

**COMPUTER SCIENCE**

FACULTY OF SCIENCE

**LEIDEN UNIVERSITY**

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This report was finalized on 13 December 2019.



# REPORT ON THE BACHELOR'S AND MASTER'S PROGRAMME COMPUTER SCIENCE, THE MASTER'S PROGRAMME MEDIA TECHNOLOGY AND THE MASTER'S PROGRAMME ICT IN BUSINESS AND THE PUBLIC SECTOR OF LEIDEN UNIVERSITY

This report takes the NVAO's Assessment Framework for the Higher Education Accreditation System of the Netherlands for limited programme assessments as a starting point (September 2018).

## ADMINISTRATIVE DATA REGARDING THE PROGRAMMES

### **Bachelor's programme Computer Science**

Name of the programme:	Computer Science (Informatica)
CROHO number:	56978
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Specializations or tracks:	Computer Science (Informatica) Computer Science and Economics (Informatica & Economie) Bioinformatics (Bioinformatica)
Location(s):	Leiden, Den Haag
Mode(s) of study:	full time, part time
Educational minor:	applicable (second degree qualification)
Language of instruction:	Dutch
Submission deadline NVAO:	01/05/2020

### **Master's programme Computer Science**

Name of the programme:	Computer Science
CROHO number:	60300
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	Computer Science and Advanced Data Analytics Bioinformatics Data Science Science Communication and Society Education
Location(s):	Leiden
Mode(s) of study:	full time
Language of instruction:	English
Submission deadline NVAO:	01/05/2020

### **Master's programme Media Technology**

Name of the programme:	Media Technology
CROHO number:	60206
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC

Specializations or tracks:	-
Location(s):	Leiden
Mode(s) of study:	full time
Language of instruction:	English
Submission deadline NVAO:	01/05/2020

### **Master's programme ICT in Business and the Public Sector**

Name of the programme:	ICT in Business and the Public Sector
CROHO number:	60205
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	ICT in Business ICT in the Public Sector
Location(s):	Den Haag
Mode(s) of study:	full time
Language of instruction:	English
Submission deadline NVAO:	01/05/2020

The visit of the assessment panel Computer Science to the Faculty of Science of Leiden University took place on 11, 12 and 13 June 2019.

## ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Leiden University
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	positive

## COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 15 April 2019. The panel that assessed the bachelor's and master's programme Computer Science, the master's programme Media Technology and the master's programme ICT in Business and the Public Sector consisted of:

- Em. prof. dr. T. (Theo) D'Hondt, emeritus professor in Software Languages and Software Engineering at the Faculty of Sciences and Bioengineering Sciences of Vrije Universiteit Brussel (Belgium) [chair];
- Prof. dr. ir. W.E.A. (Wim) Van Petegem, professor and policy coordinator Learning Technologies at the Faculty of Industrial Engineering Technology of KU Leuven (Belgium);
- Prof. dr. S. (Sjouke) Mauw, professor in Security and Trust of Software Systems at the Department of Computer Science of the University of Luxembourg (Luxembourg);
- Prof. dr. J.J. (John-Jules) Meyer, full professor Computer Science and Artificial Intelligence at the University of Utrecht;
- Drs. L. (Lennart) Herlaar, owner/director at Redbits.nl, a company specialized in software development and IT consultancy, and assistant professor Computer Science at the Faculty of Science of Utrecht University;
- B. (Baran) Erdogan, third year bachelor's student Computer Science at the University of Amsterdam [student member].

The panel was supported by P.A. (Peter) Hildering MSc., who acted as secretary.

## WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the bachelor's and master's programme Computer Science, the master's programme Media Technology and the master's programme ICT in Business and the Public Sector at the Faculty of Science of Leiden University was part of the cluster assessment Computer Science. Between June and December 2019 the panel assessed 29 programmes at 10 universities. The following universities participated in this cluster assessment: Leiden University, Delft University of Technology, Utrecht University, Eindhoven University of Technology, Open University, University of Amsterdam, Vrije Universiteit Amsterdam, Radboud University, University of Groningen and University of Twente.

On behalf of the participating universities, quality assurance agency QANU was responsible for logistical support, panel guidance and the production of the reports. P.A. (Peter) Hildering MSc. was project coordinator for QANU. P.A. (Peter) Hildering MSc. and M. (Mark) Delmartino MA acted as secretary in the cluster assessment.

During the site visit at Leiden University, the panel was supported by P.A. (Peter) Hildering MSc., a certified NVAO secretary.

### *Panel members*

The members of the cluster assessment panel were selected based on their expertise, availability and independence. The panel consisted of the following members:

- Em. prof. dr. T. (Theo) D'Hondt, emeritus professor in Software Languages and Software Engineering at the Faculty of Sciences and Bioengineering Sciences of Vrije Universiteit Brussel (Belgium) [chair];
- Prof. dr. ir. W.E.A. (Wim) Van Petegem, professor and policy coordinator Learning Technologies at the Faculty of Industrial Engineering Technology of KU Leuven (Belgium);
- Prof. dr. S. (Sjouke) Mauw, professor in Security and Trust of Software Systems at the Department of Computer Science of the University of Luxembourg (Luxembourg);
- Prof. dr. J.J. (John-Jules) Meyer, full professor Computer Science and Artificial Intelligence at Utrecht University;
- Drs. L. (Lennart) Herlaar, owner/director at Redbits.nl, a company specialized in software development and IT consultancy, and assistant professor Computer Science at the Faculty of Science of Utrecht University;
- T.A. (Tonny) Wildvank, owner/CEO at Wildvank Management en Advies, specialized in IT-management and -consultancy;
- Prof. dr. J. (Jan) Aerts, full professor Visual Data Analysis at the University of Hasselt and associate professor Visual Data Analysis at the faculty of Engineering Science at KU Leuven (Belgium).
- Drs. H.C. (Jeroen) Borst, senior consultant Smart Cities at TNO;
- Prof. dr. P. (Petros) Koumoutsakos, full professor Computational Science at ETH Zürich (Switzerland).
- Prof. dr. ir. J.M.W. (Joost) Visser, Chief Product Officer at Software Improvement Group Nederland and professor Large-scale Software Systems at Radboud University;
- Drs. E.A.P. (Ewine) Smits, Manager in Advanced Analytics & Big Data at KPMG Nederland;
- Prof. dr. D.P. (Danilo) Mandic, full professor Signal Processing at the department of Electrical and Electronic Engineering of Imperial College London (United Kingdom);
- Dr. ir. J.C. (Job) Oostveen, Research Manager at the Department Monitoring and Control Services at TNO;
- Prof. dr. B.A.M. (Ben) Schouten, full professor Playful Interactions at Eindhoven University of Technology.
- Dr. ir. N. (Nico) Plat, owner/CEO at Thanos IT-consultancy and architecture;
- N. (Nienke) Wessel, third year bachelor's student Computing Science, third year bachelor's student Mathematics and first year bachelor's student Linguistics at Radboud University Nijmegen [student member];



- E. (Evi) Sijben, master's student Computing Science in the specialization track Data Science at Radboud University Nijmegen [student member];
- B. (Baran) Erdogan, third year bachelor's student Computer Science at University of Amsterdam [student member];
- M. (Martijn) Brehm, third year bachelor's student Computer Science at University of Amsterdam [student member].

The assessment panel to the Faculty of Science of Leiden University consisted of the following members:

- Em. prof. dr. T. (Theo) D'Hondt [chair];
- Prof. dr. ir. W. (Wim) Van Petegem;
- Prof. dr. S. (Sjouke) Mauw;
- Prof. dr. J.J. (John-Jules) Meyer (only for the master's programme Media Technology)
- Drs. L. (Lennart) Herlaar;
- B. (Baran) Erdogan [student member].

#### *Preparation*

On March 21<sup>st</sup>, 2019, the panel chair was briefed by QANU on his role, the assessment framework, the working method, and the planning of site visits and reports. A preparatory panel meeting was organized on May 9<sup>th</sup>, 2019. During this meeting, the panel members received instruction on the use of the assessment framework. The panel also discussed its working method and the planning of the site visits and reports.

The project coordinator composed a schedule for the site visit in consultation with the Faculty. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to Leiden University, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection consisted of 15 theses and their assessment forms for the programmes, based on a provided list of graduates from 2017 and 2018. A variety of topics and tracks and a diversity of examiners were included in the selection. The secretary and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses. After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial findings and questions and distributed these amongst all panel members.

At the start of the site visit, the panel discussed these initial findings, identified the key issues to be discussed during the sessions, and agreed on a division of tasks during the site visit.

#### *Site visit*

The site visit to Leiden University took place on 11, 12 and 13 June, 2019. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received.

Towards the end of the site visit, the panel discussed its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations. The visit was concluded with a development conversation, in which the panel and the programmes discussed various development routes for the programmes. The result of this conversation is summarized in a separate report.



### *Consistency and calibration*

In order to assure the consistency of assessment within the cluster, various measures were taken:

1. The panel composition ensured regular attendance of (key) panel members, including the chair and two core panel members, The chair and one panel member attended every site visit.
2. The project coordinator was present at the panel discussion leading to the preliminary findings at all site visits

### *Report*

After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to a colleague at QANU for peer assessment. Subsequently, the secretary sent the report to the panel. After processing the panel members' feedback, the project coordinator sent the draft report to the Faculty in order to have it checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalized and sent to the Faculty and University Board.

### *Definition of judgements standards*

In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of the standards:

#### **Generic quality**

The quality that, from an international perspective, may reasonably be expected from a higher education Associate Degree, Bachelor's or Master's programme.

#### **Meets the standard**

The programme meets the generic quality standard.

#### **Partially meets the standard**

The programme meets the generic quality standard to a significant extent, but improvements are required in order to fully meet the standard.

#### **Does not meet the standard**

The programme does not meet the generic quality standard.

The panel used the following definitions for the assessment of the programme as a whole:

#### **Positive**

The programme meets all the standards.

#### **Conditionally positive**

The programme meets standard 1 and partially meets a maximum of two standards, with the imposition of conditions being recommended by the panel.

#### **Negative**

In the following situations:

- The programme fails to meet one or more standards;
- The programme partially meets standard 1;
- The programme partially meets one or two standards, without the imposition of conditions being recommended by the panel;
- The programme partially meets three or more standards.



## SUMMARY JUDGEMENT

### *Bachelor's programme Computer Science*

The bachelor's programme Computer Science convincingly profiles itself as a fundamental, theoretical and research-oriented core programme in Computer Science, with a variety of specialization opportunities, including multidisciplinary tracks in Bioinformatics and CS & Economy, about which the panel is very positive. The intended learning outcomes meet the expectations of the academic and professional field through alignment with the international ACM benchmark curriculum, and are fitting for an academic bachelor's programme in terms of level and orientation. The panel is positive about the specialization-specific ILOs that are implemented by the programme.

The programme has adequately translated its intended learning outcomes into a coherent curriculum for both the full-time and part-time variant. It offers both a broad generalist computer science track as well as unique multidisciplinary tracks with economics and biology. The panel praises the integration of the fields within these tracks through the Integration Courses. The clear integration of research and education keeps the curriculum fresh and up-to-date. The panel recommends to make a clear overview of the current implicit learning trajectories within the programmes. The didactics of the programme are fitting, although the panel does think the programme could benefit from an increased attention to innovative teaching methods.

The programme is feasible, and has an active policy to prevent early exits to industry, which the panel applauds. Education at multiple locations in the CS&E track in the bachelor's programme is well-implemented. The panel is positive about the teaching staff of the programme, and praises the professionalization of teachers through BKO's. The programme is successfully dealing with the growth in student numbers, although the programme could use more teaching assistants. The programme offers adequate facilities, although the building is clearly outdated. The panel endorses any measures that can be taken to improve this until future relocation.

The programme has an adequate assessment system that assesses students on all intended learning outcomes. The assessment methods are varied and fit the goals of the programme. To improve the validity and reliability of the exams, the panel recommends to implement the peer review principle for all exams. It also recommends to keep paying attention to a timely grading of assignments, especially in the case of formative assessment.

The thesis assessment of the programme is adequate, and provides a transparent motivation of the final grades. The panel recommends to reconsider the rule that an unsatisfactory score for a subcategory of the thesis assessment can still lead to a satisfactory final grade. The Board of Examiners adequately fulfils its role in the quality assurance of assessment, but could take a more proactive and normative stance with regard to adherence to assessment policy and regulations.

The panel concludes that the final projects of the programmes are of sufficient quality, and convincingly show that the intended learning outcomes have been achieved. The panel agrees with the grading. It recommends to pay extra attention to the level of command of the English language. The bachelor's students experience no obstacles in their respective master's programme.

### *Master's programme Computer Science*

The master's programme Computer Science offers a very solid core in computer science, focusing on a theoretical, research-focused approach with a wide variety of specialization opportunities, including a unique track in Bioinformatics. The intended learning outcomes meet the expectations of the academic and professional field using the international ACM benchmark curriculum as basis, and are fitting for an academic master's programme in terms of level and orientation. The panel was positive about the specialization-specific ILOs that were implemented by the programme. It also agrees with



the programme's choice to discontinue participation in the SBB specialization in favour of the ICT in Business master's programme.

The programme has adequately translated its intended learning outcomes into a coherent curriculum. The programme offers a wide variety of choices for students to specialize. The panel supports the planned curriculum change towards more structured tracks, and thinks this will further improve the coherence and feasibility of the programme. The clear integration of research and education keeps the curriculum fresh and up-to-date. The panel recommends to make a clear overview of the current implicit learning trajectories within the programme. The didactics of the programme are fitting, although the panel does think the programme could benefit from an increased attention to innovative teaching methods.

The programme is feasible, and has an active policy to prevent early exits to industry, which the panel applauds. The panel is positive about the teaching staff, and praises the professionalization of teachers through BKO's. The programme is successfully dealing with the growth in student numbers. The use of English as the language of instruction fits the international character of the programme and prepares students for the international job market. The programmes offer adequate facilities, although the building is clearly outdated. The panel endorses any measures that can be taken to improve this until future relocation.

The programme has an adequate assessment system that assesses students on all intended learning outcomes. The assessment methods are varied and fit the goals of the programme. To improve the validity and reliability of the exams, the panel recommends to implement the peer review principle for all exams. It also recommends to keep paying attention to a timely grading of assignments, especially in the case of formative assessment.

The thesis assessment of the programmes is adequate, and provides a transparent motivation of the final grades. The panel recommends to reconsider the rule that an unsatisfactory score for a subcategory of the thesis assessment can still lead to a satisfactory final grade. The Board of Examiners adequately fulfils its role in the quality assurance of assessment, but could take a more proactive and normative stance with regard to adherence to assessment policy and regulations.

The panel concludes that the final projects of the programme are of sufficient quality, and convincingly show that the intended learning outcomes are achieved. The panel agrees with the grading, and praises the programme for the high number of scientific publications resulting from master's theses. The graduates of the programme are very much in demand on the labour market, both as PhD researcher as well as in industry, and almost all students find a job during or immediately after completion of the programme.

#### *Master's programme ICT in Business and the Public Sector*

The master's programme ICT in Business and the Public Sector is very much geared towards the demand of the professional field for graduates that can bridge the gap between ICT and industry/society. The panel recognizes the need for these professionals, and praises the programme for taking this on. The intended learning outcomes are aligned with the expectations of the academic and professional field, and are fitting for an academic master's programme in terms of level and orientation. The panel is positive about the specialization-specific ILOs that are implemented by the programme for both specializations.

The programme has adequately translated its intended learning outcomes into a coherent curriculum. The interdisciplinary core of computer science, business (management) and economics connects students to both ICT and the practice of business and government, fitting the goals of the programme. The panel recommends introducing a bridging programme to level students before the start of the curriculum. This bridging programme should aim for a smooth transition between this

programme and the CS&E track in the bachelor's programme Computer Science, and address deficiencies of students entering through another route. The panel was happy to learn during the site visit that the programme management is already considering to introduce such a bridging programme. It strongly encourages the programme to continue with this. Furthermore, the programme should carefully monitor and evaluate the courses to make sure that they are challenging enough for all students. The panel is confident that the programme will be able to implement these changes in the near future. Furthermore, the panel recommends the programme to better integrate research skills within the curriculum rather than only focusing on these in the Methodology courses.

The panel is positive about the didactics of the programme, which combines research and practice, and involves actual business and governmental organizations. This clearly contributes to the goal of the programme to bridge the gap between ICT and industry/society. The use of English as the language of instruction in the master's programme fits the international character of the programme and prepares students for the international job market. The panel recommends the programme to investigate whether additional measures are necessary to address the limited proficiency in English of some of the international students. The programme is feasible and students experience no obstacles in completing the curriculum in a timely manner. The teaching staff is well-qualified, and reflects the integration of research and practice that the programme aims for. The panel recognizes the need for external lecturers, and praises the attention of the programme to monitor the external teaching staff to ensure the academic level of the courses. It recommends the programme to keep this up, and to also keep stimulating its external lecturers to obtain a BKO qualification. The panel applauds the planned initiative to create a research group in ICT in Business and the Public Sector at LIACS, which it thinks would strengthen the programme and further improve the balance between research and practice.

The programme has an adequate assessment system that assesses students on all intended learning outcomes. The assessment methods are varied and fit the goals of the various programmes. To improve the validity and reliability of the exams, the panel recommends to implement the peer review principle for all exams. It also recommends to keep paying attention to a timely grading of assignments, especially in the case of formative assessment. The thesis assessment of all four programmes is adequate, and provides a transparent motivation of the final grades. The panel recommends to reconsider the rule that an unsatisfactory score for a subcategory of the thesis assessment can still lead to a satisfactory final grade. The Board of Examiners adequately fulfils its role in the quality assurance of assessment, but could take a more proactive and normative stance with regard to adherence to assessment policy and regulations, such as the rules for academic qualification of examiners.

The panel concludes that the final projects of the programmes are of sufficient quality, and convincingly show that the intended learning outcomes are achieved. The panel agrees with the grading. It recommends to pay extra attention to the level of command of the English language, and to the requirements for thesis topics. The graduates of the programme are very much in demand on the labour market, and almost all students find a job during or immediately after completion of the programme.

#### *Master's programme Media Technology*

The master's programme Media Technology is a unique interdisciplinary programme propagating a creative and playful approach to scientific research. It uses the creative and performing arts as means for research in the natural sciences, using computer science technologies in creative ways. The panel is convinced that the skills and creative attitude on which the programme focuses are very valuable in a professional as well as a research context. The ILOs reflect the focus on skill and attitude that the programme embraces, and demonstrate their master's level and academic orientation.



The teaching-learning environment of the programme facilitates students to achieve the intended learning outcomes. The unique curriculum combines various topics in technology, art and research into a coherent, interdisciplinary core, allowing students to develop their skills and attitude in order to investigate research questions in a playful and creative way. Students are offered a large amount of flexibility and choice in composing their own curriculum through electives and projects. The panel is positive about this amount of flexibility, but encourages the programme to introduce a more formalized approach to the selection of electives to help students compose a more coherent curriculum. It also recommends introducing ethical aspects of working with human test subjects into the curriculum. Furthermore, it thinks that the programme should create a bridging programme in which students can remedy their deficiencies before entering the programme, rather than using introductory courses in the programme's core curriculum to this end.

The panel was impressed by the student-centred and multidisciplinary didactic approach of the programme, and the wide range of possibilities that the programme offers in order to enable *learning by doing*. Projects are well-facilitated through project rooms with equipment for students to use. The use of English as the language of instruction fits the international character of the programme and facilitates the international classroom that the programme pursues. The panel concludes that the programme is feasible and has a very low number of dropouts. It encourages the programme to keep up their good work on measures to encourage timely completion of student projects. The teaching staff of the programme is well-qualified, creates a stimulating learning environment and forms a committed team dedicated to the students.

The programme has an adequate assessment system that assesses students on all intended learning outcomes. The assessment methods are varied and fit the goals of the programme. To improve the validity and reliability of the exams, the panel recommends to implement the peer review principle for all exams. It also recommends to keep paying attention to a timely grading of assignments, especially in the case of formative assessment. The thesis assessment is adequate, and provides a transparent motivation of the final grades. The additional documentation on the process adds to the transparency and validity of the grading with regard to the research process, which is an important characteristic of the programme. This might be even further improved by adding a student reflection that ties the various components in the process documentation together. The panel recommends to reconsider the rule that an unsatisfactory score for a subcategory of the thesis assessment can still lead to a satisfactory final grade. The Board of Examiners adequately fulfils its role in the quality assurance of assessment, but could take a more proactive and normative stance with regard to adherence to assessment policy and regulations.

The panel concludes that the final projects are of sufficient quality, and convincingly show that the intended learning outcomes are achieved. The panel agrees with the grading. The graduates of the programmes are very much in demand on the labour market, both as PhD researcher as well as in industry.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

*Bachelor's programme Computer Science (both full-time and part-time)*

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

*Master's programme Computer Science*

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

*Master's programme ICT in Business and the Public Sector*

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

*Master's programme Media Technology*

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

The chair, em. Prof. dr. T. (Theo) D'Hondt, and the secretary, P.A. (Peter) Hildering MSc., of the panel hereby declare that all panel members have studied this report and that they agree with the judgements laid down in the report. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 13 December 2019

# DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED PROGRAMME ASSESSMENTS

## **Standard 1: Intended learning outcomes**

The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

## **Findings**

The bachelor's programme Computer Science (Dutch: *Informatica*) and the master's programmes Computer Science, ICT in Business and the Public Sector, and Media Technology are organized by the Leiden Institute of Advanced Computer Science (LIACS), one of the eight institutes of Leiden University's Faculty of Science. The programmes are headed by the programme director, supported by four programme managers responsible for the day-to-day business of the individual programmes. LIACS hosts two Boards of Examiners, and two Educational Committees: in both cases one for the bachelor's programme and one for the three master's programmes.

### *Bachelor's and master's programme Computer Science*

The bachelor's and master's programme Computer Science have a fundamental and theoretical character, with a predominant research focus inspired by the fundamental scientific research carried out at LIACS. Both programmes aim to offer a flexible and up-to-date curriculum with a broad range of courses that cover the basics of the field of computer science, as well as ample opportunities for students to adapt the programme to their own preferences.

At the start of the *bachelor's programme Computer Science*, students choose between three specializations: Computer Science (CS), Computer Science and Economics (CS&E) and Bioinformatics (BI). Each specialization aims to provide students with a broad understanding in computer sciences, focused either on the fundamentals of computer science (CS), ICT in organizations and businesses (CS&E) or the use of computer techniques in life sciences and health (BI). The CS&E specialization is offered in close collaboration with the Erasmus School of Economics of the Erasmus University Rotterdam (EUR), which provides the economy-related subjects. The BI specialization has been introduced in 2015-2016, reflecting the increasing role of computational tools and data in life sciences and health. The biology courses in this specialization are offered through the Institute of Biology Leiden (IBL) of Leiden University.

The *master's programme Computer Science* considers itself a specialist programme as specified in the ACM model curriculum (see below) that builds upon the bachelor's programme, allowing students to specialize in an area of their preference through a flexible curriculum. It offers three specializations to guide students in their choice of research area:

- Computer Science and Advanced Data Analytics (ADA), focusing on foundations and applications of smart computing technologies such as data mining, multimedia, embedded systems, natural computing and formal methods. This specialization will be redesigned and split into three new specializations per 2019-2020 in order to provide students with more distinctive profiles (see Standard 2):
  - Advanced Computer Science (multimedia, signal processing, embedded systems)
  - Foundations of Computer Science (algorithms and software)
  - Artificial Intelligence (machine learning, optimization algorithms, decision support techniques)
- Data Science (DS), offered jointly with the master's programme Statistical Science for the Life and Behavioural Sciences, focusing on extracting information from large data sets using advanced statistical techniques, machine learning and algorithms for data analysis;
- Bioinformatics (BI), which teaches students how to research, develop and apply computational tools for biological, medical, behavioural and health data.

Additionally, the master's programme Computer Science offers students the opportunity to participate in one of two society-oriented specializations: Science Communication and Society (SCS)



and Education (EDU). These are faculty-wide specializations in which students from various master's programmes can participate.

Before 2018, the programme also allowed its students to participate in the society-oriented specialization Science-Based Business (SBB). The previous accreditation panel noted a substantial overlap in the aims of the SBB specialization and the master's programme ICT in Business and the Public Sector. In response, the programme decided to withdraw from the SBB specialization, and instead provided students interested in science-based business with the opportunity to enrol in the master's programme ICT in Business and the Public Sector. This programme in turn has increased its cooperation with the Business Studies department within the faculty to better cover the topics previously offered by SBB.

The goals of both programmes have been summarized in a set of twelve (bachelor) and six (master) general intended learning outcomes (ILOs, Appendix 2), which describe the knowledge and skills the programmes aim its graduates to achieve. Each specialization has specified a set of additional ILOs, covering knowledge and skills specific to the specializations. To keep the programmes aligned with the rapidly evolving expectation of both the discipline and the professional field, the programmes regularly benchmark their ILOs with the characteristics and knowledge areas defined in the Computing Curriculum of ACM. This benchmark consists of a standard bachelor's curriculum for computer science programmes maintained by the international society for the discipline of computer science. This document also serves as the domain-specific framework of reference for this accreditation (see Appendix 1), with the master's programmes building upon the described bachelor's curriculum. Recently, this benchmark has led to a more prominent place of, for instance, security, data science, bioinformatics and artificial intelligence within the programmes, as well as more attention to teamwork and communication skills as required by the professional field.

The panel has studied the profile of the bachelor's and master's programme, as well as the intended learning outcomes. It concludes that bachelor's programme offer a very solid theoretical core in computer science, covering all knowledge areas of the ACM benchmark curriculum. The master's programme builds upon the bachelor's programme and offers students the opportunity to expand their expertise in these knowledge areas. The panel praises the programmes for their clear choice to focus on a theoretical, research-focused approach, with a wide variety of specialization opportunities for students. The panel is very positive on the multidisciplinary focus of the CS&E specialization in the bachelor's programme, and the BI specialization in both programmes. The panel recognizes the need for specialists in these areas, and praises the programme for taking the initiative to offer these specializations. It considers the collaborations with the Erasmus University Rotterdam (CS&E) and the Institute of Biology in Leiden (BI) fruitful approaches to achieve multidisciplinary within the specializations. Finally, the panel agrees with the choice to discontinue the participation of the master's programme in the SBB specialization in order to decrease overlap with the master's programme ICT in Business and the Public Sector.

According to the panel, the ILOs of both programmes are well-formulated. The research focus of the programmes is clearly reflected in the attention to research skills. The connection to the discipline and the professional field, is strengthened through the benchmark with the ACM curriculum. Furthermore, the panel was presented with an overview that tied the ILOs of both programmes to the Dublin descriptors for respectively academic bachelor's and master's programmes in an insightful way. The panel was positive on the specialization-specific ILOs that were implemented by both programmes in response to recommendations of the previous accreditation panel. It considers these appropriate considering the multidisciplinary nature of several specializations.



### *Master's programme ICT in Business and the Public Sector*

The master's programme ICT in Business and the Public Sector aims to provide students with a deeper understanding of challenges and opportunities offered by ICT in a business and/or governmental context. Graduates are expected to be able to bridge the gap between the ICT domain and the application domain, using specialist knowledge, analytical skills and a rigorous attitude with respect to reliability and credibility of information. Students can choose between two specializations:

- ICT in Business, focusing on issues in commercial organizations, such as marketing and finance;
- ICT in the Public Sector, focusing on issues in the public domain, such as politico-administrative relations, European procurement and data-driven policy development.

The programme was originally developed with ICT professionals for businesses in mind. In 2017-2018, the Public Sector specialization was added in response to demand from the professional field. The programme considers itself a generalist programme, as defined in the ACM benchmark curriculum, designed with the needs of employers in mind. Although it thematically aligns with the CS&E specialization in the bachelor's programme Computer Science, it does not specifically focus on the influx of this programme, but admits all types of (academic and professional) Computer Science bachelors. Students are expected to build upon the fundamental computer science skills obtained in their bachelor's education to develop generic competencies such as analytical skills, communication, teamwork and project management. The programme maintains close contact with both industry and the public sector through frequent use of (guest) lecturers from the professional field.

The goals of the programme have been summarized in a set of six general intended learning outcomes (ILOs, Appendix 2), which describe the knowledge and skills the programme aims its graduates to achieve. Both specializations have a specified set of additional ILOs, covering knowledge and skills specific to either business or the public sector.

The panel has studied the profile of the master's programme ICT in Business and the Public Sector, as well as the ILOs. It concludes that the programme is very much geared towards the demand of the professional field for graduates that can bridge the gap between ICT and industry/society. The panel recognizes the need for these professionals, and praises the programme for taking this on. The recent addition of the Public Sector specialization shows that the programme is well-connected to the professional field and is able to adapt the programme to meet its demands. At the same time, the panel clearly recognizes the academic orientation of the programme, with explicit mention of research skills, critical reflection and learning skills in the programme's ILOs. In an overview presented to the panel, the ILOs were tied to the Dublin descriptors for academic master's programmes in an insightful way, demonstrating their master's level and academic orientation. The panel was positive on the specialization-specific ILOs. It considers these appropriate considering the difference in focus of both specializations.

### *Master's programme Media Technology*

The master's programme Media Technology stimulates students to become independent and creative researchers. As it considers creativity and playfulness important factors in scientific innovation, it aims to create an environment in which students are allowed to translate their personal inspirations and curiosities into research projects. The programme encourages unusual questions, unconventional research methods and alternative forms of scientific output such as installations, games, robots and books. It is part of the Faculty of Science, since it identifies with the research methods of the natural sciences. It is embedded in LIACS as it views computer science as an accelerant of scientific innovations, and sees computer technologies as the ultimate and most flexible research tools for small and independent research. Examples of such research projects are setting up an installation to monitor position changes of someone watching a movie, observing interaction between drones and birds, or studying the use of virtual reality environments for stress reduction.

Students are prepared for a role where they can apply new technologies and understand their meaning in a human context. This can be as researcher, teacher, within the cultural sector, the

creative industry or as self-employed artists or designer. Within the ACM benchmark, Media Technology views itself as a generalist programme, focused on the application and meaning of technology rather than on technology itself. It uses technology in a research-oriented way, applying it in creative ways to carry out scientific research. The programme does not limit itself to computer science bachelor's graduates, but allows students from all fields as long as they have the required motivation, which includes daring to be creative, going beyond established paths and enjoying critical thinking. In addition, students need to have a demonstrable interest in science and scientific research, demonstrable affinity with technology and programming skills (or the capability to acquire these quickly). The goals of the programme have been summarized in a set of ten intended learning outcomes (ILOs, Appendix 2), which describe the knowledge and skills the programme aims its graduates to achieve. These include theoretical and practical skills in the field of computer science, artificial intelligence, and the creative and performing arts, as well as insight in their societal role, their research skills and the skills to study in a self-directed manner.

The panel has studied the profile of the master's programme Media Technology, as well as the ILOs. It was surprised by the unique interdisciplinary character of the programme and its unusual approach to scientific research. Through inspiring interviews with students and teaching staff, the panel came to understand the creative and playful approach to science the programme propagates, and why the programme considers itself at home at a computer science institute. It concludes that the creative and performing arts are the means rather than the goal of the programme, and that ultimately, the programme is geared towards the research methods of the natural sciences, using computer science technologies in creative ways. The panel is convinced that these skills and creative attitude, although they are not geared towards a specific profession, are very valuable in a professional as well as a research context. The ILOs reflect the focus on skills and attitude that the programme embraces, as well as its research orientation. They do not list specific knowledge or technologies for students to master, but list skills and attitudes that enable students to learn on their own using the tools provided by the programme. These skills align very well with the Dublin Descriptors (i.e., learning skills, making judgements) at master's level. In an overview presented to the panel, the ILOs were tied to the Dublin descriptors for academic master's programmes in an insightful way, demonstrating their master's level and academic orientation.

### **Considerations**

The *bachelor's programme Computer Science* convincingly profiles itself as a fundamental, theoretical and research-oriented core programme in Computer Science, with a variety of specialization opportunities, including multidisciplinary tracks in Bioinformatics and CS & Economy, about which the panel is very positive. The intended learning outcomes meet the expectations of the academic and professional field through alignment with the international ACM benchmark curriculum, and are fitting for an academic bachelor's programme in terms of level and orientation. The panel is positive about the specialization-specific ILOs that are implemented by the programme.

The *master's programme Computer Science* offers a very solid core in computer science, focusing on a theoretical, research-focused approach with a wide variety of specialization opportunities, including a unique track in Bioinformatics. The intended learning outcomes meet the expectations of the academic and professional field using the international ACM benchmark curriculum as basis, and are fitting for an academic master's programme in terms of level and orientation. The panel was positive about the specialization-specific ILOs that were implemented by the programme. It also agrees with the programme's choice to discontinue participation in the SBB specialization in favour of the ICT in Business master's programme.

The *master's programme ICT in Business and the Public Sector* is very much geared towards the demand of the professional field for graduates that can bridge the gap between ICT and industry/society. The panel recognizes the need for these professionals, and praises the programme for taking this on. The intended learning outcomes are aligned with the expectations of the academic and professional field, and are fitting for an academic master's programme in terms of level and



orientation. The panel is positive about the specialization-specific ILOs that are implemented by the programme for both specializations.

The *master's programme Media Technology* is a unique interdisciplinary programme propagating a creative and playful approach to scientific research. It uses the creative and performing arts as means for research in the natural sciences, using computer science technologies in creative ways. The panel is convinced that the skills and creative attitude on which the programme focuses are very valuable in a professional as well as a research context. The ILOs reflect the focus on skill and attitude that the programme embraces, and demonstrate their master's level and academic orientation.

### **Conclusion**

*Bachelor's programme Computer Science*: the panel assesses Standard 1 as 'meets the standard'.

*Master's programme Computer Science*: the panel assesses Standard 1 as 'meets the standard'.

*Master's programme Media Technology*: the panel assesses Standard 1 as 'meets the standard'.

*Master's programme ICT in Business and the Public Sector*: the panel assesses Standard 1 as 'meets the standard'.

### **Standard 2: Teaching-learning environment**

The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

### **Findings**

#### Curricula

##### *Bachelor's programme Computer Science*

In the bachelor's programme Computer Science, students choose one of the three specializations (Computer Science, Computer Science & Economics or Bioinformatics) from the very beginning, and follow the curriculum associated with this specialization. The three specializations have 81 EC courses in common, which are concentrated in the first two years of the programme. These courses cover the foundations of computer science, including programming, mathematics and academic skills. Furthermore, all students finish their curriculum with a 15 EC individual bachelor's thesis.

The specializations have 84 EC of specialization-specific courses in which students either follow further courses in computer science (CS), economics and business courses at Erasmus University Rotterdam (CS&E) or Biology courses at IBL (BI). In addition, the CS&E and BI specializations have 12-14 EC of Integration courses, in which the multidisciplinary content of the programme is integrated. The CS specialization includes a 30 EC mobility window, in which students can choose to follow a broadening minor, deepening electives or to study abroad. Students interested in education can opt for a university-wide 30 EC educational minor, leading to a second-degree teaching qualification. Due to their multidisciplinary character, CS&E and BI do not have room for such a mobility window, although BI does offer 12 EC room for electives. The remaining 15 EC is spent on a bachelor's thesis, in which students perform an individual research project in one of LIACS's research groups. In parallel, they follow the bachelor's class, which offers training on academic skills such as research skills, academic writing and research ethics.

The panel has studied the curriculum of the programme, as well as the content of a number of courses. It concludes that the ILOs are adequately translated into coherent curricula for each of the three specializations, with a solid common core in computer science. This core, and especially the elaboration on this in the CS specialization, reflects the generalist nature of the programme, as it covers all elements of the ACM model curriculum for computer science. The specializations CS&E and

BI are balanced, and offer students a unique opportunity to study computer science in a multidisciplinary context. The panel especially praises the Integration courses within these specializations, which it considers a very good method to compose a coherent multidisciplinary programme. According to the panel, the research-focused bachelor's thesis reflects the research orientation of the programme, and offers an appropriate capstone to a fundamental and theoretical programme.

The panel does remark that some topics of the ACM model curriculum are only covered as part of a single course. It recommends the programme, if it wants to maintain full coverage, to keep a good overview of this. This is especially relevant as the programme regularly updates its curriculum to include emerging topics and fields, such as AI. Such an overview could also be helpful if the programme ever has to make a choice of dropping certain elements from the curriculum.

The panel noted that the learning trajectories within the programme are rather implicit. The courses are grouped into five themes (programming, systems, theory, mathematics and skills & projects) and the coherence within these themes is regularly discussed among teachers. However, the programme does not explicitly describe for its students how knowledge and skills are built up within these themes throughout the curriculum. The panel recommends the programme to make an insightful overview for students of the learning trajectories within the curriculum. This is especially the case for the skills & projects theme. Although elements of skills training are present in many of the courses, they were not always recognized by students as academic skills training. A clear learning trajectory might remedy this.

The large majority of students follow fulltime education, but as an extra service the programme provides a part-time variant for all three specializations. On average, 1-3 students per year register for this variant. With these part-time students, the programme arranges for an individual curriculum of 30 EC per year. These students follow the regular courses, in which the programme takes care that the individual part-time curriculum is consistent and meets the prerequisites of the respective courses. The panel concludes that this set-up sufficiently allows students to achieve the intended learning outcomes on a part-time basis.

#### *Master's programme Computer Science*

The master's programme Computer Science offers students the opportunity to specialize in a computer science field of choice. It offers a wide range of specialist courses offered by the researchers at LIACS. The programme aims to have all LIACS researchers contribute to the master's programme by offering a course in their specialism. This means that the offer of electives can fluctuate yearly as the research staff and their specializations change. Students have a lot of freedom to compose their own curriculum. They choose one of five specializations (as per 2019-2020 – see Standard 1), which offer a semi-structured curriculum of mandatory, electives and specialization courses in either Advanced Computer Science, Foundations of Computer Science, Artificial Intelligence, Data Science or Bioinformatics.

These specializations typically have 30-36 EC of mandatory courses within the field of the specialization, and 36-48 EC of specialization courses and electives, which can be chosen from a selection of courses offered within the specialization (specialization courses) or from all master's courses offered within the programme (electives). All students finish the programme with a master's thesis of 42 EC, in which they perform an independent research project, either within one of LIACS's research groups or externally at another institution or company. Students that participate in the Science Communication and Society (SCS) or Education (EDU) specialization follow a 60 EC one-year curriculum in Computer Science (consisting of a thesis and a series of electives associated with the thesis topic), and either a dedicated 60 EC curriculum in the field of SCS, completed with an internship, or a 60 EC curriculum dedicated to becoming a teacher in computer science in secondary school. The CS thesis is considered the formal capstone of this master's programme.



The panel has studied the curriculum of the programme, as well as the content of a number of courses. It concludes that students have the opportunity to choose from a wide number of topics in computer science to fit their preferences. The five specializations offer a coherent curriculum within specific subfields, while the wide variety of electives offered by LIACS researchers allow students to add on to this subfield as they see fit. The frequent changes in the electives offered keeps the programme fresh and up-to-date, without compromising the solid core of the programme. The panel considers the five new specializations an improvement over the current situation with more loosely structured tracks, as it helps students to construct a more coherent curriculum from a wealth of choice. The research focus of the programme is clearly reflected in the electives offered by LIACS researchers on their field of expertise, as well as in the master's thesis that requires students to perform a 42 EC independent research project.

As in the bachelor's programme, the master's programme Computer Science could benefit from an explicit description of the learning trajectories within the programme. In this programme this is even more relevant, as many of the courses that offer academic skills training are electives, causing an uneven distribution in the amount of training in certain academic skills throughout the student population. An explicit learning trajectory for skills could help students to compose a more coherent curriculum in terms of academic skills training.

#### *Master's programme ICT in Business and the Public Sector*

The curriculum of the master's programme ICT in Business and the Public sector consists of 55 EC compulsory courses, distributed over ICT and Business (32 EC), Business Management Fundamentals (14 EC) and Methodology (9 EC). Methodology consists of three courses dedicated to research skills, most prominently the skills needed to perform the master's thesis. Furthermore, students choose a specialization in either Business or the Public Sector, for which they follow 18 EC of specialization courses. 9 EC is reserved for electives, and 38 EC for the research project that is the master's thesis of the programme. As of 2018-2019, the programme has started a closer cooperation with the Business Studies department at the Faculty. This allowed the programme to extend its scope to include topics previously covered by the Science-Based Business specialization of the master's programme Computer Science. These topics are mostly provided in electives.

The panel has studied the curriculum of the programme, as well as the content of a number of courses. It concludes that in general, the programme has adequately translated the intended learning outcomes into a coherent curriculum. The interdisciplinary core of computer science, business (management) and economics connects students to both ICT and the practice of business and government, fitting the goals of the programme. Students have the opportunity to specialize in either ICT for business or the public sector, allowing them to pre-sort for a career in either field. The electives allow students to specialize further with regard to their own preferences. The recent addition of extra electives in Business Studies resulting from the cooperation with the SBB-specialization provides students with extra opportunities to specialize in this direction.

Students are admitted to the programme with a bachelor's programme (either academic or hbo) in Computer Science, or a closely related subject. Students with an hbo bachelor's degree can be requested on their admission to follow additional BSc courses in parallel to the curriculum of the master's programme. The programme management ensures that the scheduling of the curriculum allows for this. The programme has no standard pre-master's programme. It uses part of the compulsory bachelor's courses to level students with regard to knowledge and skills in Computer Science and Economics & Business. As a result, some courses have an overlap in content with related courses from the CS&E track in the bachelor's programme Computer Science at Leiden. Therefore students that previously followed the CS&E track are exempted from following the business and economics courses and instead follow a 15 EC standard package of computer science electives. All students from the bachelor's programme Computer Science at Leiden can also opt to replace the 3 EC Software Engineering with an elective.

Throughout the site visit, the panel discussed the topic of admission and bringing students of various groups up to the same level. Students indicated to the panel that the level of students admitted to the programme varied considerably with regard to either business & economics, computer science, mathematics or research skills. As a result, they felt that some of the courses were not as challenging as they could have been due to the time spent on levelling students. The teaching staff of the programme thinks that this might partly be attributed to a start-up problem resulting from the recent integration with the SBB specialization, as the Business Studies teaching staff has to adapt to a different audience. The panel agrees that this might be correct, but also suggests that the set-up of the curriculum and the absence of a bridging programme contribute to this. According to the panel, it is unusual that the master's programme ICT in Business and the Public Sector is considered by LIACS to be the logical follow-up of the CS&E-track in the bachelor's programme, and yet also has a substantial overlap of 15-18 EC with this same programme. The panel does understand that the programme aims for these master's courses to exceed the bachelor's level courses with regard to the speed of introducing new topics and advanced exercises. However, it thinks that the overlap is too significant for a master's programme, which is reflected in the fact that CS&E students are exempted from these courses.

The panel recommends the programme to address deficiencies of students in a bridging programme. This should include bringing hbo students up to the desired level before the start of the programme rather than in parallel. If necessary, the programme could label a limited part of electives as deficiency space to prevent extended study duration for students with small deficiencies. The panel was happy to learn during the site visit that the programme management is considering to introduce such a bridging programme. It strongly encourages the programme to continue with this. The additional space that is freed up in the curriculum could for instance be used to make (parts of) the CS electives currently offered to CS&E-students part of the mandatory curriculum. Furthermore, the programme should carefully monitor and evaluate the courses to make sure that they are challenging enough for all students. This is especially the case for the Business Studies courses offered by teaching staff new to this programme. After discussions with the programme management and LIACS management, the panel is confident that the programme will be able to implement these changes in the near future.

With regard to the integration of research skills within the programme, students felt that the Methodology courses are rather isolated within the curriculum. They would prefer research skills training to be better integrated in the other courses, which they think are more focused on professional skills, especially in the ICT in Business specialization. According to the students, this could add to the challenge of the courses as well as allow students to get more research practice before starting on the master's thesis. The panel agrees with this, and recommends the programme to better integrate research skills within the curriculum rather than only concentrating them into three separate courses.

#### *Master's programme Media Technology*

The master's programme Media Technology consists of 62 EC of mandatory courses, 16 EC electives, a 12 EC research and exhibition project and a graduation project of 30 EC.

The *mandatory courses*, which are mainly programmed in the first year, provide theory and skills necessary to conduct research using new technologies. Students follow a number of introductory courses in the first block, such as Introduction to Programming, Research Fundamentals and Essentials in Arts and Music. The other three blocks include theoretical courses on for instance Human Computer Interaction, Sciences and Humanities and Non-Human Cognition, and more skills-oriented courses such as Research Fundamentals, Playful & Creative Science and Sound, Space and Interaction. Students can substitute certain mandatory courses with additional electives when they have proven knowledge of the topics from previous education. For instance, students with a Computer Science background usually apply to substitute the Introduction to Programming course. The Board of Examiners makes the decision on substitutions after consulting the programme's Executive Board.



The *electives* can be scheduled by students whenever they see fit, but are usually taken in the second year. Students can choose master's level courses from all Leiden University's faculties or at other institutions after permission by the programme's Executive Board, or in the case of non-standard choices by the Board of Examiners. This decision is based on the motivation of the student of how the particular subject fits the individual curriculum of the student, and the level and content of the course. Students occasionally choose either an internship or an international exchange programme. Such requests are handled individually, and are usually scheduled by replacing the research and exhibition projects and/or electives.

The second year is concluded with two larger projects, the *research and exhibition project* and the *graduation project* (thesis). In the research and exhibition project, students create an innovative product or installation to answer a research question, after which all creations are exhibited in a place open to the public. In the graduation project, students perform an individual research project that should at least have a technological component, and requires creativity to answer the research question. Alongside the graduation project they follow the Graduation Lab, a number of meetings in which students receive additional training on skills and discuss their project progress with fellow students and staff members.

The panel has studied the curriculum of the programme, as well as the content of a number of courses. It is positive about the heterogeneity of the mandatory courses, through which the programme combines various topics in technology, art and research into a coherent, interdisciplinary core. Together it forms a unique curriculum for students looking to develop their skills and attitude in order to investigate research questions in a creative way. With regard to the electives, the panel values the freedom students have to choose their own courses. It however thinks that students could benefit from a more formalized approach to the choice of electives in order to improve the coherence between electives and the mandatory courses and projects. For instance, the programme could ask students to propose an individual curriculum for approval with regard to coherence, rather than approval of separate electives. The panel considers that the projects in the second year fit the goals of the programme very well, and stimulate students to apply their knowledge and skills to creative research projects using technology.

The panel is positive about the attention to research skills within the programme. Even though students of the programme often work with performing and creative arts, they identify as researchers beyond any doubt. The skills courses within the programme ensure that students learn to always apply art and new technology as a means to answer scientific research questions rather than as a goal by itself. This approach was also consequently reflected in the course materials and projects that the panels studied. One academic skill that the panel missed in the courses was awareness of ethical considerations when working with human test subjects. It recommends the programme to include this topic in the skills courses and in the projects.

During the site visit, the panel discussed with various groups to what extent the introductory courses, such as Introduction to Programming, are fitting as part of a master's programme, or whether they should belong in a bridging programme. These courses in the first block are intended to bring the diverse student population on the same level with regard to arts, programming and academic skills. According to the programme, the courses are called introductions but they clearly differ from bachelor's level courses with regard to the speed of introducing new topics and advanced exercises. The panel agrees with the programme that the content of these courses cannot be compared to similar courses at bachelor's level. However, it also thinks that this does not diminish the fact that these courses are intended for bringing students up to the same level, and that 10 EC is quite high for this purpose. It recommends the programme to create a bridging programme in which students can remedy their deficiencies before entering the programme. If necessary, the programme could label a limited part (smaller than the current 10 EC) of electives as deficiency space to prevent extended study duration.



## Didactic concepts

### *Bachelor's and master's programme Computer Science*

The bachelor's and master's programme Computer Science aim to offer a balance of theory and practice throughout the curriculum. This is reflected in the didactic concept of the programmes. Most courses offer lectures combined with assignments and projects in which students can apply the theory offered in the lectures in practice. These projects are often performed in teams to give students the opportunity to practice transferable skills such as communication and teamwork. An example is the bachelor's course Software Engineering, in which students are assigned to projects submitted by staff and work on real problems in groups of two or three. In some of the bachelor's courses and in many of the master's courses, assignments take the form of scientific essays or papers, in order to reflect the research focus of the programme and to offer students the opportunity to practice their academic skills.

The panel is positive about the didactics in the bachelor's and master's programme Computer Science. It praises the clear connection with both the research focus of the programme and the practice of computer science. It does note that the programmes only sporadically use innovative teaching methods, such as flipping the classroom or using digital tools for active learning. Upon discussing this with the teaching staff, the panel noted some hesitance towards experimenting with such teaching methods. The panel encourages the programmes to explore the use of innovative teaching methods, as it considers the use of IT in teaching a natural fit for computer science programmes.

### *Master's programme ICT in Business and the Public Sector*

The master's programme ICT in Business and the Public Sector aims to integrate LIACS's research strengths with a practical component provided by lecturers active in business or the public sector. This practical component begins at the very start of the programme, where students do a one-day business game simulation, giving students an impression of managing a company. Courses often include realistic problems from or in collaboration with companies and public institutions, and are aimed to provide students with transferable, professional skills as well as research skills. This didactic concept is used throughout the entire programme, but is most apparent in the Capstone Cases, in which students work in groups on an actual problem of a real company, integrating research in a practical setting.

The panel is positive about the didactics of the programme, which it thinks fits the goal of the programme to bridge the gap between ICT and industry/society. Students value the teaching methods of the programme, and specifically the connection to the professional field. This connection is guaranteed through the involvement of businesses and public institutions in the courses. The programme is connected to research through the involvement of LIACS's research staff, although the institute does not have a designated group for ICT in Business research. The planned expansion of LIACS's research staff in this direction (see teaching staff) is aimed to strengthen this tie, an initiative which the panel applauds.

### *Master's programme Media Technology*

The didactic concept of the master's programme Media Technology is *learning by doing*. It is a small-scale programme in which students continuously work on projects in which they apply theory in practice. They are stimulated by their supervisors to develop their own research projects based on their own scientific curiosity and questioning. These projects often include a concrete product, such as a new technological concept or a physical installation. These are not supposed to be gimmicks or art, but a demonstration of research results. Students often work in multidisciplinary project teams, in which they are stimulated to use the diversity in background, opinions and methods to approach a topic from various angles.



The panel was impressed by the student-centred didactic approach of the programme, and the wide range of possibilities that the programme offers in order to enable *learning by doing*. Through the interviews with teaching staff and students, as well as through the tour of the facilities, the panel learned that students are very satisfied with this approach, and feel challenged to apply new technologies to creatively try to answer scientific questions. Due to the small-scale nature of the programme, students can be closely coached to develop academically sound and feasible projects to investigate research questions in a playful way. The diverse student population in terms of academic and cultural background allows the programme to form truly multidisciplinary and diverse project teams in a genuine international classroom.

### Language of instruction

The bachelor's programme Computer Science is offered in Dutch, but some of the courses are given in English, most prominently in the third year. This gives students the opportunity to get acquainted with English as instruction language to prepare them for a master's programme. It also allows the programme to assign non-Dutch teaching staff to more advanced bachelor's courses. Students appreciate this set-up, in which they can gradually learn to adapt from Dutch to English as instruction language.

All three master's programmes are offered in English, as the programme considers this the common language for international research in the natural sciences. As active researchers in the field, all the teaching staff sufficiently master the English language. Upon hiring, the university requests teachers to either show or obtain a Qualification of English Proficiency at level C1. Students are satisfied with the English language proficiency of their teachers.

The panel agrees with the choice of the bachelor's programme to gradually switch to English, and thinks this is a good way to help students adapt to English as instruction language. It fully supports the use of English in the master's programmes, and is positive about the proficiency qualification required of the teaching staff. It however points out that this does not include external teachers, which form a significant part of the teaching staff in the master's programme ICT in Business and the Public Sector. It recommends this particular programme to also request an English proficiency qualification for external teaching staff that is structurally involved in the courses. Based on some of the theses of the master's programme ICT in Business, the panel concludes that the English language proficiency of some of the international students is subpar. It recommends the programme to investigate whether extra measures might be necessary to improve this. The panel considers the intake interview that the master's programme Media Technology conducts with prospective students to be a good practice in this regard.

### Feasibility

#### *Bachelor's and master's programme Computer Science*

The panel has studied an overview of the study success for both programmes, and discussed the feasibility of the programmes with students, teaching staff and programme management. This overview shows that students take longer than intended to complete the programme, with only half of the students graduating within nominal+1 year study duration in both programmes. On the other hand, the drop-out rates are low throughout the programmes, with 15% or less leaving before graduation.

The exception is the track Bioinformatics in the bachelor's programme, where more than 40% of students drop out, as compared to approximately 10% in the other tracks. The supposed causes for this are the underestimation of the computer science content by prospective students, and the mismatch of the semester system in LIACS and the 4-block system in IBL. The programme has remedied this with introducing matching interviews before enrolment and by making the deadlines for Bioinformatics students more flexible to address the mismatch between the semester and block systems. In 2019/20, the track will switch to a hybrid block/semester system to facilitate better

scheduling. These measures seem to be effective, as the 2018/19 cohort of students show a much more favourable drop-out rate.

The programme attributes the long study duration in the Computer Science programmes mainly to extracurricular causes, most prominently to the fact that many students have part-time jobs in the IT sector. To get a grip on this, LIACS has launched the Applied Data Science Lab, which acts as an intermediary between students and industry, to prevent industry from directly approaching students with job offers. The Applied Data Science Lab employs students so they can do projects for industry, while being facilitated to complete their study programme. The programme also hopes that the new structure of the master's programme Computer Science helps to remove a possible curricular cause of long study duration, as it helps students compose a more structured curriculum without being overwhelmed with choices and electives.

The panel is positive about the feasibility of the Computer Science programmes, and was able to verify in the interviews that students experience no curriculum-related obstacles in completing the programme. The panel applauds the Applied Data Science Lab initiative and the attention the programmes have to prevent students of exiting the programme without diploma. It endorses the measures the programme has taken to reduce drop-outs in the bachelor's track Bioinformatics and agrees that these seem to be effective. It is also positive about the restructuring of the master's programme Computer Science into more fixed specializations to help students streamline their curriculum. It advises the programme to also pay attention in the new structure to advising students on their curriculum in order to improve feasibility, as the new structure still has a lot of room for individual choice.

#### *Master's programme ICT in Business and the Public Sector*

For the master's programme ICT in Business and the Public sector, roughly 60% of the student population graduates within three years, and only a limited percentage (<20%) drops out. The programme expects that the study success will further improve in the coming years, as it has recently dropped its post-experience programme where students enrolled that combined the programme with a part-time or full-time job. The panel approves of the feasibility of the programme, and notes that the students experience no obstacles in completing the curriculum in a timely manner.

When studying the curriculum, the panel noticed a discrepancy in the study load between the blocks. For instance, block 1 of the first year has a 20 EC study load, whereas block 4 has 14 EC. The programme mentions that this imbalance is only on paper, and that in practice, the study load is evenly distributed between blocks. This was confirmed by the students. The panel however recommends the programme to show this balance also on paper, and adapt the (presentation of) the curriculum accordingly.

#### *Master's programme Media Technology*

For the master's programme Media Technology, the study success has improved in the last years from half of the students graduating within three years, to two-thirds. Only a very small percentage (<5%) drops out. The programme attributes this increase in the success rate to successful measures taken to decrease thesis duration, including stricter deadlines, and extra meetings to support students working on their thesis. The panel approves of the feasibility of the programme, and praises the programme for the low number of drop-outs, which it thinks is the result of a very successful admission procedure. The panel also notes that the students experience no obstacles in completing the curriculum in a timely manner, although they do mention that they sometimes have trouble keeping to deadlines due to excessive enthusiasm about their own projects. The panel agrees that the open nature of the projects within the programme has the associated risk of spending more time on it than intended. According to the panel, the programme is aware of this, as is reflected in the measures taken for timely completion of the thesis. The panel encourages the programme to keep this up, for the thesis projects as well as for other student projects.

Just as in the master's programme ICT in Business and the Public sector, the panel noticed a discrepancy in the study load between the blocks. For instance, block 1 of the first year has a 12 EC



study load, whereas the other three blocks have 16 EC. The programme mentions that this unbalance is only on paper, and that in practice, the study load is evenly distributed between blocks. This was confirmed by the students. The panel however advises the programme to show this balance also on paper, and adapt the (presentation of) the curriculum accordingly.

### Teaching staff

#### *Bachelor's and master's programme Computer Science*

Almost all teaching staff of the Computer Science programmes is associated with the LIACS institute, with the exception of the biology and economy & business courses in the bachelor's programme. Nearly every permanent staff member of LIACS is involved in education, at the minimum through an elective in the master's programme. Obtaining a Basic Qualification in Teaching (BKO) has been a prerequisite for every new teacher since 2008, and >90% of these teachers currently has a BKO or is in the process of obtaining one. Students indicated to the panel that they are enthusiastic about their teachers, and feel that the staff is very approachable, even though the number of students in LIACS is high. The panel is positive about the teaching staff of the Computer Science programmes, and praises the professionalization of teachers through BKOs. As active researchers, the teaching staff is able to connect the courses to their own research, providing students with the opportunity to stay up-to-date on current research.

Both the bachelor's and master's programme Computer Science have experienced a substantial increase in student numbers with the associated increase in workload for the teaching staff, with almost double the numbers (96 to 170 for the bachelor, 36 to 67 for the master) compared to 2014. The programmes have been able to counter this by a growth in teaching staff, mainly due to investments in fields such as artificial intelligence, data science and security. The teaching staff considers the workload high, but still feasible. The bachelor's programme has hired more student assistants to relieve the workload of the teaching staff. In the interviews with staff and students, the panel learned that the programme cannot always find suitable candidates for these positions due to competition with other lucrative part-time jobs for master's students. The panel advises to step up the efforts towards hiring more student assistants, if necessary among PhDs or elsewhere, as it understood that there is a need for this. In general, the panel supports the measures the programme management take to match growing student numbers with an increase in staff, and to keep monitoring this closely.

#### *Master's programme ICT in Business and the Public Sector*

The teaching staff of the masters programme ICT in Business and the Public Sector consists of lecturers with different background:

- LIACS research staff offering the computer science courses;
- Staff from the Business Studies department at the Faculty of Science for the business courses;
- Lecturers of the Institute of Public Administration for the Public Sector courses;
- External lecturers associated with business or government for the integrative, practical courses.

The first three groups of lecturers are all associated with Leiden University, hold a PhD and are required to obtain a basic qualification in education (BKO). The last group of external lecturers provides the connection to practice rather than research, and often does not hold a PhD. As for their teaching competence, they are selected based on previous teaching experience and are regularly evaluated. Most of the collaborations of the external lecturers in the programme are a long-term cooperation where the lecturer has a broad teaching experience. External lecturers can participate in the BKO courses on a voluntary basis, which some of them have done.

The panel is positive about the quality of the teaching staff of the programme. Students are satisfied with their teachers and told the panel that they think their teachers are well-qualified and approachable. They in particular value the collaboration with external lecturers from within the

professional field, which they feel contributes to the goals of the programme. The panel agrees with this, and thinks the integration of research and practice, which the programme aims to bridge, is well reflected in the teaching staff. It recognizes the need for external lecturers, and praises the attention of the programme to monitoring the external teaching staff to ensure the academic level of the courses. It advises the programme to keep this up, and to also keep stimulating its external lecturers to obtain a BKO qualification.

During the site visit, the panel understood that LIACS is in the process of creating a research group in ICT in Business and the Public Sector, specifically to create a better connection between this master's programme and current research within the field. This would include the appointment of a full professor in ICT in Business, who would become closely involved in this programme. The panel applauds this. Although qualified experts, not all current teaching staff is involved specifically in research concerning ICT for business and the public sector. A research group dedicated to this field would strengthen the programme and further improve the balance between research and practice.

#### *Master's programme Media Technology*

The master's programme Media Technology is offered by a small team of eight teachers employed at LIACS with a broad background and expertise in technology, such as human-computer interaction and multimedia. Some (parts of) courses related to arts and music are taught by lecturers from Leiden University's Academy for Creative and Performing Arts, and external lecturers associated with the Royal Conservatoire and the Royal Academy of Arts in The Hague. All teachers have obtained a BKO or are in the process of obtaining one, and all of the educational staff hold a PhD.

The panel is positive about the teaching staff of the programme, and considers the team a good mix of the various disciplines relevant to this multidisciplinary programme. It concludes from the interviews during the site visit that the teachers are highly committed to the programme. Students mention that their teachers create a very stimulating and creative atmosphere, and that they are very accessible to students. The panel praises the programme for this. It realises that the unique concept of the programme means that it has a small window of viability around 30-35 students annually. Too few students and the multidisciplinary environment and the feasibility of the programme is endangered, too many students and the workload for the small teaching staff will be too high. The programme manages to stay within this window through a careful admission procedure through which it selects roughly 30-35 students annually. The panel considers this wise. It also encourages the programme management to keep looking for cross-fertilization with other programmes within the university to share teaching staff and make the programme less vulnerable in this aspect.

#### Facilities

Three of the four programmes are all located in the LIACS building on the Leiden Campus. The master's programme ICT in Business and the Public Sector is located in The Hague (although some courses are offered in Leiden), as well as parts of the bachelor's programme (track CS&E). In the case of CS&E students, some of the courses are scheduled in Rotterdam at the Erasmus University. Due to the short distances between these cities and the scheduling of courses to minimize travel during the day, students experience little to no obstacles.

The panel encountered widely shared complaints between students of all programmes concerning the LIACS building and the associated facilities. Among the complaints were suboptimal temperature control, desktop computers instead of laptops for students and dated furniture and equipment. The programme management is aware of these issues and indicated that relocation to a new building is planned for 2023. The panel understands the situation, and endorses any temporary solutions that can be taken to improve the facilities. The programme could for instance consider to provide bachelor's students with laptops or to support the bring-your-own-device principle, which is common practice in many similar programmes.



Another complaint that the panel encountered more than once during the site visit, mentioned by the staff was the uSIS system for student administration, which some of the staff members consider so problematic that they prefer to use own data or alternative techniques to get student information. The panel cannot appreciate the full extent of this issue but advises the faculty to ensure that this situation will not have negative consequences for students in the future.

The master's programme Media Technology has additional facilities for its students to accommodate projects, which the panel has had a chance to visit during the site visit. The programme has a dedicated student room where students can work on their projects and leave them there overnight, as well as a number of labs with equipment that students can use for their projects. The panel is very positive about these facilities, and sees this as an enhancement of the programme.

## **Considerations**

### *Bachelor's and master's programme Computer Science*

Both the bachelor's and master's programme Computer Science have adequately translated their intended learning outcomes into a coherent curriculum. The bachelor's programme offers both a broad generalist computer science track as well as unique multidisciplinary tracks with economics and biology. The panel praises the integration of the fields within these tracks through the Integration Courses. The master's programme offers a wide variety of choices for students to specialize. The panel supports the planned curriculum change towards more structured tracks, and thinks this will further improve the coherence and feasibility of the programme. The clear integration of research and education keeps the curriculum fresh and up-to-date. The panel recommends to make a clear overview of the current implicit learning trajectories within both programmes. The didactics of the programmes are fitting, although the panel does think the programme could benefit from an increased attention to innovative teaching methods. The part-time variant of the bachelor's programme allows for an individual, coherent curriculum in which students can achieve the intended learning outcomes on a part-time basis.

The programmes are feasible, and have an active policy to prevent early exits to industry, which the panel applauds. Education at multiple locations in the CS&E track in the bachelor's programme is well-implemented. The panel is positive about the teaching staff of the Computer Science programmes, and praises the professionalization of teachers through BKO's. The programmes are successfully dealing with the growth in student numbers, although the bachelor's programme could use more teaching assistants. The use of English as the language of instruction in the master's programme fits the international character of the programme and prepares students for the international job market. The programmes offer adequate facilities, although the building is clearly outdated. The panel endorses any measures that can be taken to improve this until future relocation.

### *Master's programme ICT in Business and the Public Sector*

The master's programme ICT in Business and the Public Sector has adequately translated its intended learning outcomes into a coherent curriculum. The interdisciplinary core of computer science, business (management) and economics connects students to both ICT and the practice of business and government, fitting the goals of the programme. The panel recommends introducing a bridging programme to level students before the start of the curriculum. This bridging programme should aim for a smooth transition between this programme and the CS&E track in the bachelor's programme Computer Science, and address deficiencies of students entering through another route. The panel was happy to learn during the site visit that the programme management is already considering to introduce such a bridging programme. It strongly encourages the programme to continue with this. Furthermore, the programme should carefully monitor and evaluate the courses to make sure that they are challenging enough for all students. The panel is confident that the programme will be able to implement these changes in the near future. Furthermore, the panel recommends the programme to better integrate research skills within the curriculum rather than only focusing on these in the Methodology courses.

The panel is positive about the didactics of the programme, which combines research and practice, and involves actual business and governmental organizations. This clearly contributes to the goal of the programme to bridge the gap between ICT and industry/society. The use of English as the language of instruction in the master's programme fits the international character of the programme and prepares students for the international job market. The panel recommends the programme to investigate whether additional measures are necessary to address the limited proficiency in English of some of the international students. The programme is feasible and students experience no obstacles in completing the curriculum in a timely manner. The teaching staff is well-qualified, and reflects the integration of research and practice that the programme aims for. The panel recognizes the need for external lecturers, and praises the attention of the programme to monitor the external teaching staff to ensure the academic level of the courses. It recommends the programme to keep this up, and to also keep stimulating its external lecturers to obtain a BKO qualification. The panel applauds the planned initiative to create a research group in ICT in Business and the Public Sector at LIACS, which it thinks would strengthen the programme and further improve the balance between research and practice.

#### *Master's programme Media Technology*

The teaching-learning environment of the master's programme Media Technology facilitates students to achieve the intended learning outcomes. The unique curriculum combines various topics in technology, art and research into a coherent, interdisciplinary core, allowing students to develop their skills and attitude in order to investigate research questions in a playful and creative way. Students are offered a large amount of flexibility and choice in composing their own curriculum through electives and projects. The panel is positive about this amount of flexibility, but encourages the programme to introduce a more formalized approach to the selection of electives to help students compose a more coherent curriculum. It also recommends introducing ethical aspects of working with human test subjects into the curriculum. Furthermore, it thinks that the programme should create a bridging programme in which students can remedy their deficiencies before entering the programme, rather than using introductory courses in the programme's core curriculum to this end.

The panel was impressed by the student-centred and multidisciplinary didactic approach of the programme, and the wide range of possibilities that the programme offers in order to enable *learning by doing*. Projects are well-facilitated through project rooms with equipment for students to use. The use of English as the language of instruction fits the international character of the programme and facilitates the international classroom that the programme pursues. The panel concludes that the programme is feasible and has a very low number of dropouts. It encourages the programme to keep up their good work on measures to encourage timely completion of student projects. The teaching staff of the programme is well-qualified, creates a stimulating learning environment and forms a committed team dedicated to the students.

#### **Conclusion**

*Bachelor's programme Computer Science:* the panel assesses Standard 2 as 'meets the standard'

*Master's programme Computer Science:* the panel assesses Standard 2 as 'meets the standard'

*Master's programme Media Technology:* the panel assesses Standard 2 as 'meets the standard'

*Master's programme ICT in Business and the Public Sector:* the panel assesses Standard 2 as 'meets the standard'

**Standard 3: Student assessment**

The programme has an adequate system of student assessment in place.

**Findings***Assessment system*

All four programmes adhere to the assessment policy and exam regulations decided upon at the Faculty level. The assessment policy prescribes for each programme an assessment plan that contains an overview of the learning goals for the entire curriculum, coupled to the various exams within the courses. Assessment methods include written exams with open questions, written reports, oral presentations, essays and demonstration of particular skills, such as programming. The particular form of assessment depends on the nature of the course and the intended learning outcome and can be defined by the teacher as long as it is explicitly made clear beforehand what students can expect concerning the nature, form, depth, length and content of the assessment. If group work is a part of the assessment, this never accounts for more than 40% of the total grade to prevent free-riding, with the exception of the bachelor's course Software Engineering that has cooperation as a main learning objective. To prevent fraud and plagiarism, the topic of research ethics is scheduled as part of the research skills courses for each of the four programmes. The Turnitin software is used systematically to detect plagiarism in theses, and lecturers can use specific software to check plagiarism in programming assignments.

The panel studied the assessment system of the programmes, an overview of the assessment methods and criteria per course, and some examples of exams used within the programmes. It is positive about the variety of assessment methods and the attention paid to the assessment of various skills within the programmes, and the way in which they are aligned with the programmes goals. For instance, the master's programme ICT in Business and the Public Sector often uses assignments and projects inspired by real-life problems in business or the public sector, whereas the master's programme Media Technology mainly relies on research and/or creative projects in which students can demonstrate their ability to approach research questions in a playful and creative manner. The panel is also positive about the attention to prevention and detection of plagiarism and fraud.

The panel noted that not all courses yet implement peer review (four-eyes principle) when composing an exam. The programme management mentions that they would preferably do this for all exams, but that they think this would add too much to the workload of the teaching staff. The panel wants to stress that peer reviewing of exams is an important measure to improve the validity and reliability of exams, and recommends the programmes to implement this structurally. Furthermore, an occasional exceeding of the grading period of 15 days for assignments and exams was reported to the panel for all of the four programmes. The panel recommends the programme to keep paying attention to keeping the deadlines, especially for the bachelor's programme. Here assignments often have a formative function, but can only function as such when students receive timely feedback. The panel was assured that indeed this issue has the attention of the programme management.

*Assessment research projects*

In all four programmes, students conclude their curriculum with an individual research project. With the exception of the master's programme Media Technology (which will be discussed below), this results in a written thesis and a presentation in public. The project is independently assessed by two examiners: the supervisor and a second examiner not directly involved in the project. For the bachelor's programme, only the supervisor is required to have a PhD, while for the master's programmes both examiners must have a PhD. In master's programmes Media Technology and ICT in Business and the Public Sector, exceptions are sometimes allowed for one of the examiners, as long as the examiner involved has his/her educational and assessment skills approved by the Board of Examiners. The assessment focuses on four criteria: project work, thesis, execution of the project and the presentation and defence. The two examiners decide collectively on a grade on all four criteria, and substantiate and register this on a standardized assessment form. The final grade is a



weighted average of the four criteria, with the thesis itself accounting for the largest part (50%). Every thesis is checked for plagiarism using the Turnitin software archive.

The panel has studied the assessment form and the use thereof in the bachelor's and master's programme Computer Science, as well as the master's programme ICT in Business and the Public Sector. It considers that the assessment procedure for research projects is adequate. The independent second reader increases the validity of the grading. The assessment forms contain qualitative feedback which generally provides a clear motivation about the grade, and adds to the transparency of the grading, although the quantity of written feedback differs substantially between various assessors. The distinction between the four criteria mentioned above provides insight into the composition of the final grade. The panel noted that the assessment policy of the Faculty does not require students to obtain a sufficient grade on each of the four criteria. In one of the 45 master's theses the panel studied for the three programmes, a student obtained an insufficient grade (5) on the thesis, but due to higher scores on the other three criteria this was raised up to a 6, and the student was allowed to graduate. Based on the thesis text, the panel thinks that this was an undesirable outcome, and that this particular work was an insufficient basis for graduation, independent of the student's performance on other parts of the process. It recommends the faculty as well as the Board of Examiners to reconsider the policy of allowing unsatisfactory subgrades. This especially applies to the thesis sub-criterion, as this is the main criterion for which the assessment can be transparently reproduced, as opposed to for instance execution of the project and presentation.

Due to the nature of the master's programme ICT in Business and the Public sector, most research projects are conducted in-company. Students investigate a real-life problem related to ICT and Business or the Public Sector from both a scientific and a practical perspective. To properly assess these two perspectives, of the two assessors one should have a research background, and the other a professional background. Due to this vision, the Board of Examiners has provided the programme with dispensation for the rule that the supervisor should hold a PhD, as long as the second examiner holds a PhD. Nevertheless, the panel encountered a small number of theses where both examiners did not hold a PhD. The programme management and the Board of Examiners stated that this was due to practical limitations, and that it accepted this as an exception. The panel thinks that this is not desirable for an academic programme and that such exceptions should not be repeated.

In the master's programme Media Technology, students do not write a thesis, but perform a research project on a topic of choice and present their final results in the form of a paper, often in addition to a product that needs to be experienced. In principle, the project is graded using the same procedures and assessment form as the other three programmes at LIACS. However, as the nature of the programme emphasizes the process of doing research in a playful and creative way, the process through which the student performed the research projects plays a major role in the assessment. Based on the recommendations of the previous accreditation, the programme has implemented systematic documentation of this process to guarantee the validity and transparency of this grading process. Students start their graduation project by initially providing a written research proposal to the programmes Executive Board. After approval, the student is assigned a supervisor who considers a second, more detailed research proposal a few weeks further into the process. During the entire process, students keep a log in which they note important steps in the process. At the end of the research project, students describe their results in a scientific-style paper and present this paper, usually together with a product demonstrating the research results, to their supervisors in an open event. The two research proposals, the logbook and the paper together form the documents that substantiate the final grade.

The panel has studied a selection of these documents that accompanied the research projects, and concludes that they provide enough basis to transparently and reliably assess the content as well as the master's level of the research projects. The panel thinks the documentation concerning the research project could be even further developed by including a student reflection. In such a



document, students could bring the proposals, logbook and paper together by reflecting on the process they went through during their projects.

### *Boards of Examiners*

The educational programmes at LIACS are formally served by two Boards of Examiners: one for the bachelor's programme and one for the three master's programmes. In practice, the two Boards overlap in all but the external member. The Boards appoint the programme's examiners and monitors the quality of assessment within the programme. They monitor the quality of assessment through questionnaires filled in by students and perform systematic checks of the exams within the programme in terms of clarity, completeness and level of difficulty. This includes the bachelor's courses offered by IBL and Erasmus University Rotterdam. The Boards also conduct a post-hoc check of the quality of all exams through sampling, with every course being checked approximately once every five years. In addition, they perform statistical checks of the success rate of exams to guarantee comparable standards through time and across courses. A sample of research projects is checked annually for each of the programmes in terms of adequate grading and thesis quality, as well as the correct use of the assessment form. This includes all theses with a 6 or lower, a 9 or higher and a random selection of other theses. In recent samples, the Boards were satisfied with the quality of the judgement.

The panel spoke with the Boards of Examiners and studied a number of their annual reports. It judged that the Boards adequately fulfil their role in the quality assurance of assessment within the programme. The quality assurance measures the Boards have in place are fitting and contribute to the validity of the assessment within the programmes. In several instances mentioned above, the panel noted that not all regulations are strictly adhered to within the programmes. For instance, the panel noted that the Board of Examiners was not familiar with the abovementioned research project that scored a 5 on the thesis subcategory, although it should have been as part of the thesis checks. Furthermore, the Board has occasionally allowed students of the master's programme ICT in Business and the Public Sector to be assessed by two examiners without a PhD. For the same programme, the rule that a minimum of 20% of the thesis content should relate to ICT is not always adhered to (see Standard 4). Finally, the deadlines for grading are not always met in all four programmes. These taken together lead the panel to the conclusion that the Boards of Examiners should take a firmer stance in enforcing the assessment policy and regulations. It recommends the Boards to take up this role and step up its efforts in taking up non-compliance with regulations with the programme management and individual teachers.

### **Considerations**

The programmes have an adequate assessment system that assesses students on all intended learning outcomes. The assessment methods are varied and fit the goals of the various programmes. To improve the validity and reliability of the exams, the panel recommends to implement the peer review principle for all exams. It also recommends to keep paying attention to a timely grading of assignments, especially in the case of formative assessment.

The thesis assessment of all four programmes is adequate, and provides a transparent motivation of the final grades. In the master's programme Media Technology, the additional documentation on the process adds to the transparency and validity of the grading with regard to the research process, which is an important characteristic of the programme. This might be even further improved by adding a student reflection that ties the various components in the process documentation together. For all programmes, the panel recommends to reconsider the rule that an unsatisfactory score for a subcategory of the thesis assessment can still lead to a satisfactory final grade.

The Boards of Examiners adequately fulfil their role in the quality assurance of assessment, but could take a more proactive and normative stance with regard to adherence to assessment policy and regulations, such as the rules for academic qualification of examiners in the master's programme ICT in Business and the Public Sector.

## Conclusion

*Bachelor's programme Computer Science:* the panel assesses Standard 3 as 'meets the standard'.

*Master's programme Computer Science:* the panel assesses Standard 3 as 'meets the standard'.

*Master's programme Media Technology:* the panel assesses Standard 3 as 'meets the standard'.

*Master's programme ICT in Business and the Public Sector:* the panel assesses Standard 3 as 'meets the standard'.

### **Standard 4: Achieved learning outcomes**

The programme demonstrates that the intended learning outcomes are achieved.

## Findings

### *Bachelor's programme Computer Science*

Prior to the site visit, the panel studied 15 research projects of the bachelor's programme Computer Science, divided over the three specializations. The panel is positive about the quality of the projects, which they consider sufficient to good for all three specializations. The theses all correspond to the requirements for a bachelor's thesis in computer science. They showed appropriate research skills, fitting the research focus of the programme. The majority of the students choose to write their thesis in English, although in some instances their command of the language is rather poor. Even though the programme is in Dutch, it might consider paying extra attention to academic English in the thesis preparation process when it allows non-Dutch theses.

Most graduates of the programme continue with a master's programme. 60% of the bachelor graduates choose a master's programme at LIACS, mostly Computer Science or ICT in Business and the Public Sector. The remaining 40% chooses a master's programme elsewhere at Leiden University or at another university, or find a job in the ICT sector. The programme does not have exact numbers of students entering the labour market with a bachelor's degree, but estimates this to be around 10%. Alumni of the bachelor's programme report no obstacles in their respective master's programmes, which the panel considers to be an indicator of the successful realization of the intended learning outcomes of the programme.

### *Master's programme Computer Science*

Prior to the site visit, the panel studied 15 research projects of the master's programme Computer Science, divided over all specializations. The panel is positive about the quality of all projects, which they consider sufficient to high for all specializations. The theses all correspond to the requirements for a master's thesis in computer science. They show appropriate research skills, fitting the research focus of the programme. According to data provided by the programme, 24% of master's theses of the past two years have resulted in scientific publications. The panel considers this very high and praises the programme for this.

The graduates of the programme are very much in demand, both as PhD students or in industry. 10-20% of graduates continue in a PhD position, the large majority of the rest find a job in the ICT sector. Many students already find or even start a job before graduation. Those who wait until after graduation usually find a job within one month. The panel considers this to be an indicator of the successful realization of the intended learning outcomes of the programme.

### *Master's programme ICT in Business and the Public Sector*

Prior to the site visit, the panel studied 15 research projects of the master's programme ICT in Business and the Public Sector. As the Public Sector specialization started last year, there were no theses available for this specialization yet. The panel is positive about the quality of the projects, with one exception. This student obtained a 5 on the thesis, but was able to compensate this with higher marks on other subcategories, raising the overall grade up to a 6. Due to the fact that the



programme itself recognized the thesis as unsatisfactory, the panel considers this an issue concerning assessment policy rather than realized learning outcomes. This case is further discussed under Standard 3. In one other thesis that was acceptable in terms of level, the panel considered the ICT content virtually absent, although this is supposed to be at least 20% of the project. The panel recommends the programme to more strictly enforce the rules concerning thesis topics. In some instances the command of the English language was rather poor. The panel recommends paying extra attention to academic English in either the admission criteria of the programme or the thesis preparation process. In general, the theses are satisfactory, and show that students are able to bridge the gap between real-life problems in business and scientific research, in line with the goals of the programme.

The graduates of the programme are very much in demand in industry. They easily find a job as IT consultant or Chief Information Officer or alike, within the Netherlands or internationally. Alumni indicate that the job opportunities are excellent and diverse, and that their unique skill set combining business and IT is in very high demand. The panel applauds the programme for the very good career opportunities of its graduates, and thinks that this shows that the programme is successful in realizing its goals.

#### *Master's programme Media Technology*

Prior to the site visit, the panel studied 15 research projects of the master's programme Media Technology. The panel is positive about the quality of all projects, which they find of sufficient quality and often positively surprising in terms of creativity of research questions and methods. They show appropriate research skills, applied in playful and creative ways, reflecting the research focus of the programme. All involve the use of technology to answer a research question. The topics show a wide variation, ranging from using virtual reality as a context for memorizing to communication of AI in newspapers and generating musical melodies through swarm algorithms.

Compared to the other two master's programmes, Media Technology has a more diffuse labour market perspective. Alumni end up in a variety of positions, including PhD candidate or teacher, in museums, cultural organizations, the creative industry or in the broader IT sector. Students all find a job within 6 months after graduation, with more than 60% within one month. The panel is positive about the labour market position of the graduates.

#### **Considerations**

The panel concludes that the final projects of all four programmes are of sufficient quality, and convincingly show that the intended learning outcomes of the various programmes are achieved. The panel agrees with the grading, and praises in particular the master's programme Computer Science for the high number of scientific publications resulting from master's theses. It recommends to pay extra attention to the level of command of the English language in the bachelor's programme and the master's programme ICT in Business and the Public Sector, and to the requirements for thesis topics in the ICT in Business and the Public Sector programme.

The bachelor's students experience no obstacles in their respective master's programme. The graduates of the master's programmes (and to some extent also the bachelor's programme) are very much in demand on the labour market, both as PhD researcher as well as in industry. The latter is most prominently the case for the Computer Science and ICT in Business and the Public Sector master's students, where almost all students find a job during or immediately after completion of the programme.

#### **Conclusion**

*Bachelor's programme Computer Science* the panel assesses Standard 4 as 'meets the standard'.

*Master's programme Computer Science:* the panel assesses Standard 4 as 'meets the standard'.

*Master's programme Media Technology:* the panel assesses Standard 4 as 'meets the standard'.

*Master's programme ICT in Business and the Public Sector*: the panel assesses Standard 4 as 'meets the standard'.

## GENERAL CONCLUSION

The panel assesses all standards of the NVAO's Framework for a limited programme assessment 2018 for all four programmes as 'meets the standard'. According to the decision rules of the framework, the panel assesses positively on all programmes.

### **Conclusion**

The panel assesses the *bachelor's programme Computer Science (full-time, part-time)* as 'positive'.

The panel assesses the *master's programme Computer Science* as 'positive'.

The panel assesses the *master's programme Media Technology* as 'positive'.

The panel assesses the *master's programme ICT in Business and the Public Sector* as 'positive'.



## APPENDICES





## APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

The Computer Science programmes at LIACS use the ACM Computer Science Curricula 2013 as domain-specific framework of reference. This curriculum framework is used by many programmes across the world and the Dutch computer science programmes have agreed to use it for bachelor's programmes, and as starting point for the master's programmes. This extensive document is available at: [https://www.acm.org/binaries/content/assets/education/cs2013\\_web\\_final.pdf](https://www.acm.org/binaries/content/assets/education/cs2013_web_final.pdf)

The Association for Computing Machinery (ACM) is an internationally recognized institute that produces resources with the intention of helping computer science and similar fields advance scientifically as well as professionally. Besides giving detailed lists of subject matter to be covered in an undergraduate programme, it describes a computer science graduate in 11 characteristics.

At a broad level, the expected characteristics of computer science graduates include the following:

1. Technical understanding of computer science
2. Familiarity with common themes and principles
3. Appreciation of the interplay between theory and practice
4. System-level perspective
5. Problem solving skills
6. Project experience
7. Commitment to life-long learning
8. Commitment to professional responsibility
9. Communication and organizational skills
10. Awareness of the broad applicability of computing
11. Appreciation of domain-specific knowledge

For a more detailed coverage, please refer to chapter 3, page 23 on the above link.

## APPENDIX 2: INTENDED LEARNING OUTCOMES

### **Bachelor's programme Computer Science**

Graduates with a Computer Science degree have achieved the following learning outcomes:

- a. They have knowledge and understanding in the basic courses, current concepts and methods of Computer Science;
- b. They are able to independently study further relevant subjects and to acquire the necessary skills for a follow-up study that presupposes a high level of autonomy;
- c. They have sufficient theoretical and practical skills in Computer Science to conduct research under (strict) supervision;
- d. They have the ability to think critically, to abstract, and to analyse a scientific problem;
- e. They have insight into the way in which current hypotheses can be tested through experiments, and how acquired knowledge can lead to the formulation of theories;
- f. They have insight into the position of different sub-areas within Computer Science and their relation to adjacent scientific areas;
- g. They have the ability to communicate with research colleagues about research results;
- h. They have sufficient knowledge and understanding of the social and societal role of computer sciences to be able to reflect on scientific and societal problems from acquired knowledge and insight.
- i. They have the ability to apply basic mathematics, algorithmic principles and computational theory in the modelling and design of software systems in a way that shows the understanding of the compromises involved in design choices.
- j. They are capable of designing, implementing and evaluating a process, component or program on a computer system alone or in a team, while meeting the desired needs of the user.
- k. They are also able to analyse a problem and identify and define the computational requirements needed for the solution.
- l. They have basic knowledge of the functioning of a computer at hardware level.

Graduates of the specialization Computer Science:

- m. are able to apply design and development principles in the construction of software systems of different complexity;
- n. understand the interplay between theory and practice;
- o. can describe how operating systems are structured in general;
- p. have sufficient insight into the quantitative principles of the design of computer systems;
- q. have an overview of the most important subfields of foundation of computer science, artificial intelligence and data science.

Graduates from the Bioinformatics specialization integrate fundamental and applied knowledge of biology with analytical and quantitative tools. They:

- r. are able to describe formal and computational biological phenomena and can design models for analyzing and interpreting experimental data;
- s. they have an overview of the main areas of artificial intelligence and data science.

Graduates from the Computer Science & Economics specialization integrate fundamental and applied knowledge of economics and finance with computational methods. They are able to:

- t. model business processes and explore financial processes and data with methods from data science;
- u. to apply design and development principles in the construction of software systems of varying complexity.

## **Master's programme Computer Science**

### *a General learning outcomes, common to all specializations*

Graduates of the MSc programme Computer Science have attained the following general learning outcomes:

- a. theoretical and practical skills in more than one specialist area of computer science, such that they can carry out research under overall supervision;
- b. the ability to make an independent analysis of scientific problems, analysis of relevant specialist literature, formulate verifiable hypotheses, and set up and carry out research and critical reflection on one's own research and that of others;
- c. the ability to interrelate and integrate various areas of computer science;
- d. the ability to present clearly, verbally as well as in writing, one's own research results, and the ability to communicate with colleagues and to present their research results as a contribution to a congress or as (part of) a scientific publication;
- e. sufficient understanding of the social and societal role of computer science to be able to reflect upon it and in part consequently to come to an ethically sound attitude and corresponding execution of one's professional duties;
- f. have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous.

### *b1 Specific learning outcomes specialization CS and Advanced Data Analytics*

In addition to the general achievements, graduates of the specialization Computer Science and Advanced Data Analytics have obtained in-depth knowledge of a specific subject related to at least one of the following four areas:

- computing systems (programming high performance computers and embedded systems, building multimedia systems);
- data analytics (in-depth knowledge of data mining techniques, algorithms for large graphs, and neural networks);
- artificial intelligence (knowledge on deep and reinforcement learning methods, understanding the principles of evolutionary computation and its application for optimization algorithms);
- algorithms (knowledge of verification methods and modelling techniques, and understanding of advanced data structures and algorithms).

### *b2 Specific learning outcomes specialization Data Science*

In addition to the general achievements, graduates of the specialization Data Science: Computer Science have obtained in-depth knowledge of data management, have a thorough understanding of statistical analysis of data and are able to develop new data models and techniques and execute statistical analysis.

### *b3 Specific learning outcomes specialization Bioinformatics*

In addition to the general achievements, graduates of the specialization Bioinformatics have obtained in-depth knowledge of the core concepts of bioinformatics, including methods in computational biology, the design and mining of bio databases, the process and analysis of images, and the construction of mathematical models of biological systems.

### *b4 Specific learning outcomes specialization CS and Science Communication and Society*

In addition to the general achievements, graduates of the MSc programme Computer Science with the specialization Science Communication and Society have reached the following specific achievement levels:

1. knowledge and understanding of modern information and communication technology;
2. experience in science communication;
3. knowledge of ethical, historical and social aspects in the area of the natural sciences.

### *b5 Specific learning outcomes specialization Education*

In addition to general achievements, graduates of the MSc programme Computer Science with the



specialization Education have achieved all qualifications necessary for teaching all years of secondary education and technical and vocational training (for 12–18 year-olds).

### **Master's programme Media Technology**

Graduates of the MSc in Media Technology have attained the following general learning outcomes:

- a. theoretical and practical skills in more than one specialist area (including computer science/artificial intelligence, creative and performative arts, and relevant aspects of philosophy, cognitive science, and linguistics), such that they can carry out research under overall supervision;
- b. the ability to make an independent analysis of scientific problems, analysis of relevant specialist literature, formulate verifiable hypotheses, and set up and carry out research and critical reflection on one's own research and that of others;
- c. the ability to interrelate and integrate various areas of computer science, artificial intelligence, creative and performative arts with relevant aspects of philosophy, cognitive science, and linguistics;
- d. the ability to present clearly, verbally as well as in writing, one's own research results, and the ability to communicate with colleagues and to present their research results as a contribution to a congress or as (part of) a scientific publication;
- e. sufficient understanding of the social and societal role of academia, especially computer science/artificial intelligence and the creative and performative arts, to be able to critically reflect upon it and in part consequently to come to an ethically sound attitude and corresponding execution of one's professional duties;
- f. have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous.

In addition to the above general achievements, graduates of the MSc in Media Technology have:

- g. understanding of the fundamental principles and organization of academia, and of the importance of creativity and playfulness in academic research;
- h. knowledge and skills in computer programming and in the use of various media and technologies within virtual and physical environments;
- i. the ability to communicate with colleagues (e.g. via a conference contribution or scientific publication) as well as with a wider public (e.g. via an exhibition, performance, public event, or in popular-scientific writing).
- j. the ability to act as independent researchers and thinkers with a critical attitude.

### **Master's programme ICT in Business and the Public Sector**

*a General learning outcomes, common to both specializations*

Graduates of the master's programme ICT in Business and the Public Sector have attained the following general learning outcomes:

- a. theoretical and practical skills in more than one specialist area of ICT, such that they can carry out research under overall supervision;
- b. the ability to make an independent analysis of scientific problems, analysis of relevant specialist literature, formulate verifiable hypotheses, and set up and carry out research and critical reflection on one's own research and that of others;
- c. the ability to interrelate and integrate various areas of ICT;
- d. the ability to present clearly, verbally as well as in writing, one's own research results, and the ability to communicate with colleagues and to present their research results as a contribution to a congress or as (part of) a scientific publication;
- e. sufficient understanding of the social and societal role of ICT to be able to reflect upon it and in part consequently to come to an ethically sound attitude and corresponding execution of one's professional duties;
- f. have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous.

*b1 Specific learning outcomes specialization "ICT in Business"*

Graduates with the specialization ICT in Business have:

- g. obtained in-depth knowledge of how ICT enables innovations in all business areas including marketing, operations, finance, strategy and IT itself;
- h. developed practical skills and experience in applying these concepts in the context of private organizations.

*b2 Specific learning outcomes specialization "ICT in the Public Sector"*

Graduates with the specialization ICT in the Public Sector have:

- i. obtained in-depth knowledge on areas relevant in the public domain such as politico-administrative relations, European procurement, and data-driven policy development;
- j. developed practical skills and experience in applying these concepts on an administrative and managerial level.

## APPENDIX 3: OVERVIEW OF THE CURRICULUM

### Bachelor's programme Computer Science

The figures below show the 2018/19 curriculum of the three specializations. The figures below the courses indicate the number of EC; the meaning of the colours is explained below the figures.

#### Specialization Computer Science

Year/ Sem							
1 Fall	Oriëntatie Informatica	Programmeer- methoden	Digitale Technieken	Fundamentele Informatica 1	Continue Wiskunde 1	Lineaire Algebra 1	Studeren en Presenteren
	3	6	6	6	3	3	3
1 Spring	Algoritmiëk	Programmeer- Technieken	Databases	Logica	Continue Wiskunde 2	Lineaire Algebra 2	
	6	6	6	6	3	3	
2 Fall	Computer- architectuur	Concepten van Programmeertalen	Data- structuren	Fundamentele Informatica 2	Security		
	6	6	6	6	6		
2 Spring	Complexiteit	Kunstmatige Intelligentie	Operating systemen	Statistiek	Seminarium & Onderzoek	On being a Scientist	
	6	6	6	6	3	3	
3 Fall	Data Mining	Software Engineering	Electives/Minor				
	6	6					18
3 Spring	Electives/Minor		Fundamentele Informatica 3	Bachelor's project			
	12		3				15
Compulsory Computer Science Courses			Computer Science courses common to all specialisations			Electives	
Skills/proj.	Programming	Systems	Theory	Maths	Other		

Specialization Computer Science & Economics

Year/ Sem											
1	Micro-economie	Programmeer- methoden	Fundamentele Informatica 1	Continue Wiskunde 1	Lineaire Algebra 1	Studeren en Presenteren					
	Fall	8	6	6	3	3					
1	Oriëntatie I & E	Algoritmiëk	Databases	Marketing		Organisation & Strategy					
	Spring	3	6	6	8	8					
2	Digitale Technieken	Data- structuren	Logica	Accounting		Business & IT-alignment					
	Fall	6	6	6	8	4					
2	Programmeer- Technieken	Statistiek	Macro- economie	Project Management	Seminarium & Onderzoek	On being a Scientist					
	Spring	6	6	8	4	3					
3	Data Mining	Software Engineering	Security	Finance		Seminar Business Information Systems					
	Fall	6	6	6	8	6					
3	Requirements Engineering	Data Science & Process Modelling	Bachelor's project								
	Spring	6	7	15							
<table border="1"> <tr> <td>Common courses</td> <td>Specific CS courses</td> <td>Economics courses</td> <td>Integration courses</td> <td colspan="2">Electives</td> </tr> </table>						Common courses	Specific CS courses	Economics courses	Integration courses	Electives	
Common courses	Specific CS courses	Economics courses	Integration courses	Electives							
<table border="1"> <tr> <td>Skills/proj.</td> <td>Programming</td> <td>Systems</td> <td>Theory</td> <td>Maths</td> <td>Other</td> </tr> </table>						Skills/proj.	Programming	Systems	Theory	Maths	Other
Skills/proj.	Programming	Systems	Theory	Maths	Other						

### Specialization Bioinformatics

In BA3 students choose as electives either the Biology course Molecular Design (12 EC) or the computer science courses Computer Graphics (6E EC) and Human Computer Interaction & Information Visualization (6 EC).

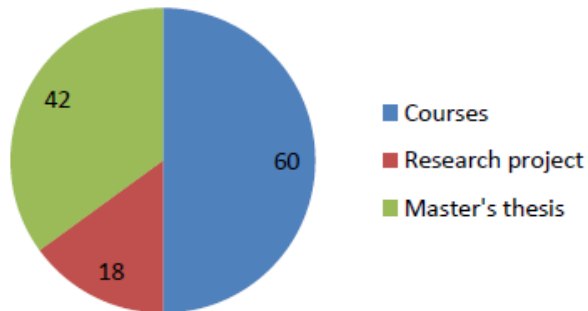
Year/ Sem																							
1 Fall	Cell Biology	Cell Fysiology	Micro-biology	Molecular genetics 1	Programmeer-methoden	Fundamentele Informatica 1	Studeren en Presenteren																
	3	3	3	6	6	6	3																
1 Spring	Orientation Bioinformatics	Chemistry of Life	Biochemics	Algoritmiëk		Databases	Logica																
	3	3	6	6	6	6	6																
2 Fall	Bio-ethics	Molecular Biology	Molecular Genetics 2	Continue Wiskunde 1	Data-structuren	Digitale Technieken	Lineaire Algebra 1	Sequence Analysis															
	3	6	6	3	6	6	3	3															
2 Spring	Programmeer-Technieken		Statistiek		Continue Wiskunde 2	Seminarium & Onderzoek	On being a Scientist	Technology Trends															
	6		6		3	3	3	3															
3 Fall	Data Mining	Natural Computing	Biological Data-sharing and Integration		Biomedical Security	Electives (Bio or CS)																	
	6	6	3		3	12																	
3 Spring	Lineaire Algebra 2	Data Science	Kunstmatige Intelligentie	Bachelor's project																			
	3	6	6	15																			
<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:12.5%;">Common courses</td> <td style="width:12.5%;">Specific CS courses</td> <td style="width:12.5%;">Biology courses</td> <td style="width:12.5%;">Integration courses</td> <td colspan="4" style="width:37.5%;">Electives</td> </tr> <tr> <td>Skills/proj.</td> <td>Programming</td> <td>Systems</td> <td>Theory</td> <td>Maths</td> <td colspan="3">Other</td> </tr> </table>								Common courses	Specific CS courses	Biology courses	Integration courses	Electives				Skills/proj.	Programming	Systems	Theory	Maths	Other		
Common courses	Specific CS courses	Biology courses	Integration courses	Electives																			
Skills/proj.	Programming	Systems	Theory	Maths	Other																		



## Master's programme Computer Science

The pie charts below show the general outline of the curriculum for each specialization. The numbers indicate the weight of each component in terms of EC's. The table on the pages thereafter shows all the courses offered and their nature (compulsory or elective).

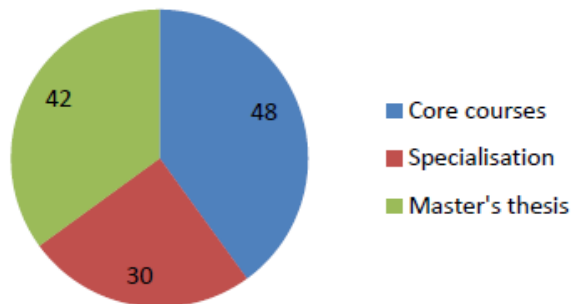
### 1 Specialisation CS and Advanced Data Analytics



*Remarks:*

- coursework consists of a mixture of recommended courses and electives;
- for each of the four tracks, specific courses are recommended;
- the courses are scheduled in the first year; the second year is dedicated to the introductory research project and the master's thesis research project.

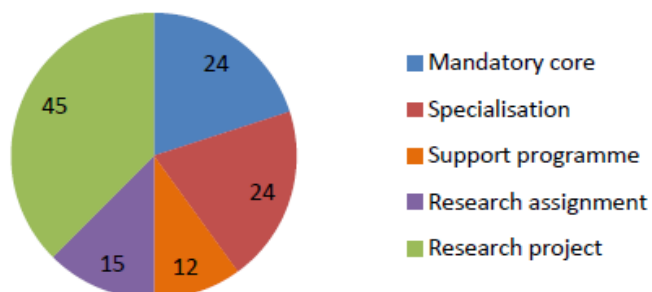
### 2 Specialisation Data Science



*Remark:*

The master's thesis includes the masterclass.

### 3 Specialisation Bioinformatics

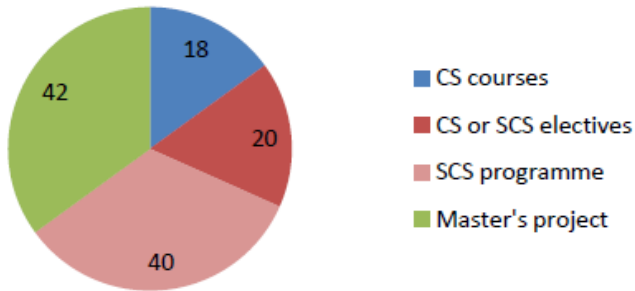


*Remarks:*

- the support programme is meant for students with minor deficiencies in their prior education; students without deficiencies choose 12 EC's;
- the mandatory and specialisation courses are scheduled in the first year, the research assignment and project in the second year.



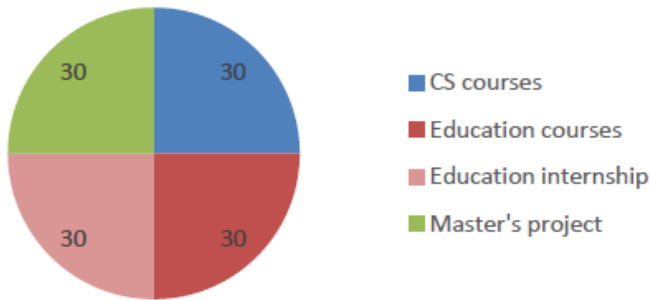
4 Specialisation CS and Science Communication and Society



*Remarks:*

- the master's project is a CS project;
- students choose CS courses relevant to the master's project
- they may dedicate the electives (20 EC) to either CS courses, SCS courses or a mixture of both

5 Specialisation CS and Education



*Remarks:*

- the master's project is a CS project;
- students choose CS courses relevant to the master's project
- there are two internships of 15 EC each (teaching practice)

All courses amount to 6 EC, unless stated otherwise.

specialisations	Advanced Data Analytics				Bioinformatics	Data Science	Science and Society	Education
	Advanced Computing and Systems	Data Analytics	Algorithms and Software Technology	Artificial Intelligence				
tracks								
	<b>Fall semester</b>							
Advances in Data Mining								
Audio Processing and Indexing								
Complex networks (BNM)								
Databases and Data Mining								
Evolutionary Algorithms								
Information Theoretic Data Mining								
Multicriteria Optimization and Decision Analysis								
Multimedia Systems								
Parallel Programming I								
Seminar Swarm-based Computation with Applications in Bioinformatics								
Social Network Analysis for Computer Scientists								
System Development & Project Management								
Testing Object-Oriented Software								
Text Mining								
Pattern Recognition (TU Delft)								
Introduction to Data Science for Computer Science								
Linear & generalized linear models and linear algebra (MI)						9 EC		
Statistical learning (MI)								
Advanced Statistical Computing (MI, 2nd year)								

Mandatory
Recommended
Electives
Not applicable

specialisations	Advanced Data Analytics				Bioinformatics	Data Science	Science Communication and Society	Education
	Advanced Computing and Systems	Advanced Data Analytics	Algorithms and Software Technology	Artificial Intelligence				
<b>tracks</b>								
<b>Spring semester</b>								
Advances in Model Checking								
Bio-Modeling and Petri Nets								
Computational Molecular Biology								
Competitive Programming								
Coordination and Component Composition								
Embedded Systems and Software								
Image Analysis with Applications in Microscopy								
Information Retrieval and Text Analytics								
Multimedia Information Retrieval								
Neural Networks								
Parallel Programming II								
Quantum Computing								
Reinforcement Learning								
Robotics								
Seminar Combinatorial Algorithms								
Seminar Distributed Data Mining								
Urban Computing								
Metabolic Network Analysis (BM)								
Functional Genomics and Systems Biology (TU Delft)								
Multivariate analysis and multidimensional data analysis (MI)								
Business Studies component (fall and spring semester)								
Science Communication and Society component (fall and spring semester)								
Education component (fall and spring semester)								
Research project (2nd year)	18 EC	18 EC	18 EC	18 EC	15 EC			60 EC
Master class + master thesis (2nd year)	42 EC	42 EC	42 EC	42 EC	45 EC	42 EC	42 EC	30 EC

### Master's programme Media Technology

The numbers in brackets indicate the number of EC's. The scheduling of the electives is free and will depend on the electives chosen. Below, they have been scheduled in the second year, since that fits better EC-wise.

Block 1	Block 2	Block 3	Block 4
<b>YEAR 1</b>			
Ars Electronica Festival (1)	Meta Media (2)	Sciences & Humanities (4)	Research Seminar: Social Technologies (5)
Essentials in Art and Music (2)	Hardware & Physical Computing (3)	Language Evolution (4)	Non-Human Cognition (3)
Research Fundamentals (4)	Playful & Creative Science (6)	Sound, Space & Interaction (5)	New Media & New Technologies (5)
Introduction to Programming (4)		Research Seminar Artificial Intelligence (6)	
Human Computer Interaction & Information Visualization (6)			
<b>YEAR 2</b>			
Exhibition: Statement to Experience (12)		Graduation Project (30)	
Portfolio (1)			
Electives (16)			
Graduation Lab (1)			
Compulsory courses	Electives	Project	

## Master's programme ICT in Business and the Public Sector

Block 1	Block 2	Block 3	Block 4	
<b>YEAR 1</b>				
Global Business Game (1)	Decision and Risk Analysis (3)	Process Modelling (3)	Research Methods (5)	
Strategy (5)		Accounting (3)		
Technology and Operations Mgt (4)		ICT Architectures (6)		
ICT enabled Process Innovation (3)		Financial Management (3)		Entrepreneurial Opportunities (3)
Leading and Managing People (5)		Electives "in Business" (6)		
Software Engineering (3)		Role of IT in Public Administration (6)	Working for Govnmt as ICT expert (6)	
System Development and Project Mgt (6)				

<b>YEAR 2</b>			
Applied Research Applied Research Methodology		Applied Research Methodology (4)	
	Intelligence (4)		
Digital Gvt - Citizen interaction (3)	Data driven policy making (3)		
Capstone cases (3)			
Electives "in Business" (3)			
Electives (9)			
Research Project (38)			
Common courses	Specialisation courses "Business" Electives "Business"	Specialisation courses "Public Sector"	General electives

## APPENDIX 4: PROGRAMME OF THE SITE VISIT

### DAG 1

### DINSDAG 11 JUNI 2019

10.30	10.45	Ontvangst
10.45	14.00	Vorbereidend overleg panel
13.00	14.00	<b>Interview inhoudelijk verantwoordelijken</b>
14.00	14.15	Pauze
14.15	15.00	<b>Interview studenten + alumni Media Technology</b>
15.00	15.15	Pauze
15.15	16.00	<b>Interview docenten Media Technology</b>
16.00	17.00	Intern overleg
17.00	17.30	Inloopsprekuur

### DAG 2

### WOENSDAG 12 JUNI 2019

09.00	09.30	Vorbereidend overleg panel
09.30	10.15	<b>Interview studenten bachelor</b>
10.15	10.30	Pauze
10.30	11.15	<b>Interview studenten + alumni master CS</b>
11.15	11.30	Pauze
11.30	12.30	<b>Interview docenten bachelor + master CS</b>
12.30	13.30	Lunch
13.30	14.00	<b>Rondleiding</b>
14.00	14.45	Intern overleg
14.45	15.30	<b>Interview studenten + alumni ICT in Business</b>
15.30	15.45	Pauze
15.45	16.30	<b>Interview docenten ICT in Business</b>
16.30	17.00	Intern overleg

### DAG 3

### DONDERDAG 13 JUNI 2019

09.00	09.30	Intern overleg
09.30	10.15	<b>Interview examencommissie</b>
10.15	10.45	Intern overleg
10.45	11.15	<b>Interview formeel verantwoordelijken</b>
11.15	13.30	Opstellen oordelen (inclusief lunch)
13.30	13.45	<b>Mondelinge terugkoppeling</b>
13.45	14.00	Uitloop
14.00	14.45	<b>Ontwikkelsprek</b>
14.45	15.00	Afronding



## APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the bachelor's programme Computer Science, 15 theses of the master's programme Computer Science, 15 theses of the master's programme Media Technology and 15 theses of the master's programme ICT in Business and the Public Sector. Information on the selected theses is available from QANU upon request.

During the site visit, the panel studied, among other things, the following documents (partly as hard copies, partly via the institute's electronic learning environment):

- Overview programme content for each programme (study guide, electronic learning environment and a selection of course materials)
- Selection of exam questions and answer models for each programme
- Education and Exam Regulation
- Teaching staff overview
- Annual reports 2013-2018 Boards of Examiners
- Assessment plans for each programme
- Year reports 2013-2018 for each of the programmes
- Logbooks and forms of the 15 theses for the master's programme Media Technology
- Plans for bridging programmes master's programmes ICT in Business and the Public Sector and Media Technology
- Panel reports of the 2013 Programme Assessments, including the repair trajectory for the master's programme Media Technology