MASTER'S PROGRAMME

MATERIALS SCIENCE AND ENGINEERING

MECHANICAL, MARITIME AND

MATERIALS ENGINEERING

DELFT UNIVERSITY OF TECHNOLOGY

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This report was finalized on 28 March 2019.

REPORT ON THE MASTER'S PROGRAMME MATERIALS SCIENCE AND ENGINEERING OF DELFT UNIVERSITY OF TECHNOLOGY

This report takes the NVAO's Assessment Framework for Limited Programme Assessments as a starting point (September 2016).

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

Master's programme Materials Science and Engineering

Name of the programme:	Materials Science and Engineering
CROHO number:	66958
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	Materials in Engineering Applications (MEA) Metals Science and Technology (MST) Materials for Sustainable Development (MSD) Advanced Construction Materials (ACM)
Location(s):	Delft
Mode(s) of study:	full time
Language of instruction:	English
Expiration of accreditation:	31/12/2019

The visit of the assessment panel Mechanical Engineering to the Faculty of Mechanical, Maritime and Materials Engineering of Delft University of Technology took place on 13-14 December 2018.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Delft University of Technology
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 20 August 2018. The panel that assessed the master's programme Materials Science and Engineering consisted of:

- Prof. dr. K.G.S. (Sören) Östlund, professor of Packaging Technology at the Department of Solid Mechanics of the KTH Royal Institute of Technology (Sweden) [chair];
- Prof. dr. H.J. (Henry) Rice, professor, Mechanical Engineering and head of the School of Engineering of Trinity College Dublin (Ireland);
- Dr. M. (Maddalena) Velonà, coordinator of studies at the Department of Mechanical and Process Engineering (D-MAVT) at Eidgenössische Technische Hochschule (ETH) Zürich (Switzerland);
- Drs. J.J. (Jan) Steen, consultant Quality of Education at Wageningen University & Research;
- Prof. dr. R.W. (Richard) Birmingham, professor in Small Craft Design at the Marine Technology Group of the School of Engineering, Newcastle University (United Kingdom);
- Ir. J. (Jan) Leideman, new business development manager at DEMCON Advanced Mechatronics;
- A.J. (Alicia) Knijnenburg, BSc, master student Mechanical Engineering at the University of Twente [student member].

The panel was supported by dr. B.M. (Barbara) van Balen, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the master's programme Materials Science and Engineering at the Faculty of Mechanical, Maritime and Materials Engineering of Delft University of Technology was part of the cluster assessment Mechanical Engineering. In December 2018 the panel assessed eleven programmes at three universities. The following universities participated in this cluster assessment: Delft University of Technology, Eindhoven University of Technology and the 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. Dr. Alexandra Paffen was project coordinator for QANU. Dr. Barbara van Balen acted as secretary in the cluster assessment. She is a certified NVAO secretary.

Panel members
The members of the assessment panel were selected based on their expertise, availability and independence.

Preparation
On 9 December 2018, 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 December 2018. During this meeting, the panel members received instruction on the use of the assessment frameworks. The panel also discussed their working method and the planning of the site visits and reports.

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

Before the site visit to Delft University of Technology, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection existed of fifteen theses and their assessment forms for the programmes, based on a provided list of graduates 2016-2017. A variety of topics and tracks and a diversity of examiners were included in the selection. The project coordinator and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst all panel members.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation reports and the theses, as well as the division of tasks during the site visit.

Site visit
The site visit to Delft University of Technology took place from 13 to 14 December 2018. During the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners.

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.

Consistency and calibration
In order to assure the consistency of assessment within the cluster, the following measures were taken:

1. The panel composition ensured regular attendance of (key) panel members, including the chair;
2. The secretary was present at the start of all site visits as well as the panel discussion leading to the preliminary findings at all site visits of Delft University of Technology, Eindhoven University of Technology and the University of Twente.

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 reports to the Faculty in order to have these 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.

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 both the standards and the programme as a whole.

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

Unsatisfactory
The programme does not meet the generic quality standard and shows shortcomings with respect to multiple aspects of the standard.

Satisfactory
The programme meets the generic quality standard across its entire spectrum.

Good
The programme systematically surpasses the generic quality standard.

Excellent
The programme systematically well surpasses the generic quality standard and is regarded as an international example.

SUMMARY JUDGEMENT

Standard 1
The master's programme Materials Science and Engineering (MSE) is offered by the Faculty Mechanical, Maritime and Materials Engineering (3mE) of Delft University of Technology (TU Delft). It is the only Materials Science and Engineering master's programme in the Netherlands. Materials Science and Engineering is dedicated to providing coherent and innovative research and teaching focused on the sustainable development, characterisation and understanding of materials that perform better, last longer, enhance function, conserve resources and have a low environmental footprint. The educational programme addresses the societal aspects of materials usage, reflected in the attention paid to re-usage and recycling of materials and the development of associated technologies for a circular economy.

The programme defines intended learning outcomes (ILOs) in line with its vision. The panel finds them well considered, specific and measurable. The ILOs meet the Dutch qualifications framework and sufficiently reflect the academic master's level. The ILOs tie in with the international perspective of the requirements set by the professional field and the discipline. The panel, however, recommends broadening the scope of the programme by including more materials along with metals.

Standard 2
MSE offers the following specialisations: Materials in Engineering Applications, Metals Science and Technology, Materials for Sustainable Development and Advanced Construction Materials: Roads and Buildings. The curriculum (120 EC, two years) consists of three parts: the core programme (41 EC), a specialisation course (39 EC) and the graduation project (40 EC). The courses offered by the MSE programme do not cover the whole field of materials science, and students are also allowed to define a specialisation course of their own using modules offered by other master's programmes.
The panel verified that the MSE curriculum enables the students to achieve the ILOs. The curriculum is well structured, with a good alignment between the ILOs and the courses. The programme uses a variety of teaching methods, is well connected to research and industry, and has a hands-on approach.

The panel agrees with the importance of materials science and thinks that the programme could prepare the students even better for challenges in the future with a broader and more innovative scope.

The quality and quantity of the teaching staff are good, but the panel encourages continuing to broaden the expertise by hiring new staff members.

Standard 3
The Faculty aims to achieve a high level of quality in its teaching and assessment. The Faculty's assessment system and policy are well developed and implemented according to the panel. All teachers are aware of the policies and measures implemented to assure the validity and reliability of the assessments. The Faculty has ensured that the teachers are supported in their tasks by the appointment of an educational advisor.

The courses use a variety of assessment methods, which are very well aligned, with the help of test matrices, with the learning outcomes and the curriculum. The procedures are transparent for teachers and students.

The panel is very positive about the way the Board of Examiners is performing its tasks and concluded that the examinations, tests and the thesis assessment are transparent, valid and reliable.

Standard 4
The panel studied a selection of 15 master's theses to assess whether the graduates had achieved the intended learning outcomes. It concludes that graduates of the master programme Materials

Science and Engineering have achieved the intended learning outcomes. They are well prepared for continuing in a PhD programme or a career in industry.

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

Master's programme Materials Science and Engineering

Standard 1: Intended learning outcomes	satisfactory
Standard 2: Teaching-learning environment	satisfactory
Standard 3: Student assessment	good
Standard 4: Achieved learning outcomes	satisfactory
General conclusion	satisfactory

The chair, prof. Sören Östlund, and the secretary of the panel, dr. Barbara van Balen, hereby declare that all panel members have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 28 March 2019

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

General remarks cluster Mechanical Engineering

This report constitutes part of the limited programme assessment of the NVAO Assessment cluster Mechanical Engineering representing 11 bachelor and masters programmes in Mechanical Engineering, Automotive Technology, Marine Technology, Offshore and Dredging and Materials Science and Engineering at University of Twente, Eindhoven University of Technology and Delft University of Technology. The findings for each programme are based on the self-evaluations performed by each programme and site visits taking place on December 10-14, 2018.

In the self-evaluation reports and during the site visits, the evaluation panel has encountered many knowledgeable and dedicated programme managers, skilled and engaged teachers, well-educated and enthusiastic students and successful alumni. It is therefore with great pleasure that we can conclude that the overall outcome of the evaluation panel ends on a positive note.

All programmes are based on intended learning outcomes well set in national or international perspective of the requirements currently set by the professional field and the discipline, programme managers, teachers and students work hard to create a motivating and dynamic teaching and learning environment, all programmes have elaborated assessment plans and the achieved learning outcomes are good. Many of the theses read by the evaluation panel are indeed of very high quality, and graduates from the eleven programmes in general have very good career opportunities.

There is of course always room for improvements, and, particularly, the processes around internships, the overall study times and the high dropout rates are areas that should be given continued high attention. The increased internationalisation of the programmes, the growth in number of students and the level of the students are other challenges that needs consideration in the coming years. However, it is the opinion of the assessment panel that the programmes in the Assessment cluster Mechanical Engineering are well prepared to meet these.

On behalf of the Mechanical Engineering assessment panel,
Sören Östlund (Chair)

Governance structure of the Faculty

The master's degree programme in Materials Science and Engineering (MSE) is provided by the Department of Materials Science and Engineering, one of the seven departments of the Faculty of Mechanical, Maritime and Materials Engineering (3mE) at Delft University of Technology (TU Delft). The 3mE Faculty offers the MSE programme along with the bachelor's and master's programmes Mechanical Engineering, the bachelor's and master's programmes Marine Technology and the master's programme Offshore and Dredging Engineering, which are also assessed in this cluster assessment. It also offers the bachelor's and master's degree programmes Technical Medicine and the master's programmes Biomedical Engineering and System and Control.

Standard 1: Intended learning outcomes

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

Findings

The Materials Science and Engineering Department is dedicated to providing coherent and innovative research and teaching focused on the sustainable development, characterisation and understanding of materials that perform better, last longer, enhance function, conserve resources and have a low environmental footprint. The educational programme addresses the societal aspects of materials usage, reflected in the attention paid to re-usage and recycling of materials and the development of

associated technologies for a circular economy. The master's programme Materials Science and Engineering is unique in the Netherlands. In an appendix to the self-evaluation, a comparison is made with several European and international programmes in Materials Science.

The 3mE Faculty aims to deliver T-shaped[1] engineers with a clear Delft stamp, creative team workers and engineers with an open mind for future developments. It wants to achieve this aim by offering programmes that are at the leading edge of societal trends, while providing a thorough grounding in the relevant professions. According to the Faculty policy, the programmes should have a substantial focus on ethics, environment and 'Bildung', using both challenging teaching methods as well as massive online material in projects. The MSE programme translated these objectives into intended learning outcomes, using the framework of the 4TU criteria for Academic Master's Curricula, known as the Meijers Criteria[2] (Appendix 2). The panel established that the ILOs are formulated in line with the mission and sufficiently indicate what could be expected from programmes at a master's level. It also ascertained that the ILOs meet the internationally accepted description for academic master's programmes, the Dublin descriptors, which are elaborated for the engineering programmes into the 4TU (Meijers) criteria. It considers the ILOs to be well defined, specific and measurable. They indicate the content, level and orientation of the master's programme MSE and fit the professional field. In the panel's opinion the ILOs adequately describe the objective of the programme to educate students with a focus on sustainable development. This is formulated, in particular, in final qualification 7 'Considering the temporal and social context'. The panel noticed that the content of the master's programme is mainly focused on metals, which was not clear to the students before entering the programme. In its opinion, new materials have a critical part to play in the future, and it would highly recommend broadening the scope and including polymers and new materials. Furthermore, prospective students should be aware of the scope of the programme.

Considerations
The panel concluded that the ILOs of the master's programme MSE are well considered, specific and measurable. They meet the Dutch qualifications framework and sufficiently reflect the academic master's level. They tie in with the international perspective of the requirements set by the professional field and the discipline.

The master's programme is unique in the Netherlands, so a benchmark was provided with academic programmes in Materials Science in Europe and internationally to provide information about level and content. This was appreciated by the panel. However, it recommends either broadening the scope of the programme by including more materials other than metals or being more transparent about the metals focus in the programme.

Conclusion
Master's programme Materials Science and Engineering: the panel assesses Standard 1 as satisfactory.

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
The programme
The MSE programme focuses on three connected goals:
- To teach students the theory underlying materials science;
- To train students in using characterisation techniques in a job environment;

[1] T-shaped professional is a person with sufficient depth of related skills and expertise in a single field, and the ability to collaborate across disciplines with experts in other areas and to apply knowledge in areas of expertise other than one's own.
[2] https://www.ram.ewi.utwente.nl/embedded2017/doc/Meijers_summarised.pdf

- To coach students to perform materials-related research at an academic level.

MSE offers the following specialisations: Materials in Engineering Applications, Metals Science and Technology, Materials for Sustainable Development and Advanced Construction Materials: Roads and Buildings. The curriculum (120 EC, two years) consists of three parts: the core programme (41 EC), specialisation courses (39 EC) and the graduation project (40 EC).

The programme starts in the first year with the core programme consisting of ten obligatory modules. During the second quarter, an information meeting is organised with all students to present an overview of the available specialisation courses. At the end of the first semester, students should specify their preference for a specialisation. Since the specialisations offered do not cover the whole field, students are also allowed to define a specialisation course of their own, using modules offered by other master's programmes. Therefore, they can formulate their own learning trajectory.

In the second year of the programme, students continue to follow specialisation courses of their own choice, and they do their master's thesis project (40 EC). The goal of the master's thesis project is to let students work individually on a complex problem, working independently with the tools and methods provided, to develop new theory and design methods to solve material-related problems. The starting point of each project is a literature survey. This survey can be used as input for the thesis.

The students confirmed that all courses are related to ongoing research, so that they know what they can do if they want to continue in research. Students appreciated the focus on application; the programme is not merely theory, but pays attention to hands-on experience and ties in with industry. As already mentioned under standard 1, both the panel and the students noticed that most of the research is metals oriented. During the site visit, the teaching staff told the panel that polymer science is taught elsewhere in TU Delft, and students can take courses on that subject in their specialisation trajectory. The programme is designed to avoid overlap with other programmes at TU Delft. The panel appreciates the efficiency argument, but nevertheless thinks that the programme would profit from closer cooperation with the departments of TU Delft that specialise in polymer and other materials and recommends offering a coherent, student-centred package of courses that covers a broader field of materials science.

Students and study yield
The intake of students in the MSE has increased over the last years from 20 to 40 on average; about 60% of the students is international. Students take on average 28 months to graduate, and international students, 25 months. The relatively high percentage of international students in the programme indicates that there is a demand for graduates in materials science and that the materials science and engineering department is well-known internationally.

Teaching staff
All instructors in the MSE programme are academic staff members with a PhD, 85% holds a UTQ, and 50% of the staff comes from abroad. During the site visit the students reported that they are satisfied with the teaching quality. The self-evaluation report provided information about the staff's scientific track record, summarising the research grants received, which is very good in the panel's opinion. The panel learned during the site visit that new academic staff members are being hired with additional expertise in artificial intelligence, for instance, which provides a good opportunity for innovative research and teaching.

The Faculty is strongly committed to developing and maintaining the quality of its teaching staff. To promote involvement and improve mutual communication, an Education Day is organized each year in August for all teaching staff in the Faculty. At this event, the staff receive information on the latest developments in education and professional practice from experts in the field of education. Educational policy and new developments in education are discussed, and attendees participate in workshops organized around various educational themes.

Considerations
The panel established that the curriculum of the master's programme Materials Science and Engineering meets the standards for accreditation. It found that the curriculum contains a core programme that provides the students with a solid foundation in materials science. Students can build their own study trajectory by selecting courses offered by the MSE programme as well as by other programmes in TU Delft, enabling them to specialise in the materials science of their choice. The panel appreciates the close connection of the courses to ongoing research and the focus on application, the attention paid to hands-on experience, and the ties with industry.

The quality and quantity of the teaching staff are good, but the panel encourages the programme management to continue to broaden the expertise by hiring new staff members.

Conclusion
Master's programme Materials Science and Engineering: the panel assesses Standard 2 as satisfactory.

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

Findings
Assessment policy
The Faculty aims to achieve a high level of quality in its teaching and assessment. The aim is to achieve the highest possible quality standards in relation to validity, reliability and transparency for assessments, within the limits of feasibility. Its full vision and policy on assessment is described in the document 'Toetsing bij 3mE'. In order to determine adequately whether a student has achieved the final qualifications, every form of assessment is tailored to the learning objectives and teaching formats (constructive alignment). An examiner should have the UTQ certificate or be in the process of obtaining one. All examiners in the bachelor's and master's programme are employed by TU Delft.

In the process of constructing tests, examiners have to apply the 'four-eyes' principle with a colleague in the interests of safeguarding the quality of assessment. This can vary from the provision of feedback to doing trial tests, discussing the answer model and jointly determining the pass mark. Examiners have to prepare a test matrix in advance as a blueprint for their exams to guarantee the constructive alignment.

Once every three years, the educational advisor provides the examiners with feedback on test issues such as reliability, validity, construction and safeguarding of the learning objectives. Examiners are expected to keep working on improving quality and using the relevant instruments. The educational advisor is always available for support at the examiner's request. At the end of every semester, the educational advisor submits an evaluation with findings and recommendations to the Board of Examiners and the Director of Education.

For written exams, students receive their grades within 15 working days after the exam date. They have the right to feedback on their exam work within 20 working days after the grade publication date. Most lecturers organise offices hours or something similar for students to check their exams and ask questions. Students increasingly receive digital scans of the exams they have taken and handle the feedback procedure online as well.

During the site visit the panel learned about the test matrix that is used to align the programme-wide ILOs, the learning outcomes of the course, the course exam and the assessment. It found this matrix to be very helpful and a good instrument to improve the validity and quality of assessments. It approves the assessment policy in general and the position of the educational advisor and the support given by the educational advisor to the teaching staff to improve the assessment quality.

Assessment methods
In the MSE programme, several formative and summative methods of testing are used: written exams, oral exams, individual project work, group project work, and homework assignments.

The graduation project is split into two parts: a literature survey and a thesis project. The student writes a report about the literature survey, which is graded separately and provides an indication of the final grade for the thesis project. The thesis is assessed by a graduation committee, which consists of at least two scientific staff members and one postdoc or PhD student. One staff member should be from another section or preferably department. The chair must be a full professor or an associate professor who is authorised by the Board of Examiners to sign the master certificate. The thesis is assessed with a uniform master thesis grading rubric.

Board of Examiners
The Board of Examiners (BoE) of 3mE consists of a chairman, a secretary, one member of each research department and an external member from another Faculty. The BoE performs its duties independently. The chairman and the secretary of the BoE hold regular meetings with the Dean, the Director of Education, and other TU Delft Boards of Examiners to discuss common concerns and improve assessment.

The BoE monitors the quality of assessment and the correct application of the Teaching and Examination Regulations. It also deals with students with special personal circumstances and with appeal cases. It has regular meetings in which it decides on cases brought in by students and staff members. The outcomes of the decisions are communicated in writing. In order to promote the equal treatment of students and preserve the ability to act decisively, decisions are transformed into policy wherever possible and recorded in internal policy documents.
The BoE has set strict rules for the composition of graduation committees and for graduating with distinction. It has a fraud and a complaints committee, each consisting of three members. These committees advise the BoE. The BoE has to make the final decisions. There is a protocol for the procedure to be followed in cases of fraud. The BoE maintains close contact with the educational advisor about the quality of the exams. The semester evaluation by the educational advisor is regularly discussed in a meeting of the BoE. In specific cases, the BoE can request the educational advisor to provide feedback or an analysis of an exam that was not assessed that year. Every year, the BoE writes an annual report on the performance of its statutory duties.

The BoE inspects the thesis work and accompanying assessment forms twice a year from a number of randomly chosen master students and assesses whether the graduation committees made fair judgements leading to the final grades.

According to the panel, the BoE has put adequate procedures in place to check the quality of assessment in the programme. The panel is very positive about the way the BoE is performing its tasks.

Considerations
The Faculty's assessment system and policy are well developed and implemented. All teachers are aware of the policies and measures implemented to assure the validity and reliability of the assessments. The Faculty has appointed an educational advisor who supports teachers with their tasks.

The courses in the master's programme use a variety of assessment methods, which are very well aligned, with the help of the matrices, with the learning outcomes and the curriculum. The assessment procedure for the master's thesis is well developed, documented and transparent.
The panel is very positive about the way the BoE is performing its tasks and concludes that the examinations, tests and the thesis assessment are transparent, valid and reliable.

Conclusion
Master's programme Materials Science and Engineering: the panel assesses Standard 3 as good.

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

Findings
The panel studied a selection of 15 master's theses to assess whether the graduates had achieved the intended learning outcomes. It concluded that they did indeed achieve the level that can be expected of them. It studied a selection of theses with a mix of high grades and low grades and found them to be of a master's degree level overall. The theses showed that the graduates are able to conduct research and design independently, have a scientific approach to complex problems and ideas, and have the ability to seek new potential applications. They reveal an advanced level of knowledge in a specialised field and a systematic understanding of the key aspects and concepts in materials science and engineering.
Graduates easily find a job; the self-evaluation provided an overview of the companies where graduates are employed. They find jobs in materials-related industries, academia or research institutes within a few months after graduation. The Faculty has an active Industrial Advisory Board that meets twice a year and is involved in curriculum changes, research reviews and the profile of the graduates. A recent survey of employers showed that the professional field perceives the graduates as competent. This was confirmed by the alumni in a national survey in 2017.

Considerations
The panel concludes that graduates of the master's programme Materials Science and Engineering have achieved the intended learning outcomes. It studied a selection of theses with a mix of high grades and low grades and found them to be of a master's degree level overall. The students are well trained for doing research and prepared for continuing in a PhD programme and seen as competent by employers.

Conclusion
Master's programme Materials Science and Engineering: the panel assesses Standard 4 as satisfactory.

GENERAL CONCLUSION

The panel assesses standard 3 of the master programme as good and standards 1, 2 and 4 as satisfactory. It was positive about the assessment system. Following the NVAO decision rules, the panel's general conclusion is that the programme is assessed as satisfactory.

Conclusion
The panel assesses the *master's programme Materials Science and Engineering* as satisfactory.

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

The discipline of Materials Science and Engineering involves investigation of the relationship between structures and properties of materials (science) and designing structures to produce predefined properties (engineering). Additionally, the science and engineering of materials considers the material processing needed to obtain a specific structure and the material performance that results from its properties.

The structure of a material relates to the arrangement of its internal parts and can be subdivided into subatomic structure (electrons and interaction with nuclei), atomic structure (organisation of atoms / molecules relative to one another), microscopic structure (agglomerations of large groups of atoms) and macroscopic structure. A material property relates to the response of a material to a specific type of stimulus and can be split into various categories including mechanical, electrical, thermal, magnetic, optical and degenerative. Knowledge of techniques for materials characterisation is essential to be able to study structures and measure properties. Computational techniques are becoming increasingly important for understanding and predicting material properties.

The Materials Science and Engineering is dedicated to providing coherent and innovative research and teaching focused on the sustainable development, characterisation and understanding of materials that perform better, last longer, enhance function, conserve resources and have a low environmental footprint. The educational programme addresses the societal aspects of materials usage, reflected in the attention paid to re-usage and recycling of materials and the development of associated technologies for a circular economy.

The scientific staff within the department has a broad range of academic and industrial contacts actively initiating and supporting research. Academic contacts are internationally widespread including universities in Germany, Belgium, UK, Australia, Japan, China, USA and India. Industrial collaborators include representatives from material manufacturers Tata Steel, Arcelor-Mittal, Thyssen-Krupp, Van Gansewinkel and Nedstaal; from the offshore and maritime sector Allseas, Heerema, Damen and IHC; from the automotive sector, DAF, SKF, VDL Weweler and Nedschroef; from the energy sector NRG and from the consumer-goods sector Philips. The scientific staff also collaborates and has regular contact with the TO2 institutes TNO, ECN and NLR. These collaborations offer potential for placement of masters students for internships and research projects providing students with both the scientific and soft skills necessary to address industrial and societal challenges.

The master programme Materials Science and Engineering is unique in the Netherlands in the way that it is the only master programme that provides a broad education dedicated to the field of Materials Science. Aspects of materials science, generally focusing on specific applications, are included in many other masters programmes within the Netherlands, but no other programme offers a comparable focus on both fundamental and engineering aspects. A comparison with other (international) Materials Science and/or Engineering programmes is presented in Appendix A (of the Self-evaluation). It may be seen that the focuses and the structures of the programmes differ, probably because of differences in the research environments and/ or educational systems. A comparison of the levels is therefore somewhat difficult, but can be based on the similarities with respect to selection criteria and study load and by considering the options for mobility between the programmes.
It can be concluded that the level of the TU Delft Materials Science and Engineering programme meets or exceeds that of the programmes considered in the comparison due to the demanding entry requirements together with the combination of compulsory and elective subjects offered.

APPENDIX 2: INTENDED LEARNING OUTCOMES

1.Competent in the scientific discipline Materials Science and Engineering

A graduate in Materials Science and Engineering is able to…

1A. apply physics, chemistry, characterisation and computational methods in materials science.
1B. design, carry out and evaluate experiments.
1C. relate processing, structure, properties and performance of materials.
1D. identify, select and modify materials in relation to specific material applications.
1E. describe the interaction between materials and the environment.

2. Competent in doing research

A gradauate in Materials Science and Engineering is

2A. characterise and describe different microstructural aspects of materials at various length scales.
2B. generate knowledge within the discipline of Materials Science and Engineering.

3. Competent in designing

A graduate in Materials Science and Engineering is able to…

3A. systematically design new materials aiming at specific properties or performance.
3B. generate innovative contributions to the discipline of Materials Science and Engineering.

4. A scientific approach

A graduate in Materials Science and Engineering Engineering is able to…

4A. apply paradigms, methods and tools to characterise and (re)design materials.
4B. manage own scientific research independently.
4C. formulate and interpret scientific results.
4D. analyse problems and use theory, modelling, simulation, design, experiments and integration towards solutions.

5. Basic intellectual skills

A graduate in Materials Science and Engineering is able to…

5A. analyse and solve technological problems in a systematic way.
5B. plan and execute research and design in changing circumstances.
5C. integrate knowledge in an R&D project, considering ambiguity, incompleteness and limitations.
5D. identify and acquire lacking expertise.
5E. critically reflect on own knowledge, skills and attitude.
5F. remain professionally competent.
5G. take a standpoint with regard to a scientific argument within the research area.

6. Competent in cooperating and communicating

A graduate in Materials Science and Engineering is able to…

6A. work both independently and in multidisciplinary teams.
6B. present and report in good English.
6C. explain and defend outcomes from the research area to academia and industry, to specialists and laymen.

7. Considering the temporal and social context

A graduate in Materials Science and Engineering is able to…

7A. evaluate and assess the technological, ethical and societal impact of his/her own work.
7B. act responsibly with regard to sustainability, economy and social welfare.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Core Programme	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
Society's Needs Cooperation, managing, reading scientific papers, writing, sustainable MSE approach	3	MS43000	1	le-ws	p-r	[redacted]
Ethics and Engineering Ethical and social aspects related to technology	3	WM0320TU	1	le-ws	we	[redacted]
Structure & Properties of Materials Crystals, structure of matter, quantum mechanics, bonding, thermodynamics, phase diagrams, kinetics, interfaces, dis-tribution functions, lattice vibrations, thermal properties, free electrons, band theory, semiconductors	8	MS43005	1 & 2	le-ws	we-e	[redacted]
Characterisation of Materials Lectures & lab classes on optical micro¬scopy, SEM & EDS, XRD, corrosion, mechanical testing, thermal & dilatation analysis	6	MS43010	1 & 2	le-pr	we-r	[redacted]
Metals Science Nucleation & growth, interfaces, texture, grain boundaries, disloca¬tions, twinning, martensite, hardening, de¬formed state, recovery, recrystallization, grain growth	4	MS43015	2	le	we	[redacted]
Polymer Science Chain models, statistics, entropy, excluded volume interac-tions, miscibility, solvent quality, phase separation, entangle-ment, polymer tube	4	CH4011MS	2	le	we	[redacted]
Functional Ceramics Crystals, bonding, electronic structure, semi¬conductors, defect chemistry, charge transport, semiconductor junctions and space charges	3	CH3531	3	le	we	[redacted]
Computational Materials Science Basics, electronic structure methods, molecular dynamics, Monte Carlo, polymers, ThermoCalc/FactSage	3	MS43020	3	le-pr	we	[redacted]
Mechanical Behaviour of Materials Stress, strain, elasticity, plasticity, mechanical characteristics related to microstructure for ceramics, polymers, metals, composites	4	MS43025	3	le-ws	we	[redacted]
Processing of Materials Casting, extrusion, forming, produc¬tion methods, joining, relation to microstructure	3	MS43030	3	le-ws	we	[redacted]

Specialisation Course Materials in Engineering Applications	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
Science of Failure Linear elastic and elastic-plastic fracture mechanics, failure mechanisms and assessment, fatigue, influence of environ-ment	3	MS43100	3	le-ws	we	[redacted]
Processing of Materials II Advanced methods, a/o powder technology; based on papers	4	MS43105	4	pr	p-r	[redacted]
Joining Technologies Welding, soldering, mechanical joining, adhesive joining, joining composites	3	MS43110	4	le	p-we	[redacted]
Materials Selection for Engineering Applications Materials in design, materials selection and processing, case studies, data sources	3	MS43115	4	le-ws	r	[redacted]
Corrosion Engineering Protection, principles, prevention, galvanic, intergranular, pitting and crevice corrosion, coatings, surface layers	3	MS43120	4	le	we-r	[redacted]
Internship	15	MS53100	--	pr	r	[redacted]
Electives	8	--	--	--	--	various

Specialisation Course Metals Science and Technology	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
Science of Failure Linear elastic and elastic-plastic fracture mechanics, failure mechanisms and assessment, fatigue, influence of environment	3	MS43100	3	le-ws	we	[redacted]
Metals Science II Microstructural evolution: basics, specifics for Ti, Al, Mg, shape-memory alloys; defects: introduction mechanisms, effects on properties	4	MS43200	4	le	we	[redacted]
Computational Materials Science II Models bridging time and length scales, kinetic Monte Carlo, phase field models, mesoscale models, integrated computational materials engineering, materials informatics	3	MS43205	4	le-pr	we	[redacted]
Advanced Characterisation Electron and ion beams, tomography, orienta¬tion imaging microscopy, dilatometry, thermo¬gravimetry, calorimetry, thermal conductivity	4	MS43210	4	le-pr	we-r	[redacted]
Steel Science Fe, interstitials, strengthening, Fe-C, solutes, martensite, bainite, acicular ferrite, harden¬abil¬ity, tempering, ther-mome¬chan¬ical treat-ment, embrittlement, stainless steel, weld micro¬structures, nanostructured steels, modelling	3	MS43215	5	le-pr	e-r-p	[redacted]
Corrosion Science Basic concepts, thin oxide films, passivity, lo¬calised corrosion, stress corrosion, hydrogen embrittlement, atmospheric corrosion, corro¬sion protection, coating adhesion / delamina¬tion, advanced research techniques	3	MS43220	5	le-ws	we-r	[redacted]
Electives	19	--	--	--	--	various

Specialisation Course Materials for Sustainable Development	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
Materials and Sustainable Development Introduction on MSD: context Critical Materials & Solutions: substitution, recycling, reuse, design, remanufacturing, + Ashby books : Materials and sustainable development ; Materials and environment	3	MS43300	3	le-ws	p-r	[redacted]
Computational Materials Science II Models bridging time and length scales, kinetic Monte Carlo, phase field models, mesoscale models, integrated computational materials engineering, materials informatics	3	MS43205	4	le-pr	we	[redacted]
Advanced Characterisation Electron and ion beams, tomography, orienta¬tion imaging microscopy, dilatometry, thermo¬gravimetry, calorimetry, thermal conductivity	4	MS43210	4	le-ws	we-r	[redacted]
Materials for Clean Energy Technology Materials for hydrogen, solar and thermo-electric applications	4	MS43305	4	le	we-oe	[redacted]
Materials at High Temperature Creep, high temperature (thermomechanical) fatigue and corrosion	4	MS43310	4	le-ws	we	[redacted]
Recycling Engineering Materials Circular economy, resources, scarcity, pre-treatment, technologies, product quality, energy consumption, economic analysis, environmental impact, waste management, thermodynamic aspects	4	MS43315	5	le-ws	we-r	[redacted]
Electives	17	--	--	--	--	[redacted]

Annotation Technology in Sustainable Development	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
For students completing the MSD specialisation: a chapter in MSc thesis on sustainability plus the module						
Engineering for Sustainable Development	5	WM0939TU	6			

Specialisation Course Advanced Construction Materials: Roads and Buildings [redacted]	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
Concrete – Science and Technology	4	CIE5110	5	le	oe	[redacted]
Repair and Maintenance of Construction Materials	4	CIE5100	6	le-ws	oe	
Micromechanics and Computational Modelling of Building Materials	3	CIE5146	6	le-ws	oe	
Forensic Building Materials Engineering	3	CIE5102	7	le-ws	oe	
Electives	25	--	--	--	--	various

Graduation	EC	Code	Quarter	Teaching method	Assess-ment	Organiser
Master's Thesis Project	40	MS53000	6, 7 & 8	pr	r-p-oe	various

Teaching Method:

le	*lectures*
pr	*project*
ws	*workshop*

Assessment:

e	*exercises*
oe	*oral examination*
we	*written examination*
r	*report*
p	*presentation*

APPENDIX 4: PROGRAMME OF THE SITE VISIT

Thursday 13 December 2018

Time	Activity	Function
08.30–08.45 h	Welcome	Director of Education 3mE
08.45–09.45 h	Programme Management	Dean 3mE Director of Education 3mE Director of Studies Master's coordinator Master's coordinator Head Education & Student Affairs
09.45 – 10.00 h	*Break*	
10.00–10.45 h	Bachelor Students Mechanical Engineering	
10.45–11.00 h	*Break*	
11.00–11.45 h	Master's Students Mechanical Engineering & Materials Science & Engineering	
11.45–12.15 h	*Lunch*	
12.15–12.45 h	Roundtour	
12.45–13.30 h	Staff Mechanical Engineering	
13.30-13.45 h	*Break*	
13.45–14.30 h	Staff Materials Science & Engineering	
14.30–14.45 h	*Break*	
14.45–15.15 h	Board of Examiners	Chair Member Member Secretary Educational Advisor
15.15–15.30 h	*Break*	
15.30–16.30 h	Professional Field Alumni	Boskalis (ME) Huisman Equipment (MSE) De Voogt Nav.Arch. (ODE) Alumnus ME Alumnus ME Alumnus MT
16.30–18.00 h	*Drafting preliminary conclusions*	

Friday 14 December 2018

Time	Activity	Function
08.30 – 08.45 h	Arrival	
08.45–09.45 h	Programme Management Marine Technology & Offshore and Dredging	Dean 3mE Director of Education Director of Studies Director of Studies Master's coordinator Head Education & Student Affairs
09.45–10.00 h	*Break*	
10.00–10.45 h	Students Marine Technology	
10.45–11.00 h	*Break*	
11.00–11.45 h	Staff Marine Technology & Offshore and Dredging Engineering	
11.45–12.30 h	*Lunch*	
12.30–13.00 h	Students Offshore & Dredging Engineering	
13.00–13.45 h	Programme Management Representatives	Dean 3mE Director of Education Director of Studies Director of Studies Head Education & Student Affairs
13.45–16.00 h	*Drafting preliminary conclusions*	
16.00–17.15 h	Feedback meeting & drinks	

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the master's programme Materials Science and Engineering. 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):

- 3mE Vision on Education
- Criteria for Academic Bachelor's and Master's Curricula
- Film Lab Facilities
- Toetsing bij 3mE
- Teaching and Examination Regulations Mechanical Engineering 2018-2019
- Masters 3mE Graduation Procedure
- Results of Employers Survey
- Year report Master degree programme Materials Science and Engineering 2016-2017
- 3mE Annual Report, MSc Mechanical Engineering 2016-2017
- Minutes Board of Examiners 2017-2018
- Minutes Board of Studies 2017-2018