COMPUTER SCIENCE

FACULTY OF ELECTRICAL ENGINEERING,
MATHEMATICS AND COMPUTER SCIENCE

UNIVERSITY OF TWENTE

QANU
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

Phone: +31 (0) 30 230 3100
E-mail: support@qanu.nl
Internet: www.qanu.nl

Project number: Q0745

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This report was finalised on 21 April 2020

REPORT ON THE BACHELOR'S PROGRAMME TECHNICAL COMPUTER SCIENCE AND MASTER'S PROGRAMME COMPUTER SCIENCE OF THE UNIVERSITY OF TWENTE

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 Technical Computer Science

Name of the programme:	Technical Computer Science
CROHO number:	59335
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Location:	Enschede
Mode of study:	full time
Educational minor:	applicable (second degree qualification)
Language of instruction:	English
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
Specialisations or tracks:	Cyber Security (incl. double degree) Data Science and Technology Internet Science and Technology Software Technology
Location:	Enschede
Mode of study:	full time
Language of instruction:	English
Joint programme:	
partner institutions involved:	University of Rennes University of Trento University of Turku Eötvös Loránd University Université Paris-Sud EURECOM SophiaTech
type of degree awarded:	double degree (UT + one of the partner institutions)
Submission deadline NVAO:	01/05/2020

The visit of the assessment panel Computer Science to the Faculty of Electrical Engineering, Mathematics and Computer Science of the University of Twente took place on 9 and 10 December 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	University of Twente
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 programme Technical Computer Science and the master's programme Computer Science 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. 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;
- M. (Martijn) Brehm, third-year bachelor's student Computer Science at 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 programme Technical Computer Science and the master's programme Computer Science at the Faculty of Electrical Engineering, Mathematics and Computer Science of the University of Twente was part of the cluster assessment Computer Science, and also included the master's programme Interaction Technology in Twente. 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, University of Utrecht, 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 the University of Twente, the panel was supported by P.A. (Peter) Hildering MSc, who is a certified NVAO secretary.

Panel members

The members of the 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 the University of Utrecht;
- Drs. L. (Lennart) Herlaar, owner/director at Redbits.nl, a company specialised in software development and IT consultancy, and assistant professor Computer Science at the Faculty of Science of Utrecht University;
- A. (Antonia) Wildvank, owner/CEO at Wildvank, Management en Advies, specialised in IT-management and -consultancy;
- Prof. dr. ir. 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 (SIG) 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 BSc, master's student Computing Science and bachelor's student Mathematics and Linguistics at Radboud University [student member];
- E. (Evi) Sijben BSc, master's student Computing Science in the specialisation track Data Science at Radboud University [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].

Preparation
On 21 March 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 organised on 9 May 2019. During this meeting, the panel members received instruction on the use of the assessment framework. The panel also discussed their working method and the planning of the site visits and reports.

The project coordinator and secretary 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 the University of Twente, QANU received the self-evaluation reports of the programmes involved and sent these to the panel. A thesis selection was made by the panel's chair and secretary. The selection consisted of the work of 15 students of the bachelor's programme Technical Computer Science: a total of 5 design group projects and 15 individual research papers. For the master's programme, this consisted of 15 final master projects and their respective assessment forms, based on a provided list of graduates in the academic years 2017-2018 and 2018-2019. A variety of topics 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 projects and theses, and that the four specialisations in the master's programme were covered in the selection. 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 the University of Twente took place on 9 and 10 December 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 management, alumni and the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. Nobody made use of this opportunity.

The panel used the final part of the site visit to discuss 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 three programmes discussed various development routes for the programmes. The result of this conversation is summarised in a separate report.

Consistency and calibration
In order to ensure the consistency of assessment within the cluster, following measures were taken: the panel composition ensured regular attendance of (key) panel members, including the chair, and the project coordinator was present at the panel discussion leading to the preliminary findings of each programme 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 the project coordinator 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 finalised and sent to the Faculty and University Board.

Minor in Education
The Minor in Education leading to a second degree teaching qualification will be covered in-depth during the assessment of the academic teaching programmes (admission deadline:1 November 2021).

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 Technical Computer Science

The bachelor's programme Technical Computer Science convincingly profiles itself as an academic programme in a multidisciplinary setting with a strong connection with the practical, technical context of computer science. The intended learning outcomes meet the expectations of the academic and professional field through alignment with the international Association for Computer Machinery (ACM) benchmark curriculum and the 4TU Meijers criteria, and are fitting for an academic bachelor's programme in terms of level and orientation. The panel recommends the programme to connect to the Industrial Advisory Boards of the master's programme in order to profit from contributions of the professional field to define its goals, and to consider its position with regard to the field of artificial intelligence.

The programme has adequately translated its intended learning outcomes (ILOs) into a coherent curriculum. It is offered in an international, multidisciplinary context and connects its academic education to a practical context through projects. The programme offers a solid core curriculum in computer science, structured along thematic modules, learning lines and cross-cutting concerns. In particular the academic skills learning line is well-implemented and transparent. The Twente Educational Model is a strong point of the programme and fits the goals of the programme. The use of English as the language of instruction fits the international character of the programme and its teaching staff, and prepares students for the international job market.

The programme is feasible, although many students take longer to finish. The panel is positive on the improved success rates in the programme since the previous site visit, and encourages the programme to keep working on improving study success, and develop concrete measures to help students finish in time. The programme adequately deals with the rapid rise in student numbers. The student houses help the programme to maintain a small-scale feeling, and support students during the programme, but the programme should still keep paying attention to individual mentoring of students. The further structuring of previously informal processes to a more formal organisation is part of growth, and the panel encourages the programme to continue onto this path. Furthermore, the programme has taken measures to hire new teaching staff in order to keep up with the high student numbers, which the panel supports. The panel is positive about the quality of the teaching staff and the professionalisation of teachers through University Teaching Qualifications. The panel advices the programme to keep monitoring the quality of teaching assistants and take measures where necessary to maintain the required quality standards. The programme offers adequate facilities, although their availability can be limited due to high student numbers. The panel supports the plans for expansion of these facilities.

The programme has a valid, transparent and reliable system of assessment in place. The assessment methods are varied and show a good balance between individual and group assignments, with the possibility to deviate from group grades on an individual basis through peer feedback. The module and course assessment plans provide a clear overview of the module or course goals and the intended learning outcomes. The panel supports the upcoming new policy that allows for smaller assessed units rather than grading a module in its entirety. The Examination Board of the programme fulfils its formal tasks and has a proactive role with regard to assessment quality. The two final projects of the bachelor's programme together cover the programme's ILOs. They are adequately assessed by two examiners, and the objectivity of grading is further strengthened through a quality check by an external assessor. The panel recommends to include the input of this external assessor in the assessment dossier. The assessment forms are well-designed: the panel in particular liked the original design of the research paper assessment form.

The panel concludes that the final projects of both programmes are of sufficient quality, and convincingly show that the intended learning outcomes are achieved. The bachelor's students usually continue in a master's programme, fitting the goals of the programme. The graduates of the master's

programme easily find a job in fields that align well with the specialisations offered by the programme.

Master's programme Computer Science
The master's programme Computer Science offers four specialisations: Cyber Security, Data Science and Technology, Internet Science and Technology, Software Technology. According to the panel. these are relevant and well-aligned with the career opportunities of the programme's graduates. The intended learning outcomes meet the expectations of the academic and professional field through their alignment with the 4TU Meijers Criteria, and by expanding on the international Association for Computer Machinery (ACM) benchmark curriculum. They are fitting for an academic master's programme in terms of level and orientation. The panel recommends the programme to consider its position with regard to the field of artificial intelligence. The programme has four well-functioning Industrial Advisory Boards for each of the specialisations, which provides advice that keeps the programme aligned with the expectations of the professional field.

The programme has adequately translated its intended learning outcomes into a coherent curriculum. It is offered in an international, multidisciplinary context and connects its academic education to a practical context through projects. The curriculum allows students to shape their programme to fit their preferences. It offers plenty of opportunities for personalisation, such as electives, internship and international exchange through the EIT Digital consortium. The use of English as the language of instruction in the programme fits the international character and its teaching staff, and prepares students for the international job market.

The programme is feasible, although many students take longer to finish. The panel is positive on the improved success rates in the programme since the previous site visit, and encourages the programme to keep working on improving study success, and develop concrete measures to help students finish in time. The programme adequately deal with the rapid rise in student numbers. The further structuring of previously informal processes to a more formal organisation is part of growth, and the panel encourages the programme to continue onto this path. Furthermore, the programme has taken measures to hire new teaching staff in order to keep up with the high student numbers, which the panel supports. The panel is positive about the quality of the teaching staff, and the professionalisation of teachers through University Teaching Qualifications. The programme offers adequate facilities, although their availability can be limited due to high student numbers. The panel supports the plans for expansion of these facilities.

The programme has a valid, transparent and reliable system of assessment in place. The assessment methods are varied and show a good balance between individual and group assignments, with the possibility to deviate from group grades on an individual basis through peer feedback. The module and course assessment plans provide a clear overview of the module or course goals and the intended learning outcomes. The Examination Board of the programme fulfils its formal tasks and has a proactive role with regard to assessment quality. The master's projects are assessed through a solid procedure that prescribes an assessment committee of at least three examiners, and they are calibrated through occasional post-hoc checks by different examiners. The assessment form is of sufficient quality. However, the panel stresses that the programme should more closely monitor that all assessment committees provide sufficient qualitative feedback. The programme has solid procedures in place to safeguard the quality of theses conducted at partner universities of the EIT Digital consortium. The panel recommends including a written record of the additional quality check on these theses to the assessment dossier.

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 praises the programme for the high number of scientific publications and awards resulting from the theses. Graduates easily find a job in fields that align well with the specialisations offered by the programme.

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

Bachelor's programme Technical 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 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

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: 21 April 2020

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

Profile
The bachelor's programme Technical Computer Science and the master's programme Computer Science are offered by the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS) of the University of Twente. The programmes are offered as technical programmes on a human scale, in line with the educational vision of the university (High Tech, Human Touch). This is implemented by offering a solid foundation in computer science in a multidisciplinary, international context, with attention to its application in a practical, technical context. Furthermore, the programmes are proud of a small-scale and informal atmosphere, which they try to maintain even with the rise of student numbers in recent years.

The *bachelor's programme* aims to provide a computer science programme with a technical focus with attention to the human factor. Alongside offering the fundamentals of computer science, the programme focuses on the application of computer science in a technical context through assignments and projects. Furthermore, it aims to provide students with a multidisciplinary perspective, teaching them to work with professionals in other fields in order to prepare them for a professional environment. This multidisciplinary perspective is provided by sharing most of the mandatory courses with students from other bachelor's programmes within the faculty, such as Electrical Engineering or Applied Mathematics. The bachelor's degree is considered by the faculty to be in the first place a preparation for a master's programme rather than a preparation for the professional field. In comparison with other bachelor's programmes in computer science, it has a relatively large mathematics component, as well as an engineering focus in the form of attention to technical applications of computer science.

The *master's programme* enables students to shape their own programme with specialised courses in computer science. It offers four specialisations for students to choose from at the start of their studies:

- *Cybersecurity (CYBSEC)* is aligned with the strong demand for cybersecurity experts, and follows the guidelines of the Joint Task Force on Cybersecurity Education of all major international computing societies. It covers not only technology, but also people, information and process aspects of cybersecurity, and as a result has a very interdisciplinary character. Some of the courses are offered in cooperation with TU Delft, who offers a similar master specialisation. A variant of this specialisation can also be followed as an EIT Digital double degree programme, where students spend one year in Twente, and one year at one of the EIT Digital partner institutions in either France, Italy, Finland or Hungary, and receive diplomas from both institutions.
- *Data Science and Technology (DST)* is focused on extracting information from very large datasets, combining the fields of data science and service science. It prepares students for a career as data scientist or a related profession.
- *Internet Science and Technology (IST)* focuses on networks, such as the Internet, mobile and wireless networks and emerging and embedded networks. It prepares students for a career in network technology, and provides them with knowledge and skills related to dependability and security of networks, and new developments such as the Internet of Things. It is a continuation of the former master's programme with the same name (previously Telematics), and therefore shares its courses with the remaining students of the master's programme IST

who registered before the merger with Computer Science in 2019. They have the opportunity to obtain a degree of the master's programme IST until 2020 as part of the phasing out of the programme.
- *Software Technology (ST)* enables students to become experts in the developing of high-end software, preparing them either for a career in software engineering research or a professional career as software developer.

Students also follow in the master's programme many courses together with students from other programmes within the faculty, providing them with a multidisciplinary perspective. Additionally, many projects within each specialisation are offered in collaboration with local, national or international companies, allowing students to become acquainted with relevant aspects of working life in the professional field.

The panel has studied the profile of the bachelor's and master's programme and concludes that both programmes have a clear and distinctive profile. The programmes combine academic education in a multidisciplinary setting with a strong connection with the practical, technical context of computer science. The bachelor's programme is specifically aimed at preparing for a master's programme and less on direct outflow to the professional field, which the panel considers a clear choice fitting the profile of the programme. The specialisations of the master's programme are well-balanced and in line with the career options for graduates. Their strong connection to the professional field adds to the professional relevance of the content. The panel notes that both programmes have a limited focus on artificial intelligence (AI): it is not a focal point of the bachelor's programme, and the master's programme does not offer an AI specialisation. The panel recommends the programmes to consider their positioning with regard to this rapidly expanding field.

Intended learning outcomes
The intended learning outcomes (ILOs) of the *bachelor's programme* are grouped in four sets: the content-based ILOs describing the knowledge and skills that students should achieve in the field of computer science, and the skills and attitudes that are expected of students in terms of design, research and organisations. The latter three categories reflect the educational philosophy of the University of Twente, which describes education of students in different roles (the 3 O's: 'onderzoeken', 'ontwerpen' and 'organiseren'). The ILOs of the *master's programme* are divided in a set of general ILOs in the domain of computer science, and four sets of specific ILOs for the four specialisations. The general ILOs describe the generic knowledge, skills and attitudes for all students, and the specialisation-specific learning objectives describes the additional skills associated with these specialisations.

In order to show that students acquiring these ILOs qualify as academic bachelors respectively masters according to international standards, the programmes presented the panel with an overview in which the ILOs for the programmes are linked to the Academic Competences and Quality Assurance (ACQA) framework for bachelor's and master's programmes. The ACQA framework (also known as the Meijers criteria) has been developed by the Dutch technical universities (4TU) as a translation of the Dublin descriptors for higher education in engineering. To demonstrate the alignment of its ILOs with the international requirements of the field, the programme showed a table in which the ILOs are linked to the ACM Computer Science Curriculum 2013 (Appendix 1), which the universities involved in the computer science accreditations defined as the domain-specific framework of reference for all bachelor's programmes, and serves as a source of inspiration for master's programmes with regard to the general competences.

The panel studied the ILOs of the bachelor's programme Technical Computer Science and the master's programme Computer Science, and concluded that they form a convincing and well-structured overview of the main goals of the programmes translated into the knowledge and skills to be acquired by the students. The use of the Meijers criteria in designing the ILOs guarantees that they meet the respective bachelor's and master's level, as well as academic orientation, and cover the general engineering skills required by the academic and professional field. The panel noted that

the ILOs of both programmes cover the eleven competences of computer science as formulated by ACM, and as a result, meet the expectations of the field.

To further align the ILOs of the master's programme with the expectations of the professional field, the master's programme appointed Industrial Advisory Boards (IABs) for each of the four specialisations consisting of representatives of various companies that often hire graduates from the programme. They meet on a regular basis with programme representatives to discuss developments in the professional field and possible implications for the ILOs and curricula of the specialisations. In addition, the IAB members often contribute to the programme by offering projects or guest lectures. The panel praises the master's programme for its involvement of the professional field into the fine-tuning of the ILOs and the curriculum. It recommends the programme to also include the bachelor's programme in the focus of the IABs, as this programme too could benefit from a similar involvement of the professional field.

Considerations
The bachelor's programme Technical Computer Science convincingly profiles itself as an academic programme in a multidisciplinary setting with a strong connection with the practical, technical context of computer science. The intended learning outcomes meet the expectations of the academic and professional field through alignment with the international ACM benchmark curriculum and the 4TU Meijers criteria, and are fitting for an academic bachelor's programme in terms of level and orientation. The panel recommends the programme to connect to the Industrial Advisory Boards of the master's programme in order to profit from contributions of the professional field to define its goals, and to consider its position with regard to the field of artificial intelligence.

The master's programme Computer Science offers four relevant specialisations that are well-aligned with the career opportunities of the programme's graduates. The intended learning outcomes meet the expectations of the academic and professional field through their alignment with the 4TU Meijers Criteria, and by expanding on the international ACM benchmark curriculum. They are fitting for an academic master's programme in terms of level and orientation. The panel recommends the programme to consider its position with regard to the field of artificial intelligence. The programme has four well-functioning Industrial Advisory Boards for each of the specialisations, which provide advice that keeps the programme aligned with the expectations of the professional field.

Conclusion
Bachelor's programme Technical 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'.

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

Curriculum: bachelor's programme
The curriculum of the bachelor's programme Technical Computer Science is structured using the principles of the Twente Educational Model (TEM). This model is characterised by the integration of courses in thematic modules of 15 EC each. The modules are designed to focus on overarching themes such as Software Systems, Data & Information and Intelligent Interaction Design. Within each theme, all elements are integrated into a coherent unit alongside a capstone project. This group project presents students with a specific challenge that requires the use of combined skills and knowledge acquired in coursework.

The programme consists of 12 modules, divided over three years. Module 1, 'Pearls of Computer Science', is an introductory module that covers the core topics in computer science and enables students to determine whether the programme is a good fit with their expectations and their abilities. Modules 2 to 7 are compulsory modules, each focusing on a single area of computer science. These modules are all shared with at least one other programme within the EEMCS faculty. Module 8 to 10 are elective modules. In module 8, students can select one out of four specialisation modules offered by the programme, whereas module 9 and 10 form a 30 EC elective minor which the student can freely choose, as long as at least 15 EC are outside the field of computer science. During this minor period, students can also opt for a university-wide 30 EC educational minor, leading to a second-degree teaching qualification. The last two modules 11 and 12 are dedicated to the two final projects of the programme: a group Design Project and an individual Research Project. In the 15 EC Design Project, students work in groups of 4-6 students on a prototype or functional implementation of a system with requirements provided by an (real or hypothetical) external client. The 15 EC Research Project is an individually performed research project, resulting in a paper presented on the last day of the module at the Twente Student Conference on IT. This conference is open to all.

Next to the thematic modules, the programme has defined Learning Lines and Cross-Cutting Concerns that are covered horizontally throughout the curriculum. Learning lines are skills and competencies that are trained during the entire curriculum, namely Mathematics and Academic Skills. Most mandatory modules have both Mathematics and Academic Skills content added, with various degrees of integration within the module content. The cross-cutting concerns (Requirements and Design, Security and Concurrency) are elements of computer science that apply to different areas of computer science and as such, are covered in multiple modules.

The panel studied the structure and content of the curriculum as well as the content of a selection of modules within the programme, and spoke to the programme management, teaching staff and students. It concluded that the programme's ILOs are incorporated well into the curriculum. This conclusion was further supported by the evidence provided in a 'heat map': an overview of the programme in which all ILOs were aligned with the learning goals for each module. In this way, it was clearly visible for the panel which ILOs were covered to what extent in each module. The panel considers the TEM approach a strong point of the programme. The projects in particular fit the goals of the programme to connect its education to a practical context, as they give students the opportunity to work on problems using the knowledge and skills acquired in the courses. The fact that the core modules are shared with other programmes add to the multidisciplinary goals of the programme. The modules offer core knowledge and skills in computer science, including mathematics and academic skills in horizontal learning lines. Based on the module content and interviews with students, the panel considers the academic skills learning line in particular to be well-implemented and transparent to students. The Design Project together with the Research Project are fitting capstones to the programme, giving students the opportunity to demonstrate both their design and research skills acquired in the programme. The panel especially liked the conference set-up of the Research Project, which it considers a very good experience for students with regard to many different academic skills.

Curriculum: master's programme

The four specialisations of the master's programme each have their own curriculum, designed around a common overall structure. There is one core course (Computer Ethics, 5 EC), shared between all specialisations. Furthermore, each specialisation has 20 EC of mandatory core courses and 15-20 EC of advanced specialisation courses, chosen from a provided list of electives. Courses usually take the form of lectures and tutorials, supplemented with project work. 25-30 EC is a free profiling space, in which students are expected to strengthen the chosen sub-area within the specialisation. This includes the possibility of a 20 EC industrial internship. Some specialisations have further requirements: CYBSEC students choose 15 EC of socio-technical courses, and ST students choose between a 10 EC design or research orientation. Each specialisation culminates in a 40 EC final project. The first 10 EC are spent on a preparatory Research Topics course, in which students choose a topic, formulate research questions and a research plan, and conduct a literature study. The other

30 EC is the actual execution of the research project. A full overview of the curriculum is included in Appendix 3.

Within the CYBSEC specialisation, students can pursue a double degree in the context of the European EIT Digital consortium. Students spend either their first or their second year in Twente, and the other year at another university in the consortium, after which they receive diplomas from both institutions. Students follow an adapted curriculum in cyber security (depending on the university) and a minor on Innovation & Entrepreneurship offered by EIT Digital. The coordinator of the CYBSEC specialisation is mandated by the Examination Board to check whether each student's curriculum fits the requirements of the programme. Each of the participating universities is accredited through the European Standards & Guidelines. In addition, EIT Digital has its own system of quality assurance for each joint programme. Approximately 12% of the programme's students is registered as EIT Digital double degree student. As of 2020, an additional EIT Digital programme in data science, aligned with the DST specialisation, will be started.

The panel studied the curriculum and course materials from each of the specialisations, and discussed the curriculum with the programme management, students and teaching staff. It concluded that the programme's ILOs have been translated well into a coherent curriculum for each of the specialisations. This conclusion was further supported by the evidence provided in a 'heat map'. an overview of the programme in which all ILOs were aligned with the learning goals for each course. In this way, it was clearly visible for the panel which ILOs were covered to what extent in each course. According to the panel, students have plenty of opportunity to shape the programme to their own preferences through the advanced specialisation courses, their own profiling space and an optional internship. The courses offer a variety of teaching methods, including project work that introduces students to practical problems within their field of choice.

The student exchange with other European universities adds to the international character of the programme, and offers students an opportunity to go abroad. The panel concluded that the programme has sufficient control of the quality of the EIT Digital programme. The programme approves each student's curriculum and is further supported by EIT Digital's own quality assurance system. Through this system, the programme has regular meetings with the partner university to discuss improvements to the quality of the double degree programme.

Feasibility
The panel has studied an overview of the study success for both programmes. This overview shows that approximately 30% of the students in the bachelor's programme finish the programme within three years, and 58% within four year. In the master's programme, 15% finishes in two years and 40% in three years. The panel discussed the success rate with the programme management, students and teaching staff, in particular in the light of the recommendation of the previous accreditation panel to improve the success rate in both programmes.

The programme management indicated to the panel that they are not satisfied with the current study success, but also that this is a persistent problem that is not easy to solve. The success rates have improved since the previous accreditation, especially in the bachelor's programme. The programme management attributes this to the TEM approach, which requires students to take 15 EC modules in their entirety at once. Nevertheless, it is not yet near the 70% nominal+1 (four years) study success that the university aims for. According to the programme, students make other choices, such as taking jobs while studying due to the high demand for IT personnel in the professional field. In the bachelor's programme, many students have jobs on the side. In the master's programme, some students already work in a full-time job and take a long time to finish their studies. Students confirmed these remarks in the interviews with the panel, and indicated not to see major stumbling stones in the curricula itself. Master's students however mentioned that they sometimes feel overwhelmed by the abundance of choice in the programme. They also mentioned that their ideal curriculum is not always possible within the nominal study duration, as courses are only offered once per year.

The panel is pleased with the improved success rates in both programmes since the previous site visit, but considers them still low. It encourages the programmes to keep working on improving study success, and develop concrete measures to help students finish the programme in time. For instance, the master's programme could consider with the rising student numbers whether it makes sense to offer popular courses twice a year in order to help students in composing their ideal curriculum.

Student support
In the past five years the programmes have seen a high increase in student numbers: from 62 to 295 students in the bachelor's programme and from 38 to 77 in the master's programme. The recent change from a small-scale, informal programme to a large programme with high student numbers has prompted the bachelor's programme to revisit its vision on student support. The small-scale atmosphere of the programme has always been a valued feature, which the programme wanted to preserve in some form. Since 2019, the programme has therefore introduced the notion of 'student houses' in the first year, which is the name used for groups of students within the cohort of at most 100 students. Student houses are always scheduled together in all but the plenary lectures, and project partners are chosen within the own student house. The programme management aims to have an even spread of diversity among the houses. The student houses were introduced too recently to evaluate their success, but students and staff have the initial impression that they work well to invoke a smaller-scale atmosphere. The panel encourages the programme to keep evaluating and further developing this concept, for instance through the creation of common rooms for the student houses. The panel also noted that the student houses have replaced a mentoring system that was in place before 2019 in the bachelor's programme. The panel thinks that student houses cannot fully replace personal mentoring, and recommends the programme to keep attention to this aspect of student support. To this end, the panel was happy to learn that the programme also invested in extra study advisors, who meet with each student at the start of the programme to ensure their well-being and advise them on their progress and possibilities within the programme. The panel is positive about the attention for students' well-being, especially with regard to the rapid growth of the programme.

The programmes have also started to formalise processes to help them handle student growth. This includes digital testing in the bachelor's programme, a structured procedure for course evaluations using focus groups and consistent use of information channels to inform students on the curriculum. The panel recognises the challenges connected to a fast evolution from an informal, small-scale programme into a large programme with high student numbers. It thinks that further structuring of processes to a more formal organisation is part of this development, and encourages the programme to continue on this path.

Talented students have the opportunity to enroll in an extracurricular honours programme, and/or pursue a double degree with another programme. The bachelor's programme facilitates a double degree with Applied Mathematics, whereas the master's programme facilitates a double degree with a programme of choice within the faculty; with Business and IT, and Science Education and Communication (resulting in a first-degree teaching qualification) being the most chosen option. The panel is positive on these opportunities and the attention of the programmes to provide extra challenges for talented students.

Language and internationalisation
Both programmes are offered in English. The master's programme has always been an English-language programme, whereas the bachelor's programme switched from Dutch to English in 2016/17. This choice is in line with the university-wide policy to offer all programmes in English. English prepares students for the field of computer science, in which English is the norm in both the academic and professional field. In addition, this allows the programme to use the latest insights in the field, which are usually only available in English, and to involve the large non-Dutch fraction of the teaching staff in education. The programmes themselves take place in an international context, due to the inflow of international students and the exchange of students in the master's programme through the EIT Digital programme. The number of international students is relatively high, both in the bachelor's (55%) and the master's programme (30%, with an expected growth to 50%). To

exploit this context in education, the programmes take care to encourage project groups to include multiple nationalities, and train their staff in teaching in an international classroom. To guarantee a sufficient command of English, the programme has implemented a (university-wide) policy that each teacher should at least have C1-level command of English.

According to the panel, the considerations of both programmes to use English as instructional language is appropriate considering the very international orientation of the field, as well as the international teaching staff within the faculty. The use of English is well-implemented within the programmes, with adequate language requirements for the teaching staff.

Teaching staff
The teaching staff of both programmes is affiliated with the EEMCS Faculty, and is for the large majority active as researcher as either full professor (32%), associate professor (23%) or assistant professor (35%). Obtaining a University Teaching Qualification (UTQ) is a prerequisite for every new teacher, and 86% of these teachers currently have a UTQ or are in the process of obtaining one. Students indicated to the panel that they are enthusiastic about their teachers, and feel that the staff still provide the feeling of a small-scale programme, even though the number of students is high. The panel is positive about the teaching staff of the programmes, and praises the professionalisation of teachers through UTQs and the personal attention they have for students. 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 in the field.

The teaching staff indicate that the rapid increase in student numbers puts a heavy strain on their workload. The programmes are dealing with this by hiring new staff, both academic staff as well as teaching-only staff for the bachelor's programme. Hiring is currently underway, and is expected by the programme to remedy the current situation. Furthermore, in particular the bachelor's programme makes heavy use of teaching assistants (TAs), which are typically third-year bachelor's students or master's students assisting with education in the first years of the programme. These TAs receive specific training to prepare them for this role. The panel is positive about the high priority that the programme management gives to the issue of staff workload. It agrees with the measures taken by the management, and encourages the programmes to continue the expansion of their teaching staff in order to keep up with the high student numbers.

From the interviews with bachelor's students, the panel understood that there are sometimes issues with the quality of the TAs. The programme management indicated to the panel that the demand for TAs is so high that sometimes less qualified students manage to obtain a position. If this is reported, the TA in question is usually put under supervision or, if necessary, dropped. The panel understands the limitations that the programme has to work with, but thinks that it is nevertheless important that the programme keep up its quality standards. If necessary, the programme could further invest in supervision or training to make sure that all TAs reach the required level.

Programme-specific facilities
The Computer Science programmes are located in the Zilverling building on the UT Campus. Programme-specific facilities include computer rooms with sufficient power plugs for laptops, and project rooms for the group work associated with many of the courses. From interviews with students, the panel understood that the growth in student numbers puts pressure on the availability of these resources. Project rooms can be short in supply, and exams are sometimes taken outside of the campus due to shortage of exam rooms. The panel considers the current facilities adequate, but recommends to keep matching the available resources with the growth in student numbers as much as possible. It understood that the faculty is at this time investigating options to expand its facilities, which the panel supports.

Considerations
Both the bachelor's programme Technical Computer Science and the master's programme Computer Science have adequately translated their intended learning outcomes into a coherent curriculum. The

programmes are offered in an international, multidisciplinary context and connect their academic education to a practical context through projects. The bachelor's programme offers a solid core curriculum in computer science, structured along thematic modules, learning lines and cross-cutting concerns. In particular the academic skills learning line is well-implemented and transparent. The Twente Educational Model is a strong point of the programme and fits the goals of the programme. The curriculum allows students to shape their programme to fit their preferences. It offers plenty of opportunities for personalisation, such as electives, internship and international exchange through the EIT Digital consortium. The use of English as the language of instruction fits the international character of the programme and its teaching staff, and prepares students for the international job market.

The programmes are feasible, although many students take longer to finish. The panel is positive on the improved success rates in both programmes since the previous site visit, and encourages the programmes to keep working on improving study success, and develop concrete measures to help students finish in time. The programmes adequately deal with the rapid rise in student numbers, in particular in the bachelor's programme. The student houses in the bachelor's programme help the programme to maintain a small-scale feeling, and support students during the programme, but the programme should still keep paying attention to individual mentoring of students. That further structuring of previously informal processes to a more formal organisation is part of growth, and the panel encourages the programmes to continue onto this path. Furthermore, the programmes have taken measures to hire new teaching staff in order to keep up with the high student numbers, which the panel supports. The panel is positive about the quality of the teaching staff of the programmes, and the professionalisation of teachers through UTQs. The panel advices the programme to keep monitoring the quality of teaching assistants and take measures where necessary to maintain the required quality standards. The programmes offer adequate facilities, although their availability can be limited due to high student numbers. The panel supports the plans for expansion of these facilities.

Conclusion
Bachelor's programme Technical 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'.

Standard 3: Student assessment
The programme has an adequate system of student assessment in place.

Findings

Assessment system
Both programmes adhere to the assessment system and exam regulations decided upon at the faculty level. The assessment policy prescribes a module (bachelor) or course (master) assessment plan in which the learning objectives, their relationship with the programme learning goals and the individual tests within the module or course are presented. The plan also describes what assessment methods will be used, and what the rules and regulations are with regard to the tests, such as their contribution to the final grade, compensation rules and the responsible lecturer. The module assessment plan in the bachelor's programme is composed prior to the start of the module by all lecturers in the module team, with advice provided by the Examination Board.

The panel studied the assessment policy of the programmes and a number of module and course assessment plans. It concluded that both programmes uses varied assessment methods that fit the learning goals of the modules. These include written exams, presentations, project work and peer feedback. Each written exam is reviewed by a colleague before it is set, adding to the validity of the exams. As mentioned under Standard 2, the bachelor's programme increasingly uses digital testing to cope with the high student numbers. While the panel in principle supports this, it understood from

students that the feedback that they receive on digital assignments is sometimes limited. The panel recommends the programme to make sure that digitalisation does not influence the quality of feedback.

To maintain the coherence of the bachelor's programme, the students are expected to follow the 15 EC modules as a whole rather than as individual courses. This is reflected by giving them a single grade for the entire module. The university is currently in transition to a new TEM model which allows for splitting a module in separately assessed parts, to prevent that students have to retake entire modules. Based on the discussions with students and staff on this topic, the panel supports this development. Multiple grades for specific elements instead of one single grade improve the transparency of assessment, and prevent additional study delay when students fail a specific part of a module.

Both programmes often make use of group projects. To prevent free-riding, the programmes use a rule that at least 50% of a module or course grade should be based on individual performance rather than group work. Additionally, project groups have the possibility to deviate from the group grade for individuals by using a green (+1) or a red (-1) card to adjust the mark of an individual group member. This possibility is used through majority vote to either reward group members that contributed more than their share to the project, or to adjust for underperforming group members. According to the students the panel interviewed, the red card is not used often, as the threat alone is often enough to get a group member back on track with regard to his or her contributions. Furthermore, the bachelor's programme aims to group students with comparable skill level (as demonstrated in previous projects) together in project groups to prevent free-riding. The panel is positive on the attention to the individual achievement of the course or module's learning outcomes by each student. It considers the green and red cards a good measure to add an individual element to the group grades. During the site visit, the panel discussed with students and teaching staff whether the group composition according to skill level in the bachelor's programme is desirable, as it might also cause segregation in the student population. The panel was ultimately convinced that the programme's choice is well-motivated, as it prevents free-riding and motivates students to learn together on a similar level. It did not detect signs of segregation, but advices the programme to remain aware of this possibility.

Assessment final projects
As described under standard 2, the *bachelor's programme* has two final projects: a group design project and an individual research project. The design project results in a collective poster session, in which each group presents their outcomes to a general audience. This project is assessed by two examiners: the project supervisor and the module coordinator. The client (in the case of a real-world assignment) acts as advisor to the examiners. Students have the opportunity for peer feedback, and can assign a red or green card to a group member to adjust the group grade for individual performance (see above). This is all documented on an assessment form that motivates the final score based on six grading criteria. The research project is performed individually by students, and consists of an academic research project conducted in one of the Computer Science departments, resulting in a paper presented at a student conference. As with the design project, the research project is assessed by the student's supervisor and the module coordinator. Furthermore, each paper is immediately afterwards read as quality check by a chair of a department not related to the project. If he or she scores the paper more than 1 point from the actual grade, the module coordinator determines the grade based on the arguments provided.

The panel is positive about the final projects of the bachelor's programme. Together they cover the knowledge, academic skills and professional skills acquired during the programme by students, with the individual research paper guaranteeing that students are not assessed on group work alone. The use of two examiners, as well as a quality check by a reviewer outside the department adds to the reliability of the assessment. The panel studied the assessment forms for both the design project and the research projects of 15 bachelor's students. It was positive about the amount of feedback and motivation for the grades, which generally reflected the impressions that the panel members

themselves got from reading the projects. The panel especially liked the design of the research paper's assessment form, which resembles a paper review form of a scientific conference. It noted that the contribution of the external reviewer was not visible in the documentation. It suggests adding the assessment of this reviewer, which the panel considers to be a good practice, to the dossier to further increase the transparency of the assessment.

The *master's programme* has a single, individual research or design project carried out either internally or externally (usually in industry). Externally conducted projects always have two supervisors: an academic supervisor from within the department who is responsible for the academic quality and assessment, and an external daily supervisor who is responsible for the relevance of the project for the external party. Each project results in a written thesis and a presentation of the results. This project is assessed by a committee of at least three examiners, which originate from at least two different research groups. This committee attends the presentation and decides upon the grades in consensus afterwards. The grades and motivation are documented in an assessment form, separated into five subgrades. The panel was impressed by the solid assessment procedure with a thesis committee consisting of multiple examiners. The panel studied the assessment forms for to the master theses of 15 students. It was positive on the quality of the assessment, and it generally agreed with the grades. For some assessment forms, the amount of qualitative feedback was limited. The panel recommends monitoring the correct use of the form by all assessment committees, and to make the use of the comment field for each subgrade mandatory.

In the case of a thesis conducted at one of the partners in the EIT Digital double degree programme, the programme takes several quality control measures. Each thesis proposal needs to be approved by both universities. Furthermore, the programme does a mid-way quality check with the student to make sure that he or she is on the right track. Finally, an examiner from Twente performs a check on basic quality and the grade before the thesis is accepted for graduation. The panel approves of these quality checks and thinks they safeguard that each double degree thesis meets the requirements for a master's degree. It recommends including a written record describing the details of this quality check to the assessment dossier for quality assurance purposes.

The master's theses have a high average grade of approximately 8.0. According to the programme, this can be partly explained by the university-wide rule that only integer grades can be given for theses, with half-point grades rounded upwards. As of 2020, half-point grades will be allowed, and the average grades are expected to drop a number of decimals. To make sure that there is no inflation of grades, the programme organised two thesis carrousels within the programme, where different examiners re-assessed a number of theses post-hoc, and an external check where TU Eindhoven and TU Delft re-assessed a small selection of master's theses. In both checks, the grading was similar to the original grading, in some cases even somewhat higher. The panel came to the same conclusion in its own thesis assessment. It praises the programme for its attention to calibration of thesis grades.

Examination Board

Both programmes are covered by the faculty-wide Examination Board EEMCS. There is a sub-committee for Computer Science that is responsible for the programme-specific affairs of both programmes. The Examination Board consists of the chairs of all sub-committees as members, and an independent overall chair, external member and secretary. The Board performs programme-independent tasks such as establishing policies for test quality, rules and guidelines and plagiarism and fraud prevention policies, whereas the sub-committee evaluates the quality of assessment within the programme and advises on test plans. The sub-committee meets with the programme management twice a year to discuss assessment of the previous semester, and the level of the final projects. It is supported by an assessment committee that evaluates the assessment within the programme under mandate.

The panel interviewed the Examination Board, including representatives of the sub-committee Computer Science, and studied a number of its annual reports. It concludes that the Board fulfils its formal tasks in safeguarding the quality of assessment within the programme, including the quality

of final projects and prevention of fraud and plagiarism. It is well-informed on the assessment within the programme, and proactively discusses improvements for assessment quality with the programme management.

Considerations
The programmes have a valid, transparent and reliable system of assessment in place. The assessment methods are varied and show a good balance between individual and group assignments, with the possibility to deviate from group grades on an individual basis through peer feedback. The module and course assessment plans provide a clear overview of the module or course goals and the intended learning outcomes. The panel supports the upcoming new policy that allows for smaller assessed units in the bachelor's programme rather than grading a module in its entirety. The Examination Board of the programme fulfils its formal tasks and has a proactive role with regard to assessment quality.

The two final projects of the bachelor's programme together cover the programme's ILOs. They are adequately assessed by two examiners, and the objectivity of grading is further strengthened through a quality check by an external assessor. The panel recommends including the input of this external assessor in the assessment dossier. The assessment forms are well-designed: the panel in particular liked the original design of the research paper assessment form. The master's projects are assessed through a solid procedure that prescribes an assessment committee of at least three examiners, and they are calibrated through occasional post-hoc checks by different examiners. The assessment form is of sufficient quality. However, the panel stresses that the programme should more closely monitor that all assessment committees provide sufficient qualitative feedback. The master's programme has solid procedures in place to safeguard the quality of theses conducted at partner universities of the EIT Digital consortium. The panel recommends including a written record of the additional quality check on these theses to the assessment dossier.

Conclusion
Bachelor's programme Technical 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'.

Standard 4: Achieved learning outcomes
The programme demonstrates that the intended learning outcomes are achieved.

Findings

Bachelor's programme Technical Computer Science
Prior to the site visit, the panel studied the work of 15 students of the bachelor's programme Technical Computer Science. This check consisted of 5 design group projects and 15 individual research papers. The panel is positive about the quality of both types of projects. The projects all correspond to the requirements for a bachelor's thesis in computer science. The design projects show appropriate professional skills and are clearly connected to practice, fitting the goals of the programme. Although limited in size, the research papers show sufficient research skills.

The large majority graduates of the programme continue with a master's programme in Twente (89%), often the master's programme Computer Science (80%). This is in line with the profile of the programme, which aims to prepare students for a master's programme rather than the professional field. According to the panel, the high throughput factor to the master's programme shows that bachelor's graduates are very satisfied with their education. Alumni of the bachelor's programme confirm this observation, and report no obstacles in their respective master's programmes.

Master's programme Computer Science
Prior to the site visit, the panel studied 15 theses of the master's programme Computer Science, divided over all four specialisations. The panel is positive about the quality of all projects. The theses all correspond to the requirements for a master thesis in computer science. They show appropriate research skills as well as professional skills, fitting the profile of the programme. The average grade of the master's theses is high (see Standard 3), but the panel found this to be justified, also considering the no-half-point-grades policy of the university. The quality is further demonstrated by the high number of peer-reviewed publications (11 in the past two years) and awards (6 in the past two years) resulting from master's thesis work.

According to research conducted by the programme, graduates quickly find a job, often already before graduation, 17% of graduates continue in academia, which is high compared to similar master's programmes. The other graduates mainly end up as software engineer (21%), security specialist (17%), data scientist (9%), consultant (6%) or project manager (6%), fitting the specialisation directions of the programme. The panel considers this to be an indicator of the successful realisation of the intended learning outcomes of the programme.

Considerations
The panel concludes that the final projects of both programmes are of sufficient quality, and convincingly show that the intended learning outcomes are achieved. The panel praises in particular the master's programmes for the high number of scientific publications and awards resulting from the theses. The bachelor's students usually continue in a master's programme, fitting the goals of the programme. The graduates of the master's programme easily find a job in fields that align well with the specialisations offered by the programme.

Conclusion
Bachelor's programme Technical 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'.

GENERAL CONCLUSION

The panel assesses all standards of the NVAO's Framework for a Limited Programme Assessment 2018 for both 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 Technical Computer Science* as 'positive'.

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

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

The Computing Science programmes 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

The Association for Computing Machinery (ACM) is an internationally recognised 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 Technical Computer Science

In the technical domain of Computer science, the graduate is capable of:

C1. In the software sub-domain: understanding, applying, analyzing and evaluating the principles of software development and software engineering; understanding and applying concepts of programming languages and formal methods;

C2. In computer and network systems: understanding, applying and analyzing theories of architecture and organization and the management of computer systems, as well as principles of communication and network systems;

C3. In fundamentals of computer science: applying algorithms, discrete structures and principles of parallel and distributed computing, and analyzing their complexity;

C4. In human media interaction: Knowing and understanding how to design intelligent systems using principles of human-computer interaction and computational science;

C5. In information management and security: Understanding theories, methods and techniques for the design of databases, as well as of relevant implementation and maintenance aspects; understanding fundamentals of security and applying them in networks; applying cryptography theories;

C6. In mathematics: Applying discrete mathematics, calculus, linear algebra, probability and statistics; analysing problems and solutions conceptually, using these mathematical theories.

Regarding the general activity of design, the graduate is capable of:

D1. Specifying a problem and devising a solution based on a general description of that problem, by selecting and applying appropriate methods, models and techniques;

D2. Selecting and applying appropriate, domain-specific knowledge, methods, models and techniques to systems design in an integrated fashion;

D3. Evaluating the properties of solutions/systems and making a substantiated choice between different solutions based on that evaluation.

Regarding the general activity of research, the graduate is capable of:

R1. Critically analysing domain-specific problems;

R2. Systematically setting up and implementing a small research project;

R3. Contributing to the further development of the domain by working in a sub-field.

Regarding the general activity of (self-)organisation, the graduate is capable of:

O1. Independently acquiring and incorporating new knowledge and skills as required;

O2. Analyzing, reflecting on and discussing ethical, social, cultural and societal aspects of problems, solutions and developments in the domain;

O3. Understanding team dynamics and working in a team and with a variety of stakeholders such as the client and end-users;

O4. Communicating effectively with colleagues and non-specialists, both orally and in writing;

O5. Organizing his/her working processes and reflecting on personal effectiveness contributions and actions;

O6. Taking a position on an issue and of substantiating this position with regard to a design or scientific argument;

O7. Appreciating, using input from and working with experts from multiple disciplines;

O8. Understanding, appreciating and working with people with different cultural backgrounds;

O9. Shaping his/her learning process, his/her competencies and develop his/her professional identity, by deliberately choosing and completing parts of the programme that match personal capacities, skills, and motives.

Master's programme Computer Science

In the general technical domain of Computer science, the graduate:

C1. has an extensive knowledge of and understand the issues relevant to their specific field of study (i.e., domain specific attainment targets);
C2. can contribute to scientific research, and independently design, conduct and present the results of small-scale research;
C3. can provide an original contribution to the development and/or application of the field of study. 'Original' is understood to mean 'demonstrative of a creative contribution';
C4. can analyze complex problems relevant to the field of study and obtain the required knowledge and information;
C5. can design, validate and implement solutions/systems in their operational context; identify and apply relevant advanced knowledge, methods and techniques from their field of study;
C6. can assess solutions/systems and their applications according to their properties and potential to solve problems even if they are new to or unfamiliar with the situation or lack information and/or reliable information; they can use their assessment as a basis for (substantiation of) decisions;
C7. understands the ethical, social, cultural and public aspects of problems and solutions in their field of study; apply this insight in their international role as scholar;
C8. can work as part of and play a leading role in a team; manage and plan a development process; document development and research processes;
C9. can substantiate research results, designs and applications in writing and verbally; critically assess and participate in debates regarding the same.
CA. can independently acquire new knowledge and skills; reflect on trends in their field of study, responsibilities and roles and use this insight as a guide for and integrate it into their own personal development;
CB. can integrate information from other disciplines into their own work if necessary;
CC. takes a critical approach to reading, incorporating information presented in and participating in debates regarding international scientific literature relevant to their field of study.

In the Cybersecurity track, the graduate:

Y1. has a profound understanding of security and privacy risks and mitigations in cyber space and are able to model and evaluate these risks and mitigations;
Y2. has understanding and skills of applying the relevant foundations of cyber security, such as cryptography, formal methods, statistics, machine learning, and data analytics;
Y3. has understanding and skills of cyber security engineering methodologies in the small and in the large;
Y4. has insight into cross-disciplinary aspects of cyber security such as law, psychology, economics, governance, and management, and are able to read and understand basic texts from those domains and communicate with experts from those domains on cyber security;
Y5. has understanding and skills of methods and approaches for practical security evaluation of ICT systems such as penetration testing, risk assessment, and monitoring & analytics;
Y6. has specialist knowledge and understanding of one or more sub-fields or aspects of cyber security, typically acquired via research in the final year project;
Y7. has practical experience conducting scientific research into cyber security, contributing to such research, applying the results, following the trends of this sub-field and contributing to its further development.

In the Data Science and Technology track, the graduate:

D1. has thorough knowledge of, and are able to design solutions for, the management of large volumes of structured, semi-structured and unstructured data, such as sensor data, multimedia data, textual data, geographic data, and social data;
D2. is able to analyze large volumes of generated data and make scientific decisions based on such data sets;
D3. understands algorithms underlying data science techniques in terms of their fundamental basis in theory (probability theory, statistics, information theory, etc);

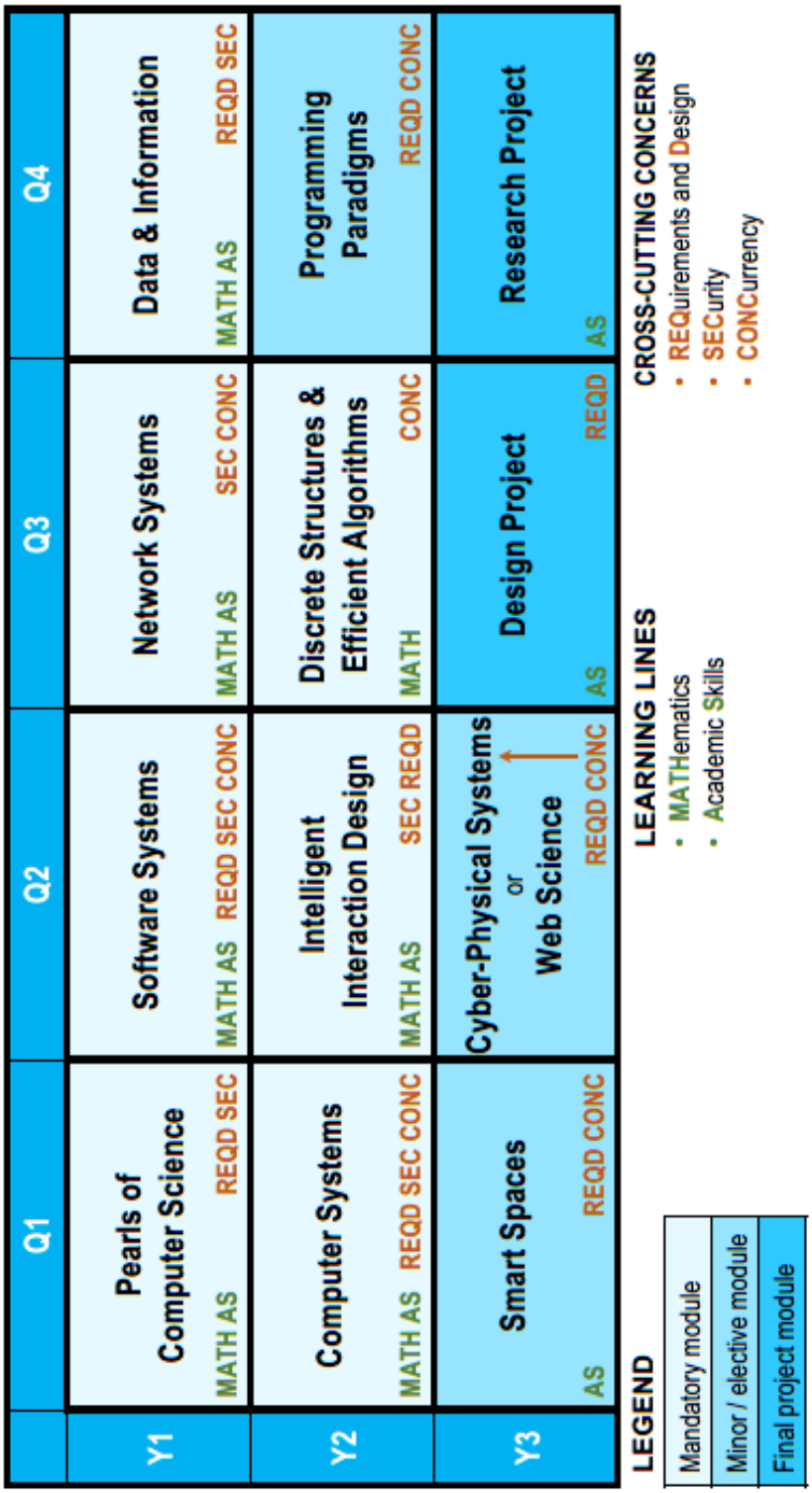
D4. has thorough knowledge of methods and techniques for the design and analysis of smart services, including those applicable to all stages of an information system's life cycle (requirement analysis, architecture design, realization and maintenance) and subsystems that make up information systems.

In the Internet Science and Technology track, the graduate:
I1. has thorough knowledge about and understanding of both wired and wireless communication devices, networks and systems, in terms of both key principles and contemporary technologies;
I2. can design and evaluate wired and wireless communication devices, networks and systems; in doing so, they can take into account both detailed aspects of the individual components, and system-wide aspects such as security and management;
I3. can quantitatively evaluate the performance of networked systems, and judge their formal correctness, using both analytical methods and computer tools;
I4. has practical experience conducting research and/or doing design work in a sub-field of networked systems, can follow trends in the field and contribute to its further development.

In the Software Technology track, the graduate:
S1. has a thorough knowledge and understanding of the different phases of the software lifecycle (ranging from requirements engineering over architectural and detailed design to construction and quality assurance) as a scientific and design discipline;
S2. has a thorough knowledge and understanding of, as well as practical experience with, the application of software engineering methods and tools in the development and validation of large-scale systems;
S3. knows the trade-offs between alternative software engineering techniques and can make educated decisions throughout the software lifecycle;
S4. has knowledge and understanding of various aspects of Software Engineering including its mathematical background, software management, quality assurance, requirements engineering, architectural design, detailed design, software construction, verification, and programming languages;
S5. has specialist knowledge and understanding of one or more sub-fields or aspects of the software engineering discipline, e.g. programming languages, software composition, service-oriented architectures, model-driven engineering, formal methods;
S6. has practical experience conducting scientific research in the realm of software engineering methods and technologies, formal methods and/or programming or design paradigms, enabling them to contribute to such research, follow the trends and apply the results.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Bachelor's programme Technical Computer Science



COMPUTER SCIENCE GENERAL

- **CS core:** Computer Ethics (5 EC, Q2)
- **Core specialisation courses** (20 EC): 4 mandatory courses
- **Advanced specialisation courses** (15 - 20 EC): Choice 3 or 4 out of 6 or 7
- **Additional requirements:** for some specialisations, e.g. socio-technical courses or design vs. research orientation
- **Profiling space** (30 EC): Elective courses from other specialisations or related Master's programmes, Internship, Exchange
- **Graduation** (10 + 30 EC):
  - Research Topics (10EC) (preparation)
  - Final project (30EC) (research project)

CYBERSECURITY

Core (20 EC)	Q
Internet security	1,3
Software Security	2
Security & cryptography	1
Cyber risk management	1

Advanced (3 out of 7)	Q
Secure Data Management	1
Security Services for the Internet of Things	4
Security Verification	Y
System Security	4
System Validation	1
Cyber Data Analytics	4
Privacy Enhancing Technologies	4

Socio-Technical (3 out of 4)	Q
Cyber-crime science	3-4
E-Law	4
Economics of security	1
Cyber security management	2

DATA SCIENCE AND TECHNOLOGY

Core (20 EC)	Q
Managing big data	2
Data science	2,3
Machine learning	1
Information theory and statistics	3

Advanced (4 out of 6)	Q
Advanced Machine Learning	2
Foundations of Information Retrieval	1
Service-oriented Architecture with Web services	3
Architectures of Information Systems	4
REDI	4
Probabilistic programming	3

INTERNET SCIENCE AND TECHNOLOGY

Core (20 EC)	Q
Internet security	1,3
Performance evaluation	2
Mobile and wireless networking	3
Internet of Things	1

Advanced (4 out of 7)	Q
Advanced Networking	1
Service-oriented Architecture with Web services	3
Cloud Networking	2
Ad-Hoc Networks	4
Internet Management and Measurement	4
Ubiquitous Computing	3
Distributed Systems	2

SOFTWARE TECHNOLOGY

Core (20 EC)	Q
ADSA-Model driven engineering	2
Testing techniques	3
Principles of programming, processes and patterns	4
System Validation	1

Advanced (4 out of 6)	Q
Advanced Logic	4
Software Management	4
Requirements Engineering Processes and Methods	2
Design of Software Architecture	1
Service-oriented Architecture with Web services	3
Modeling and Analysis of Concurrent Systems	1

Design orientation (10 EC)	Q
Industrial Software Engineering project	1-2
Research orientation (10 EC)	**Q**
Software Science	3,4
Capita Selecta Software Technology	Y

APPENDIX 4: PROGRAMME OF THE SITE VISIT

DAG 0		**8 December 2019**
17.30	19.00	Voorbereidend overleg panel
DAG 1		**9 December 2019**
09.00	09.15	Ontvangst
09.15	09.45	Voorbereidend overleg panel
09.45	10.30	**Interview opleidingsmanagement CS**
10.30	10.45	Pauze
10.45	11.30	**Interview studenten bachelor CS**
11.30	11.45	**Presentatie bachelorprojecten**
11.45	12.15	**Rondleiding Designlab**
12.15	13.15	Lunch
13.15	14.00	**Interview docenten bachelor CS**
14.00	14.15	Pauze
14.15	15.00	**Interview studenten master CS**
15.00	15.15	Pauze
15.15	16.00	**Interview docenten master CS**
16.00	16.15	Pauze
16.15	16.45	**Examencommissie**
16.45	17.00	Pauze
17.00	17.30	**Ontwikkelgesprek CS**
17.30	18.30	Intern overleg
DAG 2		**10 December 2019**
08.30	09.00	Aankomst, intern overleg panel
09.00	09.45	**Interview management ITech**
09.45	10.00	Pauze
10.00	10.45	**Interview studenten ITech**
10.45	11.00	**Presentatie studenten ITech**
11.00	11.15	Pauze
11.15	12.00	**Interview docenten ITech**
12.00	12.45	Lunch
12.45	13.30	**Eindgesprek met formeel verantwoordelijken**
13.30	15.00	Opstellen oordelen
15.00	15.15	**Mondelinge rapportage voorlopig oordeel**
15.15	15.30	Pauze
15.30	16.00	**Ontwikkelgesprek ITech**
16.00	16.15	Afronding

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied the final projects of 15 student (both group and individual projects) of the bachelor's programme Technical Computer Science, and 15 theses of the master's programme Computer Science. 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 both programmes (study guide, electronic learning environment and a selection of course materials, including course assessment plans)
- Education and Exam Regulation
- Teaching staff overview
- Annual reports Boards of Examiners
- Annual reports Programme Committee
- Assessment plan
- Panel reports of the 2013 Programme Assessments