NVAO • THE NETHERLANDS

INITIAL ACCREDITATION

WO-MASTER

QUANTUM INFORMATION SCIENCE & TECHNOLOGY (JOINT DEGREE)

Delft University of Technology and Leiden University

FULL REPORT

23 JANUARY

Content

1 Peer review

The Accreditation Organisation of the Netherlands and Flanders (NVAO) determines the quality of a new programme on the basis of a peer review. This initial accreditation procedure is required when an institution wishes to award a recognised degree after the successful completion of a study programme.

The procedure for new programmes differs slightly from the approach to existing programmes that have already been accredited. Initial accreditation is in fact an ex ante assessment of a programme. Once accredited the new programme becomes subject to the regular review process.

The quality of a new programme is assessed by means of peer review. A panel of independent peers including a student reviews the plans during a site visit to the institution. A discussion amongst peer experts forms the basis for the panel's final judgement and the advisory report. The agenda for the panel visit and the documents reviewed are available from the NVAO office upon request.

The outcome of this peer review is based on the standards described and published in the limited NVAO Assessment framework for the higher education accreditation system of the Netherlands (Stcrt. 2019, nr. 3198). Each standard is judged on a three-point scale: meets, does not meet or partially meets the standard. The panel will reach a conclusion about the quality of the programme, also on a three-point scale: positive, conditionally positive or negative. In addition, the following NVAO-protocols were used: Initial accreditation applications from Dutch Institutions for a joint programme leading to a joint degree (November 2021) and protocol for extension of regular study load (march 2022).

NVAO takes an accreditation decision on the basis of the full report. Following a positive NVAO decision with or without conditions the institution can proceed to offer the new programme.

This report contains the findings, analysis and judgements of the panel resulting from the peer review. It also details the commendations as well as recommendations for follow-up actions. A summary report with the main outcomes of the peer review is also available.

Both the full and summary reports of each peer review are published on NVAO's website www.nvao.net. There you can also find more information on NVAO and peer reviews of new programmes.

2 New programme

2.1 General data

Institutions	Delft University of Technology, coordinating and Leiden University (joint degree)
Programme	WO-Master Quantum Information Science & Technology
Variants	Fulltime: Yes. Parttime: No. Dual: No
Degree	Master of Science
Locations	Delft | Leiden
Study load	120 EC[1]
Field of study	Technology

2.2 Profile

Delft University of Technology (TU Delft) and Leiden University plan to jointly offer the Master of Science (MSc) Quantum Information Science & Technology (QIST). QIST is an interdisciplinary programme for students to become so-called 'deep generalists'. Deep generalists is a term used for professionals with extensive, advanced *high-end quantum system integration* knowledge and expert knowledge in one of the following three application fields: *quantum computing and simulations*, *quantum communication*, or *quantum sensing and metrology*. High-end quantum system integration is a new field of research that forms the foundation for design, construction and research of quantum information processing systems, such as quantum computers, quantum networks and quantum sensors. Quantum technologies have the potential to contribute to technological breakthroughs in the areas of, for example, the design of secure communication networks, clocks and sensors with exceptional sensitivity and accuracy, and solutions for problems regarding energy and medication. During the programme, students learn to design and test complex quantum information processing systems in multidisciplinary teams. The master provides students with in-depth understanding of quantum physics, mathematics, electrical engineering and computer science, and aims to develop their fundamental academic research and design skills. The programme also teaches professional skills such as autonomous reasoning, communicative skills (written and oral), and reflective skills. The new master is a joint degree offered by TU Delft and Leiden University where TU Delft is the coordinating university. Participating bodies are the Delft Faculty of Applied Sciences (AS) and Electrical Engineering, Mathematics & Computer Science (EEMCS), the Leiden Faculty of Science (FoS), and research institute QuTech (affiliated to TU Delft).

2.3 Panel

Peer experts

- Prof. Dr. Ir. Wim van Petegem (chair), associate professor Engineering Technology Educational Research (ETHER), Faculty of Engineering Technology, Head of the Media and Learning Division, KU Leuven (Belgium);
- Prof. Dr. Margriet Van Bael (member), full professor at the Department of Physics and Astronomy and Vice Dean for Education at the Faculty of Science, KU Leuven (Belgium);
- Dr. Ing. Lorenzo Tripodi, Group Head, Computational Methods for Metrology and Sensors, ASML Research, Eindhoven (the Netherlands);
- Nienke Wessel, BSc (student-member), master student Computing Science: Specialisation Data Science, Radboud University, Nijmegen (the Netherlands).

Assisting staff

Yvet Blom (secretary)
Tinka Thede (NVAO policy advisor and process coordinator)

Site visit

Delft, 15 November 2022

[1] European Credits

3 Outcome

The NVAO approved panel reaches a positive conclusion regarding the quality of the new programme Quantum Information Science & Technology (joint degree) offered by Delft University of Technology (TU Delft) and Leiden University. The programme complies with all standards of the limited NVAO framework and the protocol joint degree for initial accreditation.

The master in Quantum Information Science & Technology (QIST) has an inspiring interdisciplinary profile meant to deliver deep generalists. Students will become professionals with extensive, advanced knowledge of quantum systems integration and expert knowledge in one of three application fields: quantum computing and simulations, quantum communications or quantum sensing and metrology.

The master is offered as a joint degree programme by TU Delft and Leiden University. The panel notes that both universities have signed a cooperation agreement. TU Delft is the coordinating university and therefore some tasks are done according to the rules and regulations of TU Delft such as quality assurance. Although TU Delft is the coordinating institute, both universities are equal partners regarding use of campuses, number of FTE's in the courses, and shared responsibilities for matters such as committees and financing. The panel concludes that the QIST master meets the quality level required by NVAO for joint degree programmes.

Industry representatives who have been involved with creating the programme, are enthusiastic about the results. The programme meets their need for highly trained conceptual professionals who can work with a wide range of different specialists. Strong elements of the programme include the homologation programme (which provides students with the necessary knowledge to be able to start the programme), core courses and multidisciplinary projects. The panel really appreciates the personal profile that students have to develop during the master. Students create their profile by choosing an application field, electives and orientation of their master's thesis project (research, design or business). During the programme, students receive excellent guidance from an enthusiastic and exceptionally skilled team of lecturers. The assessment programme has a wide range of different assessment methods and formative feedback that supports students' learning process.

TU Delft and Leiden University propose a two-year master (120 EC). The panel agrees with the two universities that the extent and complexity of the interdisciplinary master programme cannot be achieved in one year. Industry representatives agree and told the panel that the professionals they hire all completed a two-year master programme. The panel therefore recommends granting the TU Delft and Leiden University the right to offer the QIST master as a two-year master programme.

The panel is convinced of the quality of the proposed MSc QIST programme and assesses it as positive.

Standard	**Judgement**
1. Intended learning outcomes	meets the standard
2. Teaching-learning environment	meets the standard
3. Student assessment	meets the standard
Conclusion	*positive*

4 Commendations

The programme is commended for the following features of good practice.

1. Appealing profile – TU Delft, Leiden University and QuTech developed an appealing profile for the Quantum Information Science & Technology master. This profile is in line with industry needs.

2. Strong foundation – The curriculum offers a strong foundation for the future QIST professional and includes a homologation programme, multidisciplinary team projects and core courses.

3. Personal profile – Students create a personal profile by choosing an application field[2], electives and an orientation[3] for their master thesis. Students have to visit information markets to discover possible career options. Students get excellent guidance when creating their profile, with the help of lecturers, researchers, study advisors and the programme coordinator.

4. Multidisciplinary team projects - Groups of students with different profiles work together on a challenging, real-life quantum technology issue proposed by a company or institute affiliated with the quantum technological field. Industry representatives are looking forward to propose cases and support QIST students during these projects.

5. Student portfolio – Students reflect on their personal goals and individual progress in their student portfolios and form small portfolio groups under supervision of a mentor. The portfolio groups focus on peer coaching to promote reflection and constructive feedback skills.

6. Passionate and skilled staff - TU Delft and Leiden University have a passionate and skilled programme management team and committed lecturers. All lecturers are active quantum researchers who use their research expertise for the courses.

7. Sound procedures – The Board of Examiners and the faculties have set up sound and transparent procedures to maintain a high level of quality assurance.

[2] Application fields that students can choose from are: quantum computing and simulations, quantum communication, and quantum sensing and metrology

[3] Orientations that students can choose from are: research, design or business.

5 Recommendations

For further improvement to the programme, the panel recommends a number of follow-up actions.

1. Adjust intended learning outcomes – Align the existing intended learning outcomes with the three application fields. Also, formulate clear intended learning outcomes that reflect the business orientation. Finally, make sure that the same terminology is used in all the intended learning outcomes.

2. Transferable skills – Include all skills in the learning objectives of the different courses to ensure that students and lecturers know which objectives students must achieve in order to successfully complete the course.

3. Lessons learned - Check with other joint degree programmes how they solved logistic issues for students having to travel to two different campuses every week and make sure students feel welcome at both places.

4. Advisory board – Set up an advisory board with a wide range of industry professionals from all three application fields as soon as possible.

5. Diversity – Actively recruit from underrepresented groups for different positions and functions (for the advisory board and for teaching positions).

6. Comparable weight application fields - Ensure that a comparable weight is assigned to the three application fields, making sure that the teaching offering for the quantum sensing and metrology fields is really equivalent to the offering for the other two fields (quantum computing and quantum communication), including at the homologation phase.

7. Company collaboration - Give students who choose the research orientation the option to collaborate with companies and not just with research related institutes. The research orientation currently focuses too heavily on the academic research component, while companies are also strongly involved in research.

8. Uniform rubric – Ensure that the intended learning outcomes are correctly assessed. The panel doubts if that is the case with the current Faculty of Applied Sciences rubric for the master's thesis. The rubric is mainly research oriented, not including aspects of the design and business orientation.

6 Assessment

6.1 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.

Judgement
Meets the standard.

Findings, analysis and considerations
Representatives of the programme as well as the information dossier demonstrate that TU Delft (the coordinating university of the QIST master) and Leiden University intend to deliver professionals who play a crucial role in high-end quantum system integration. Graduates will most likely start careers at universities or research institutes to further develop quantum technologies, or work in industries to build quantum computers, quantum communication networks, or quantum sensors. QIST has been designed to help students become so called deep generalists. The master offers a solid theoretic and practice-based foundation on quantum physics, mathematics, electrical engineering, and computer science. It gives advanced in-depth information on quantum hardware, quantum software, and electronics for quantum applications. On top of that, students create a personal profile by choosing an application field and an orientation for the master's thesis project. The application fields consist of: quantum computing and simulations, quantum communication, and quantum sensing and metrology. Students choose one application field for expert knowledge and will gain solid fundamental understanding of the other two application fields. Orientations are specialisations in research, design, and business.

Intended learning outcomes
The master has been designed by a team of academics, scientists, and engineers from TU Delft, Leiden University and QuTech. To create a relevant profile for the quantum technology industry, the development team invited industry professionals and researchers to share their opinion. The final profile consists of seven intended learning outcomes which are divided into nineteen competencies, including technical knowledge, soft skills and ethics. The panel believes that TU Delft and Leiden University have successfully formulated comprehensive intended learning outcomes. The learning outcomes are based on the principles of the *Criteria for Academic Bachelor's and Master's Curricula*. Criteria outlined by the four Dutch technical universities. According to those criteria the intended learning outcomes describe the knowledge and (professional) skills students have to acquire to successfully complete the master. The appropriate master level is based on the extensive knowledge on quantum information science and engineering, the strong research component, advanced programming skills and the ability to work in multidisciplinary teams, that all together would enable students to design, prototype and test highly complex quantum information processing systems.

The intended learning outcomes sufficiently reflect the strengths of the programme. According to the panel, the competencies are relevant as they focus on different sets of skills (not just technical knowledge, but also soft skills and ethics). However, the panel believes that the application fields and orientations that students can choose could be better reflected in the intended learning outcomes. The panel has no substantive but rather verbatim comments on the intended learning outcomes and suggests therefore the following. First, the three application fields form part of two[4] out of the seven intended learning outcomes. In order to properly align the learning objectives and outcomes with the intended learning outcomes, the panel recommends a more extensive description of the application fields in the intended learning outcomes. Second, the panel noticed that the research and design orientations form part of the

[4] However, the term 'metrology' of the application field *sensing and metrology* is missing in one of the intended learning outcomes.

intended learning outcomes, but the business orientation does not. The business orientation should be part of the intended learning outcomes to better align the learning objectives and outcomes of the business orientation with the intended learning outcomes. Third, there are several inconsistencies in the terminology used to describe the intended learning outcomes. These inconsistencies should be avoided to ensure students and lecturers know exactly what is expected of them. Based on these three recommended adjustments, the panel strongly advises TU Delft and Leiden University to polish the learning outcomes so they better reflect the three application fields as well as the three orientations. This ensures a proper translation of the intended learning outcomes into clear and measurables learning objectives and outcomes.

Joint degree
For the master, TU Delft and Leiden University signed a cooperation agreement. The cooperation between TU Delft and Leiden University was discussed at length during the conversations the panel had with TU Delft and Leiden University representatives. The deans of the relevant faculties from both universities said that the high demand for interdisciplinary quantum engineers prompted the partnership. TU Delft and Leiden University already offer several joint degree programmes and the collaboration between the two universities has been very good so far. The deans believe that it is valuable for students to get an insight into experimental technology via the TU Delft and into science via the Leiden University. TU Delft is the coordinating university and therefore some tasks are done according to the rules and regulations of TU Delft such as quality assurance. Although TU Delft is the coordinating institute, it became apparent to the panel through discussions with the deans, programme management, lecturers as well as the board of examiners, that TU Delft and Leiden University are equal partners regarding use of campuses (students visit both campuses for at least one day a week). TU Delft and Leiden University are also equal partners regarding their FTE's in the programme (each new course is jointly developed and taught by 2 lecturers) and the division of responsibilities for things like committees and financing. Programme management said that they used the expertise of people involved in other joint degree programmes to create the best possible programme. The fact that programme management made use of the expertise of external parties is positive in the eyes of the panel. However, the logistics around students having to travel to two different campuses every week is a concern. The panel would like to see TU Delft and Leiden University to check with other joint degree programmes how they dealt with that particular issue. Despite the logistic concerns, the panel concludes that the QIST master meets the NVAO’s required quality level for joint degree programmes (as laid down in the NVAO protocol joint degree TNO).

Professional field
During the site visit, the panel spoke with passionate industry experts and researchers who were involved in the development of the master. They indicated a strong demand for QIST professionals to improve quantum technology. Industry needs highly skilled conceptual professionals with a quantum background and engineering qualities. Professionals with excellent communication and interdisciplinary teamwork skills. Therefore, representatives are excited about the fact that QIST combines system engineering with quantum technology. TU Delft and Leiden University have asked the representatives to form an advisory board where important developments will be discussed in order to keep the programme as up-to-date as possible. Most representatives so far involved in the master development are quantum computing experts. It would therefore be good if TU Delft and Leiden University invite quantum communication and quantum sensing & metrology professionals to be member of the advisory board as well. The panel thus recommends setting up an advisory board with a wide range of industry professionals from all three application fields as soon as possible. The panel acknowledges the rapid changes in the quantum information technology field and the increasing demand for highly skilled quantum technologists. The involvement of industry professionals is therefore extremely important. Currently, all prospective members of the board are men. The panel urges TU Delft and Leiden University to reach a more gender-diverse composition of the advisory board as well as to aim for diversity in other aspects too.

International perspective
The panel appreciates the fact that TU Delft and Leiden University have researched other interdisciplinary quantum masters prior to designing the QIST programme. TU Delft and Leiden University looked at quantum master programmes around the world and saw that three other universities offer interdisciplinary quantum masters. One Australian and two European universities. These programmes primarily focus on quantum physics. The QIST programme is different from the other programmes because TU Delft and Leiden University include quantum physics, mathematics, electrical engineering and computer science into their programme. University and industry representatives strongly believe that the QIST master is a solid addition to the quantum technology programmes currently available, due to the unique, interdisciplinary approach to help students become deep generalists. Moreover, the rapidly growing quantum-technology industry sets high demands for quantum technologists with a multidisciplinary and system approach.

The programme management team indicated that TU Delft and Leiden University will not try to attract international students at first. Although the demand for QIST graduates is high, TU Delft and Leiden University want to take their time to set up a suitable programme and start with a small group of approximately 25 students. TU Delft and Leiden University will start the recruitment process among their current bachelor students and will not actively recruit (international) students from foreign (non-Dutch) universities in the first academic year. Based on the discussions with internal and external representatives, the panel expects a significant influx of international students once the master starts actively recruiting students. The panel therefore recommends to focus on sustainable internationalisation of the master's programme in an early stage (such as admissions, provision of information, intercultural competencies).

In summary, TU Delft and Leiden University offer a challenging interdisciplinary master in Quantum Information Science & Technology. The development team of the master, consisting of lecturers, scientists and engineers from both universities, has designed a profile to deliver deep generalists. Deep generalists will contribute to the future development of quantum technology, and build (components for) quantum computers, quantum communication networks, and quantum sensors. Research and industry representatives stated that they have actively contributed to the design of the profile and that they are happy with the end result. The profile meets their direct need for highly skilled conceptual professionals who can work with a wide range of different specialists. The intended learning outcomes are comprehensive, reflect the strengths of the programme and adhere to the required master level. The panel believes however that the application fields and orientations that students can choose should be better reflected in the intended learning outcomes, but that doesn't prevent the panel from deciding that the requirements for this standard have been met.

6.2 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.

Judgement
Meets the standard.

Findings, analysis and considerations
In conversation with programme management and lecturers, it became clear to the panel that TU Delft and Leiden University created an inspiring learning environment that encourages students to learn. The educational philosophy on which the master is based consists of the blended learning approach (synchronous and asynchronous learning activities), the combination of theory and practice (acquiring both theoretical knowledge on quantum technology as well as hands-on experience), and the concept of the reflective engineer (reflecting on personal goals and the implications of quantum technology). TU Delft and Leiden University use projects to challenge students and

teach them how to work in groups. Groups consist of students with different bachelor's degrees and professional backgrounds. In the multidisciplinary projects, students develop technical and transferable skills and gain insight into the technological, economic, ethical, and public impact of transformative quantum technology. Students use their personal portfolio to reflect on the skills they acquired and their personal goals and form small portfolio groups under supervision of a mentor. The portfolio groups focus on peer coaching to promote reflection and constructive feedback skills.

Curriculum
With the QIST master, TU Delft and Leiden University offer a comprehensive two-year curriculum (120 EC). The panel is very positive about the design of the curriculum. Strong elements include the homologation programme, multidisciplinary team projects and core courses. Q1 of the first year consists of the homologation programme (10 EC). This programme is designed to give students the necessary basic knowledge to be able to successfully complete the core courses. Q1 also contains a multidisciplinary team project (5 EC) and is called an orientation team project. During this project, students with different bachelor's degrees work together on a challenge related to quantum information processing. The core courses are taught in Q2 and Q3 (20 EC). These have a strong focus on quantum computing and quantum communication and less on quantum sensing and metrology.

In Q3 students will begin creating a personal profile by choosing an application field plus several electives (25 EC). In order for students to form a well-informed decision when choosing an application field and electives, they will get acquainted with the application fields during the homologation programme and the core courses. Furthermore, TU Delft and Leiden University will organise an information market in the beginning of Q3. The information market helps students make a decision on which application field and electives to choose for their future careers. During the information market, research groups present their current lines of research and specify which profile and electives match best.

The panel appreciates the fact that students create their personal profile by choosing one of three application fields. However, in the information dossier and via conversations with different representatives, the panel learned that the three application fields are unequally represented in the curriculum. The application field sensing and metrology seems to be slightly underrepresented compared to the other two application fields. According to the panel The topic is not in the homologation programme and only implicitly offered in the core courses. Lecturers elaborated that the emphasis within the master lies indeed on the two application fields quantum computing and simulations and quantum communication. They stated that industry has a focus on quantum computing and quantum communication. TU Delft and Leiden University therefore decided to reflect the focus of industry in the master. The panel understands the decision, but emphasises that the programme must ensure that a comparable weight is assigned to the three application fields in the master. The panel therefore advises to enable students to become acquainted with sensing and metrology by explicitly offering this topic in the homologation programme and in the core courses.

The second year of the master starts off with a multidisciplinary team project (15 EC) in Q1. Groups of students with different profiles work together on a challenging, real-life quantum technology issue. The issue at hand has a multidisciplinary character and is proposed by a company or institute affiliated with the quantum technological field. Students work closely together with the organisation that posed the problem and will present their insights or solution to the organisation. Industry representatives the panel spoke to, all stated that they are looking forward to propose a problem and guide QIST students during the project.

Master's thesis project
Master's thesis projects are based on one of the three orientations: research, design, or business. The panel appreciates the orientations since they offer students the possibility to create a strong personal profile. Students who choose the research orientation work

on a research-oriented project (44 EC). Theses within the design orientation consist of a design and/or system integration-oriented project (44 EC). The projects from these two orientations are carried out with a research group affiliated with the QIST programme. Design orientation projects can be carried out in collaboration with a company. Business orientation theses consist of an application-oriented research project (30 EC). The project falls under the responsibility of a supervisor of one of the research groups and is conducted in collaboration with a company. As students have to do additional course(s) worth 14EC, the thesis for the business orientation is only 30 EC. The courses students can choose from are about management of technology and entrepreneurship. During the site visit, the panel learnt that the business orientation is aimed at students who are interested in joining or launching a start-up. The extra courses that form part of the business orientation provide students with the necessary knowledge to be able to do that. The panel is happy with the explanation from the lecturers and now understands why the master offers the extra courses and why the business orientation project is awarded less ECs than projects of the other two orientations. The panel questions how the business orientation contributes to achieving the intended learning outcomes as the business orientation is not included in the intended learning outcomes (see standard 1). The panel believes that explicitly adding the business orientation to the intended learning outcomes could clarify how the business orientation will contribute to achieving the learning outcomes. Another concern the panel has is related to the research orientation. The panel and industry representatives both believe that the research orientation currently focuses too heavily on the academic research component, while also companies can be heavily engaged in research. The panel therefore strongly recommends TU Delft and Leiden University to give students in the research orientation the option to collaborate with companies as well.

Transferable skills
The panel asked lecturers about the development of transferable skills such as communication, presentation, argumentation and collaboration. The lecturers said that the option was discussed of either offering a transferable skills course (3 EC) or dividing the transferable skills between the different courses and projects. TU Delft and Leiden University opted for the second option. However, the universities did decide to offer a separate 1-EC course on developing transferable skills. This course is called *Student portfolio: Equipping the QIST professional*. Students follow the course in years 1 and 2 and are awarded 1 EC upon completing the course at the end of year 2. In the portfolio, students reflect on their learning activities and their individual progress. The panel questioned if this course includes things like scientific integrity and plagiarism and the lecturers confirmed this was the case.

The panel is positive about the transferable skills that are taught as well as about the student portfolio in which students learn to reflect on their personal goals and individual progress. The transferable skills that form part of the programme are important to become a solid QIST professional who can work with a wide range of specialists. However, after reading the information dossier, the panel noticed that the transferable skills are not always properly formulated as a learning objective in some of the courses. For example, academic integrity is mentioned in several course descriptions, but academic integrity is not described in the learning objectives for these courses. The panel therefore recommends including all transferable skills in the learning objectives of the courses addressing them to ensure that students and lecturers know which objectives students must achieve in order to successfully complete the course.

Study load
According to the panel, TU Delft and Leiden University have adequately explained why the universities want to offer an extended two-year master programme. The universities want to deliver deep generalists and that is what the industry wants and requires. To be able to achieve this, students need a solid foundation of core courses and projects before they can start their chosen specialisations (application field and orientation). The universities believe that the extent of skills and the level of mastery require a two-year master's programme. Industry representatives agree that a one-year programme is just not realistic. Quantum professionals that have recently entered the

workforce all completed a two-year master. The panel believes that the explanation of TU Delft and Leiden University is convincing enough to justify the need for a two-year programme. This leads to the conclusion that the QIST master meets the NVAO protocol requirements for extended statutory course duration.

Facilities
The site visit took place in Delft, as TU Delft is the coordinating university. During the site visit, the panel was given a tour of the TU Delft campus and was impressed by the excellent facilities. The panel learned about the facilities of Leiden University via the information dossier and conversations with lecturers and programme management from Leiden University. Although the facilities are top-notch, the panel believes that the commute between two universities will be a logistic challenge for students. The panel refers to it as a nomadic student lifestyle and raises the question whether this would prevent students from forming a close learning community in which they can connect with other students and build friendships. The two universities acknowledge that this could be an issue and have therefore arranged that as a rule students will not have activities (lectures, working groups etc.) on two campuses within one day. In the event of scheduling difficulties the universities will arrange that lecturers rather than students make the commute between Leiden and Delft. The two universities have also set up the orientation team projects and portfolio groups to counterbalance the commute between the two campuses. Students form part of these (project) groups from the very first day of the programme, enabling them to establish strong bonds immediately. The panel appreciates this initiative, but does recommend using the (project) groups as a foundation for students to form their own (informal) learning communities. Creating a strong learning community is important for students to build solid relationships with each other, which will enhance students' level of motivation and academic achievement.

Language
The working language of the QIST programme is English. Programme management explained that English is the working language in quantum technology and QIST graduates will most likely work in an international environment after completing the programme. Hence TU Delft and Leiden University chose to create a programme in English. In addition, an English programme is more desirable than a Dutch programme because of the international lecturers and future potential international students. The panel supports the decision to teach in English.

Admissions
The intended start date of the QIST master is September 2023. TU Delft and Leiden University hope to start with a group of 25 students. Students with a bachelor's degree from TU Delft or Leiden University in (Applied) Physics, (Applied) Mathematics, Electrical Engineering or Computer Science are eligible to join the programme. Students need to have a minimum of 5 EC in linear algebra courses, 5 EC in calculus courses, 5 EC in quantum mechanics or quantum information courses and a 12-EC research project in the last year of their bachelor. Although programme management expects students to have certain basic programming skills, these skills are not required and do not form part of the admission requirements.

As described in standard 1, the two universities want to focus on developing a strong programme before attracting a lot of students. Programme management explained that this is the reason for the strict admission requirements. Students from other universities are allowed to join the programme if they have a comparable degree plus the minimum required prior knowledge, but TU Delft and Leiden University will not actively recruit these students in the beginning. The panel is happy that programme management allows students from other universities to apply and to assess their eligibility on a case-by-case basis. In the next few years, TU Delft and Leiden University will start actively recruiting (international) students. TU Delft and Leiden University intend to then offer a bridging programme for students who do not yet meet the admission requirements.

Due to the admission requirements, TU Delft and Leiden University intend to set up an admission committee. The committee will consist of three staff members: two from TU

Delft and one from Leiden University. The panel greatly appreciates the universities setting up an admissions committee with members from both universities.

Staff
The panel spoke with a passionate and skilful programme management team and lecturers. Lecturers of the QIST master work either at TU Delft (Faculty of AS or EEMCS), Leiden University (FoS) or at QuTech. QuTech (guest) lecturers work for the faculty of AS or EEMCS and also give lectures in other MSc programmes. All lecturers are active quantum researchers who integrate their research expertise in their courses. The panel is pleased that each new course has been designed jointly by lecturers from both universities and that the programme strives to have courses taught by lecturers from both universities. Based on conversations with the programme management team and lecturers, the panel believes that the teams are adequate to implement and coordinate the programme.

Student support
Student support and study guidance is provided by the programme coordinator, study advisors and mentors (lecturers and staff). They will be involved in advising students in their choice of elective courses. Students who encounter obstacles during their master due to a disability or difficulties with studying can get support from TU Delft career and counselling services.

Diversity and inclusivity
The panel noticed, during conversations with lecturers, that TU Delft and Leiden University want to have a progressive diversity and inclusivity policy where both staff and students feel welcome and valued. They aim to attract more (fulltime) female professors, and encourage initiatives that will further improve inclusion. Both universities believe that inclusion and diversity are very important. TU Delft therefore already has a diversity and inclusion team (EEMCS faculty) and in Leiden FoS has a diversity coordinator and a diversity workgroup. This workgroup, that consists of internal employees, advises the deans and HR regarding diversity and inclusivity, organises activities, and monitors diversity among students and employees. The panel appreciates that both universities are committed to improve diversity and inclusivity. The panel believes that diversity and inclusion are challenging in the engineering and science fields. The panel saw the lack of diversity of these sectors during the site visit, as most of the lecturers and industry professionals were (white) male. The panel therefore encourages TU Delft and Leiden University to continue putting diversity and inclusivity high on the agenda.

In summary, the panel states that the QIST programme has a comprehensive curriculum that allows students to achieve the intended learning outcomes. The combination of theory and practice is an attractive aspect of the master. Students will have to form (project) groups in which they closely work together with lecturers and industry experts. The panel believes that creating a strong learning community is important for students to build solid relationships with each other. Solid relationships among students will enhance students' level of motivation and academic achievement. The teaching staff are passionate and knowledgeable research experts. The panel concludes, based on the above, that this standard meets the requirements.

6.3 Standard 3: Student assessment

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

Judgement
Meets the standard.

Findings, analysis and considerations
The QIST master has a good student assessment system. TU Delft and Leiden University decided to follow the exam policies of the coordinating faculty or, in case of elective courses, the faculty where the courses take place. Therefore, the homologation

programme, core courses, multidisciplinary team projects and the master's thesis projects fall under the exam policy of the AS faculty and the electives fall under the exam policy of the faculties (in Leiden or Delft) by which they are taught. The assessment policy has been documented in the 'Teaching and Examination Regulations' (TER) which has been drafted by the three faculties together. The TER describes the content of the assessment programme and the assessment processes. The quality assurance falls under the responsibility of the Board of Examiners (BoE) from the AS faculty. The BoE will appoint a subcommittee for the QIST master with three members (one member from each of the participating faculties). The subcommittee is responsible for the quality of the homologation programme, the core courses, the multidisciplinary team projects and the master thesis projects.

Representatives of the BoE mentioned that the exam policies of the three different faculties are virtually identical. In the master, assessment methods are geared to the learning objectives. As most courses cover multiple learning outcomes, a course can have several types of assessment. Types of assessment include written exams, presentations, group assignments, projects, and homework assignments. Many of the courses contain formative assessment. Via assignments and quizzes, students learn about their study progress as they receive formative feedback on their results. TU Delft and Leiden University use the four-eyes principle to increase the objectivity of examination. Another way the universities try to increase the objectivity is by organising monthly meetings between lecturers. Lecturers also talk informally to one another about the quality of education and assessment. The entire staff will meet twice a year to discuss the quality of education and assessment on a more formal level. The panel is positive about the procedures that have been set up by the faculties to maintain a high level of quality assessment.

The panel believes the level of the thesis is at master level because of the degree of complexity and structure in the master's thesis project and the level of multidisciplinary engineering topics. The master's thesis project is assessed with the regulations of the AS faculty by an assessment committee. The assessment committee is composed by the responsible academic supervisor. The committee consists of three members: the academic supervisor, a member of a research group different from the one the thesis supervisor belongs to, and an independent lecturer from the TU Delft or Leiden University. To successfully complete the programme students have to do an oral presentation for the assessment committee. After the presentation students receive feedback from the committee.

The information dossier included the rubric for the master's thesis project of the AS faculty. The rubric has clear formulated criteria. The panel questioned what the QIST master's thesis rubric looks like and if every orientation has its own rubric. The BoE explained that the AS faculty uses a general rubric for every master's programme within the faculty (AS consists of six master's programmes). The rubric enables lecturers to assess students via transparent and clear criteria and to ensure fair grades. The rubric also has a formative purpose by making sure students know how they perform during the project. The master uses the same rubric for all three orientations. The panel wonders whether the current rubric is detailed enough to properly assess the intended learning outcomes of all three orientations. The rubric seems to be very research oriented and does not address the design and business orientations. The panel advises the BoE to analyse if all the intended learning outcomes are correctly assessed with the current rubric.

The TER mentions that the completion date for the master's thesis project can only be postponed once. Lecturers explained that this rule is meant as a strong incentive for students to graduate within the two years. Exceptions are allowed when students are unable to graduate due to certain unforeseen circumstances. The panel appreciates the two universities encouraging a swift graduation process, but is glad that they are a little bit more flexible than the information dossier suggests.

In summary, the panel states that the master's programme has a sound and transparent assessment system. The BoE and subcommission play an important role in ensuring the quality of assessment. Members of the BoE have collaborated with the faculties to set up clear procedures to maintain a high level of quality assurance. The panel appreciates the wide variety of assessment methods and the formative feedback students receive regularly. The master's thesis project definitely has the required master level, thanks to the complexity and the level of multidisciplinary engineering issues. The panel does advice the BoE to check if the three orientations are correctly assessed with the current AS faculty wide rubric. Based on the above, the panel concludes that the requirements for this standard have been met.

6.4 Degree, field of study and review group.

The panel advises awarding the following degree to the new programme: Master of Science
The panel supports the programme's preference for the following field of study: Technology
The panel supports the programme's preference to join the following review group: *'WO Natuur- en Sterrenkunde groep 1'*

Abbreviations

AS	Applied Sciences
BoE	Board of Examiners
CROHO	Central Register of Higher Education Study Programmes
EC	European Credits
EEMCS	Electrical Engineering, Mathematics & Computer Science
FoS	Faculty of Sciences
FTE	Full-time equivalent
TER	Teaching and Examination Regulations
TNO	Toets Nieuwe Opleiding (Initial Accreditaion)
QIST	Quantum Information Science & Technology

The full report was written at the request of NVAO and is the outcome of the peer review of the new programme Quantum Information Science & Technology (joint degree) of Technische Universiteit Delft and Leiden University

Application no: AV-1450 and AV-1451

NVAO

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