programme in mathematics from the following list:

- Differentieerbare variëteiten (WISB342; 7.5 EC)
- Complexe functies (WISB311; 7.5 EC)
- Topologie en Meetkunde (WISB341; 7.5 EC)
- Maat en Integratie (WISB312; 7.5 EC)
- Stochastische processen (WISB362; 7.5 EC)
- Distributies (WISB314; 7.5 EC)
- Functionaalanalyse (WISB315; 7.5 EC)
- Inleiding Scientific Computing (WISB356; 7.5 EC)
- Inleiding niet-lineaire systemen (WISB333; 7.5 EC)
- Hamiltoniaanse dynamische systemen (WISB331; 7.5 EC)

Note: Please keep the following in mind in selecting a mathematics bachelor course from the list above. At most one of these bachelor courses can be selected as part of the master's programme. The official language of education in these courses is possibly Dutch. Appearance in this list is not a guarantee that the course will actually be taught in a particular year; this applies especially to WISB333 and WISB331. Please verify the number of credits that are given for a course in a particular year. Lastly, courses from this list, or ones that are equivalent thereto, that are listed on the bachelor's degree cannot be used for the master's degree.

Secondary electives

15.0 EC to choose out of the following list:

- Any MSc course offered by the Graduate School of Natural Sciences (including the primary elective theoretical physics courses listed above).
- With the consent of the programme director and of the Board of Examiners also other master courses may be selected.

Note: Not all courses offered are 7.5 EC. It is possible that the student follows a 6.0 EC course as a secondary elective, under the condition that the individual conditions for the primary and secondary electives are met and the sum total of the obtained ECs as is at least 40.5 ECs.

Deficiency courses

If deficiency courses are taken, the EC for these courses count as EC for secondary electives.

Research part

The research is split into thesis part 1 (NS-TP551M, 15.0 EC) and thesis part 2 (NS-TP553M, 35.0 EC).

Cum laude

The minimum grade for the course Thesis project part 2 (**NS-TP553M**) a student needs to obtain a cum laude degree qualification is 9.0. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Labour-market perspectives and scientific integrity

Both aspects are discussed during the master introduction days. In addition, students attend two additional mandatory sessions on scientific integrity in their first and second

year. Information about labour-market perspectives is now formally a part of the Student Seminar in Theoretical Physics (NS-TP504M). It is also given attention in several courses, during discussions between the student and programme coordinator, and during research projects and internships.

Profile (Educational/Complex Systems/Applied Data Science)

Instead of the regular programme described above, the student may choose to replace 30.0 EC of the regular programme with a **Educational**, **Complex Systems**, or **Applied Data Science** profile. The contents and further description of a profile, including entry requirements to specific courses, is described in a separate appendix. In order to still meet the learning outcomes of the master's programme, the remaining 90.0 EC must be filled in as described below:

Mandatory courses	29.5 EC
Primary electives	25.5 EC
Profile specific subjects	15.0 EC
Profile research part	15.0 EC
Research part*	35.0 EC
Total	**120.0 EC**

* It is permitted to combine the thesis part of the profile Complex Systems (15.0 EC) with the research part of the **Theoretical Physics** programme (35.0 EC; NS-TP553M), but the two research parts will be separately assessed.

Note: If the student fails to succesfully complete the profile, the admissible curriculum conditions for the student revert to the regular (120.0 EC) programme structure.

Special provisions for students who enrolled in the programme Theoretical Physics in the year 2018-2019 and earlier

For students enrolled into this programme prior to 1 September 2019, the following rules apply:

- The research part is only 45 EC; the first part is unaffected and the second part (NS-TP552M) is worth 30.0 EC.
- These students must complete a total of 22.5 EC of primary electives.
- These students must complete suitable mathematics courses at the master level worth (in total) 7.5 EC, or alternatively a suitable bachelor course from the list provided above, also for a total of 7.5 EC.
- Completing the old version of the Student Seminar in Theoretical Physics (NS-TP503M) requires 10.0 EC. This includes the courses Dilemmas of the Scientist (FI-MHPSDIL; 0.5 EC); Graduate School's Master Introduction (GSNS-INTRO; 0.5 EC); Seminar, either the old version (NS-TP501M; 9.0 EC), if already completed, or the new (NS-TP504M; 7.5 EC); and Theoretical Physics Colloquium, with the old-style minimum requirement of 18 attendances, but with 0.0 EC credits awarded.

Any missing credits that count towards the requisite 10.0 EC for NS-TP503M, may be compensated for by following the labour-market activities that are part of the new Theoretical Physics Colloquium (NS-TP505M) on top of the 18 mandatory attendances already required under the old format, which gives 1.0 EC. Any remaining 0.5 EC can also

be compensated for through additional labour-market activities, which go beyond the requirements of NS-TP505M.
This provision ends 31 August, 2022.

Special provisions for students who enrolled in the programme Theoretical Physics in the year 2017-2018 and earlier

The minimum grade for the Thesis to obtain a cum laude degree qualification is 8.5. Please note that additional requirements (as listed in the main text of the OER) need to be met to obtain this qualification.

Profiles

Applied Data Science Profile

Description

Data are everywhere. From the sciences to industry, commerce, and government, large collections of diverse data are becoming increasingly more indispensable for decision making, planning, and knowledge discovery. But how can we sensibly take advantage of all the opportunitities that these data potentially provide while avoiding the many pitfalls? The Master's profile Applied Data Science addresses this challenge.

Applied Data Science (ADS) is a multidisciplinary profile for students who are not only interested in broadening their knowledge and expertise within the field of Data Science, but are also eager to apply these capabilities in relevant projects within their research domain. The two mandatory courses provide a thorough introduction to data science, its basic methods, techniques, processes, and the application of data science within specific domains. The foundations of applied data science include relevant statistical methods, machine learning techniques and programming skills. Moreover, key aspects and implications of ethics, privacy and law are covered as well.

The multidisciplinary nature of the Applied Data Science profile is also embodied in the collaborative design of the mandatory courses and (optionally) the research project. This means that both the teaching staff and students will have different backgrounds as means to help broaden perspectives and stimulate creativity. We investigate data science methods and techniques through case studies and applications throughout the life sciences & health, social sciences, geosciences, and the humanities. Therefore, students applying for this master's profile should have an affinity for this multidisciplinary approach.

Admission to the profile

It is assumed that you have already completed a bachelor level course in statistics and/or programming before starting the ADS profile. If not, you must have completed a certified introductory MOOC course on basic statistical methods and/or programming in preferably Python or otherwise R beforehand instead.

To apply for the ADS profile, you should first contact the ADS profile coordinator to discuss your eligibility, and subsequently register through the online form accessible form the ADS education web pages at https://students.uu.nl/en/science/applied-data-science.
The ADS profile coordinator will then assess your profile.

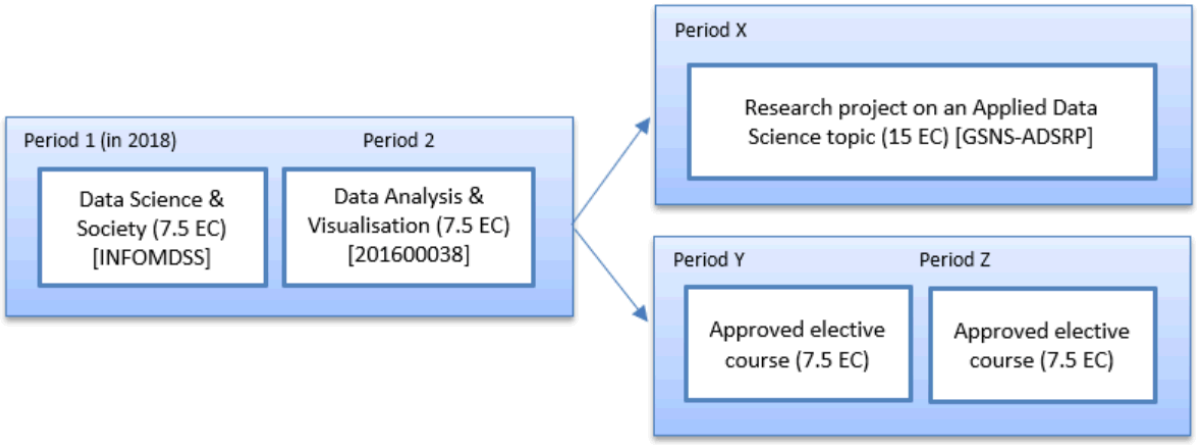
Learning outcomes

Upon completion of the Master's profile Applied Data Science the student:

- Understands the basic methods and techniques in data science
- Is able to apply this knowledge and analyse large datasets in a specific domain
- Understands the potential and risks of applying data science for research and society

Contents

The ADS profile comprises two mandatory multidisciplinary courses (15 EC), complemented with either a selection of two elective courses (15 EC) from the elective courses table listed below, OR a multidisciplanary research project (15 EC). The illustration below visualises the Master's profile Applied Data Science.



Two mandatory courses [15 EC]

- *Data Science & Society* [INFOMDSS]
  (coord: dept. Computer science / GSNS; in period 1)
- *Data Analysis & Visualisation* [201600038]
  (coord: dept. Methods & Statistics / GSSBS; in period 2)

Complementary course(s) [15 EC]

- Research project on an Applied Data Science topic [INFOMADSRP] (15 EC)

  Focus should be on interdisciplinary aspects and at least two supervisors from different departments/faculties should be involved.

  The topic should not correspond to the topic of the master thesis, however if the master reseach project deals with an applied data science subject, it is for certain master's programmes permitted to combine the research project of the master's profile Applied Data Science (15 EC) with the master research thesis. Both parts must be separately assessed and a supervisor from a different department or faculty is involved in this part of the research project.

  The topic should be approved by the profile coordinator, and by the programme director of the master programme for which the student is admitted. Upon approval the student and profile coordinator will together be responsible for finding a supervising staff member for the ADS aspects of the disciplinary project. This will be done on a case-by-case basis depending on the research topic, but commitment from an ADS staff member is required before the research project is allowed to commence.

- Two elective courses (15 EC)

  Due to the complexity of the Research Project option above, an attractive alternative to the Research Project is to complete the ADS profile by complementing the mandatory courses with two additional courses from the elective courses list below. Please refer to the Applied Data Science profile web page for up to date information, and consult your own master programme coordinator for approval nevertheless.

  Note that you can select courses from any of the participating master's programmes in the list below, as long as your own master's programme coordinator also agrees with the inclusion of the selected ADS profile courses as

eligible electives within your own master's curriculum (*i.e.* you need permission from both the ADS profile coordinator and your master's programme coordinator).

Master's programme	Elective course	Osiris code
Artificial Intelligence	Multi-agent learning	INFOMAA
	Cognitive Modeling	INFOMCM
	Experimentation in Psychology and Linguistics	INFOMEPL
	Logic and Language	TLMV13020
	Logic and Computation	WBMV13005
Business Informatics	Business Intelligence	INFOMBIN
	Process Mining	INFOMPROM
Climate Physics	Measuring Analyzing and Interpreting Observations	NS-MO501M
Computing Science	Data mining	INFOMDM
	Pattern set mining	INFOMPSM
	Big data	INFOMBD
	Pattern recognition	INFOMPR
Experimental Physics	Statistical Data Analysis	NS-EX434M
Game and Media Technology	Multimedia Retrieval	INFOMR
	Pattern Recognition	INFOMPR
Mathematical Sciences	Seminar Scientific Computing	WISM470
	Parallel Algorithms	WISL603
	Network Dynamics	WISL116
	Complex Networks	WISL115
Methodology and Statistics for the Behavioural, Biomedical and Social Sciences	Computational inference with R	MSBBSS04

Please note that the total number of EC of each master's programme will NOT be increased by completing the master profile Applied Data Science.

Profiles

Complex Systems Profile

Description and aims

The Master's profile Complex Systems is an interdisciplinary profile for students who are interested to broaden their knowledge and expertise within the field of Complex Systems. In this research field societal issues, such as a financial crisis, a sudden epidemic or climate change are studied from a quantitative modelling perspective. Students will get an understanding of the various models used in the complexity field and the behaviour (i.e. transitions, predictability) of these models.

The aim of the Complex Systems Profile is for students to develop or improve their

- affinity for quantitative approaches in order to address societal issues,
- ability to build models that are amenable to quantitative approaches,
- familiarity with standard (quantitative) methods in the toolbox for analysing complex systems, and
- ability to work in interdisciplinary teams.

Learning outcomes

Upon completion of the Master's profile the student

- is able to recognise the complex systems aspects when confronted with a societal problem,
- is able to develop models of complex systems and/o has a good overview of model-building for complex systems,
- has a good overview of the methods in the complex systems toolbox, can apply them to models and extract quantitative results, and
- communicate/explain complex-systems models and methods to (interdisciplinary) teammates.

Programme

The Master's profile comprises 30 EC and consists of the following parts:

- Two electives (7.5 EC each) from the following courses (**one of 1-4 is mandatory**):
    1. Introduction to Complex Systems (WISM484)
    2. Applying Mathematics in Finance (WISM410)
    3. Seminar Applications of Mathematics in Radiation Research (WISM409)
    4. Understanding Complexity: Economy and the Planet (NS-MO450M)
    5. A Complex Systems labelled course listed under a master programme that is **different** from the one to which the student is admitted (see list below). **Note on this list:** some programmes may require one of their own primary elective courses, labelled as Complex Systems course to be taken; the student **cannot** count them as primary electives **as well as** Complex Systems master profile courses. More information can be found in the specific programme description section of the Education and Examination Regulations.

- A research Project on a Complex Systems topic (15 EC), for which focus should be on interdisciplinary aspects and at least two supervisors from two different departments/faculties must be involved.

  The topic should not correspond to the topic of the master thesis, however if the

master research project deals with a complex system subject – currently available only for Theoretical Physics, Experimental Physics and Climate Physics Master programmes at Utrecht University – it is permitted to combine the research project of the master's profile Complex Systems (15 EC) with the master thesis project. In case the master research project deals with a complex system subject, the complex systems aspects must be separately assessed and a supervisor from a different department or faculty other than the department related to the student's master programme needs to be involved in assessing the complex system aspects of the research project.

The topic must be approved by the coordinator of the profile as well as by the coordinator of the master programme to which the student is admitted.

The total number of EC of each master's programme will NOT be increased by completing the master profile Complex Systems. Students receive a certificate by completing the Master's profile Complex Systems.

List of courses labelled as a complex systems course

Master's programme	Course	Osiris code
Climate Physics	Wave Attractors	NS-MO447M
Computing Science	Data Mining Pattern Recognition Evolutionary Algorithms	INFOMDM INFOMPR INFOEA
Energy Science	Energy Systems Modelling	GEO4-2515
Experimental Physics	Modelling and Simulation	NS-TP432M
Game and Media Technology	Pattern Recognition Crowd Simulation	INFOMPR INFOMCRWS
Mathematical Sciences	Complex Networks* Inverse Problems in Imaging* Mathematical Biology* Introduction to Numerical Bifurcation Analysis of ODEs and Maps*	WISL115 WISL430 WISL411 WISL606
Nanomaterials Science	Toy Models Modelling and Simulation	SK-MTOYM NS-TP432M
Sustainable Development	Sustainability Modelling and Indicators Environmental Systems Analysis	GEO4-2331 GEO4-2303
Theoretical Physics	Modelling and Simulation	NS-TP432M

* Registration via elo.mastermath.nl

Entry requirements

- The student belongs to one of the participating master programmes
- Upon consultation with the coordinator for the profile, it is also possible for students from outside Utrecht University to participate in the profile, when their master programme has an affinity to complex systems

Participating Master's programmes

- Climate Physics
- Computing Science
- Energy Science
- Artificial Intelligence
- Experimental Physics

- Game and Media Technology
- Mathematical Sciences
- Nanomaterials Science
- Sociology and Social Research
- Sustainable Development
- Theoretical Physics
- Multidisciplinary Economics

Legacy issues

The following courses were labelled as Complex Systems courses in the past academic years (noted in parenthesis).

Master's programme	Course	Osiris code
Game and Media Technology	Games and Agents (2017-18)	INFOMGMAG
Artificial Intelligence	Seminar Social Simulation (2018-19)	INFOMSOCS
Mathematical Sciences	Seminar mathematical epidemiology (2017-18)	WISM436
	Introduction to Numerical Bifurcation Analysis of ODEs and Maps (2017-18)	WISL606
	Mathematical Biology (2017-18)	WISL411
	Nonlinear Waves (2017-18)	WISL409
	Laboratory class for scientific computing (2018-19)	WISM454
	Interacting particle systems: Theory and applications (2018-19)	WISL431
	Numerical bifurcation analysis of large-scale systems (2018-19)	WISL425
Multidisciplinary Economics	Advanced behavioural and experimental finance (2017-18 and 2018-19)	ECRMABEF

In addition to these, Applying Mathematics in Finance (WISM410) was noted as Algorithms in Finance in the Complex Systems Master Profile OER Annex for the academic year 2018-19.

Profiles

Educational Profile

Description

A major feature of the profile is the emphasis on practitioner skills and school-based activities. Throughout the programme, learning theories and teaching methods will be taught closely linked to your day to day classroom. This programme is tailored to meet the professional development needs of teachers in the early stages of their careers.

The aim of the educational profile is to:

- convey specialised knowledge, skills and insight in the field of education for one of the school subjects computer sciences, physics, chemistry or mathematics, as well as more in-depth and comprehensive knowledge of the domain involved;
- prepare for professional practice as a teacher in one of the above-mentioned school subjects;
- prepare for professional practice in the field of (informal) education and communication about the discipline, about discipline-related academic topics and their societal context, in the wider educational field, such as in educational services and science centres, with publishers, in domain-specific educational research, information and journalism.

The programme, the level that is achieved and the qualification to be obtained depend on previous qualifications obtained by the student.

Educational profile for students without a prior educational qualification

Admission

- The exam programme of the student's current programme covers the subject matter requirements for the school subject involved.
- The student has demonstrated domain knowledge, understanding and academic skills that is founded upon the level that typically associated with Bachelor's level.
- The students has the learning skills, and the social and communicative skills that are needed to develop as a teacher in secondary education.

Matching will be part of the selection procedure. The decision about admitting a candidate is up to the admissions committee of the Graduate School of Teaching.

Learning outcomes

The following learning outcomes pertain to students who have no prior educational qualification for secondary education. The graduate of the Master's programme the profile is part of is able to:

- achieve good cooperation with individual pupils;
- create a safe learning environment for groups and individual pupils;
- set up a strong learning environment for groups and individual pupils, supporting pupils to gain mastery of the subject;
- create a well-organised and orderly task-oriented learning and working environment in group work and in other contacts with pupils;
- exchange relevant information with pupils' caretakers outside school, and to take care of coordination;
- give empirically grounded clarification of, critically examine and further develop his or her own views on being a teacher and his or her own teaching abilities.

Contents

The programme consists of the following parts:

- Teaching practice 1a (10 EC, GSTPIP1A)
- Teaching practice 1b (10 EC, GSTPIP1B)
- Teaching methodology 1 (5 EC, GSTPED1)
- Subject teaching methodology 1 - [Subject] (5 EC, GSTVAKD1IN/GSTVAKD1NK/GSTVAKD1SK/GSTVAKD1WK)

In case the student's Bachelor's programme matches with the Bachelor's programmes registered in the "Verwantschapstabel" (http://wetten.overheid.nl/BWBR0028148/2015-10-01), with these learning outcomes, the profile covers the competency requirements for a (limited) second degree teacher qualification for lower secondary education (vmbo-t and the lower grades in havo and vwo) as described in the Law on professions in education ("Wet op de beroepen in het onderwijs" – Wet BIO, 2006), and the competences derived from it as described in the nationally agreed upon competency profile for academic teacher education.

In any case the students will receive exemptions of 30 EC for the Master's programme for a first degree qualification.

Educational Profile after a previously obtained (limited) second degree teaching qualification

Admission

- The student holds a (limited) second degree teaching qualification for the particular school subject;
- The exam programme of the student's current programme covers the subject matter requirements for the school subject;
- The student has demonstrated domain knowledge, understanding and academic skillsthat is founded upon and extends and/or enhances the level that typically associated with Bachelor's level;
- The students has the learning skills, and the social and communicative skills that are needed to develop as a teacher in secondary education.

Matching will be part of the selection procedure. The decision about admitting a candidate is up to the admissions committee of the Graduate School of Teaching.

Learning outcomes

The following learning outcomes pertain to students who obtained a (limited) second degree teaching qualification (for example as the result of an educational minor). The graduate of the Master's programme the profile is part of:

- has demonstrated subject- and (subject-)didactical knowledge, insights and experiences in one of the above-mentioned school subjects that is founded upon and extends and/or enhances that typically associated with the Bachelor's level, makes critical use of these in educational practice, and does so – within or outside a research context – in an academic manner, so that he or she contributes to new knowledge about the development of school subjects and education;
- demonstrably possesses adequate theoretical knowledge in the field of communication, pedagogy and educational science to be able to contribute in a scientifically sound manner to defining, analysing and solving problems in secondary education;
- can apply knowledge, insights and problem-solving skills in new or unfamiliar situations and broader contexts, to integrate new knowledge and to handle complex materials and processes;

- has the ability to formulate judgements, also on the basis of incomplete or limited information; to act on the basis of these judgements, taking into account social, societal and ethical responsibilities that are part of subject and profession;
- is able to clearly and unambiguously pass on knowledge, motives, motivations and the conclusions based on them to various audiences (students, colleagues, parents or guardians, specialists and lay people, within or outside school);
- has the learning skills that will allow him or her to start a follow-up study with a largely self-managing or autonomous character.

Contents

The programme consists of the following parts:

- Teaching practice 2 (10 EC, GSTPIP2)
- Teaching methodology 2 (2.5 EC, GSTPED2)
- Subject teaching methodology 2 – [Subject] (7.5 EC, GSTVAKD2IN/GSTVAKD2NK/GSTVAKD2SK/GSTVAKD2WK)
- Mandatory elective (5 EC, choose from GSTPKC01 – GSTPKC07)
- Mandatory elective (5 EC, choose from GSTOKC01 – GSTOKC10, FI-MSECAD, FI-MSECHP, FI-MSECTEC, FI-MSECSIS)

With the learning outcomes, the profile in combination with the completed Master's programme, covers the competency requirements for a first degree teacher qualification as described in the Law on professions in education ("Wet op de beroepen in het onderwijs" – Wet BIO, 2006), and the competences derived from it as described in the nationally agreed upon competency profile for academic teacher education.

Non-Dutch students

As the educational profile is primarily targeted towards teaching in the Dutch school system, the courses and the internships are by default in Dutch. Non-native candidates are welcome to follow the educational profile and obtain the Dutch "limited second degree in teaching", provided they have a basic proficiency in Dutch. Should a non-native student start per **September** and do the educational profile during the first semester of the academic year, some of the courses will be in English. The course in subject-related methodology, however, will be in Dutch. There will be limited placement opportunities in bilingual or international schools.

Admission is possible if the candidate masters the Dutch language for reading and listening at B2 level. Sufficient passive control of the Dutch language can be demonstrated 1) during an interview or 2) by passing the Reading and Listening components of the State Examination NT2 before the start of the course (minimum score 500 points).

If a student start the educational profile in **February** all courses will be in Dutch, which means they need enough command of the Dutch language to follow all classes in Dutch. This command can be demonstrated through the aforementioned NT2 test or during an interview. The programme will try to find an internship in a bilingual or international school. If you already have a Dutch second degree in teaching and want to obtain a first degree in teaching, it is necessary to understand and speak Dutch fluently.