BIOMEDICAL ENGINEERING

FACULTY OF SCIENCE AND TECHNOLOGY

UNIVERSITY OF TWENTE

QANU
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

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

Project number: Q0712

© 2019 QANU
Text and numerical material from this publication may be reproduced in print, by photocopying or by any other means with the permission of QANU if the source is mentioned.

CONTENTS

This report was finalized on 5 April 2019.

REPORT ON THE BACHELOR'S PROGRAMME BIOMEDICAL TECHNOLOGY AND THE MASTER'S PROGRAMME BIOMEDICAL ENGINEERING OF UNIVERSITY OF TWENTE

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

ADMINISTRATIVE DATA REGARDING THE PROGRAMMES

Bachelor's programme Biomedical Engineering

Name of the programme:	Biomedical Engineering
CROHO number:	56226
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Location(s):	Enschede
Mode(s) of study:	full time
Language of instruction:	Dutch
Expiration of accreditation:	31/12/2019

Master's programme Biomedical Engineering

Name of the programme:	Biomedical Engineering
CROHO number:	66226
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	Bioengineering Technologies Imaging and In Vitro Diagnostics Physiological Signals and Systems Biorobotics
Location(s):	Enschede
Mode(s) of study:	full time
Language of instruction:	English
Expiration of accreditation:	31/12/2019

The visit of the assessment panel Biomedische Technologie (Biomedical Engineering) to the Faculty of Science and Technology of the University of Twente took place on 10-11 December 2018.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

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

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 27-08-2018. The panel that assessed the bachelor's programme Biomedical Engineering and the master's programme Biomedical Engineering consisted of:

- Prof. dr. ir. J. (Jos) Vander Sloten, full professor at the Faculty of Engineering Science and vice-dean Internationalisation at the Faculty of Engineering Science at the Catholic University of Leuven [chair];
- Dr. I.E.T. (Inge) van den Berg, associate professor and education coordinator at the division of Laboratories, Pharmacy and Biomedical Genetics at the University Medical Center Utrecht;
- Dr. R.L. (Richard) Kamman, Chief Information Officer (CIO) at Princes Máxima Centre for pediatric oncology in Utrecht;
- Prof. dr. A.A. (Amir) Zadpoor, full professor at the Faculty of Mechanical, Maritime, and Materials Engineering and chair holder Biomaterials & Tissue Biomechanics at the Delft University of Technology. Director of the Additive Manufacturing Lab and Biomedical Engineering Education.
- Sophie Hinterding, master's student Biomedical Engineering in the specialization track Diagnostic Imaging and Instrumentation at the University of Groningen [student member].

The panel was supported by P. (Peter) Hildering, MSc., who acted as secretary. P.H. (Petra) van den Hoorn MSc. acted as second secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The assessment of the bachelor's program Biomedical Engineering and the master's program Biomedical Engineering at the Faculty of Science and Technology at the University of Twente is part of the cluster assessment Biomedical Engineering. From October until December 2018, the assessment panel assessed a total of ten education programs at five universities. The cluster consisted of the following universities: Vrije Universiteit Amsterdam, Delft University of Technology, University of Groningen, Eindhoven University of Technology and University of Twente.

The cluster Biomedical Engineering has asked QANU to support the assessment of their programmes. Peter Hildering MSc acted as the coordinator and recourse from QANU. Peter Hildering MSc and Renate Prenen MSc acted as secretary for all site visits. Petra van den Hoorn MSc and dr. Marijn Hollestelle acted as secondary secretary during a number of the site visits.

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

- Prof. J. (Jos) Vander Sloten [chair]
- Dr. I.E.T. (Inge) van den Berg
- Dr. R.L. (Richard) Kamman
- Prof. J.A.E. (Jan) Eggermont
- P. (Pieter) Wiskerke, MSc
- Prof. S.C.G. (Sander) Leeuwenburgh
- Prof. R.J. (Roland) Pieters
- Prof. A.A. (Amir) Zadpoor
- Vera Koomen, BSc [student member]
- Sophie Hinterding, BSc [student member]

At each site visit, the chair, one of the student members and three regular panel members were present.

Preparation
On 10 September 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 3 October 2018. During this meeting, the panel members were instructed on the use of the assessment frameworks. The panel also discussed its working method and the planning of the site visits and reports.

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

Before the site visit to the University of Twente, QANU received the self-evaluation report of the programme and forwarded them to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection consisted of 15 theses and their assessment forms per programme, based on a list of recent graduates provided. A variety of topics and tracks and examiners was included in the selection. The project coordinator and panel chair ensured 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 them among all panel members.

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

Site visit
The site visit to the University of Twente took place on 10 and 11 December 2018. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni, the professional field 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, various measures were taken:
1. The panel composition ensured attendance of three key panel members at all site visits, including the chair;
2. The coordinator was present at the panel discussion leading to the preliminary findings at all site visits;
3. A calibration meeting took place on 17 December 2018, in which all three key panel members, including the chair and the project coordinator, discussed the assessments.

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 it checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Faculty and University Board.

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

Bachelor's programme Biomedical Engineering
The panel greatly appreciates the vision and ambition of the programme. It could clearly see both reflected in the stated intended learning outcomes of the programme. The intended learning outcomes of the programme reflect the academic bachelor's level and orientation. Overall, the panel is satisfied with the intended learning outcomes of the programme: they are in line with the Dublin descriptors and therefore reflect the academic level and orientation of the programme. The panel does think that the phrasing of the intended learning outcomes could be improved, and advises the programme management to reflect on a phrasing that shows differentiation between the bachelor and master level, makes it easier to verify the achievement of the intended learning outcomes, and is better aligned with the actual high level at which certain topics are taught within the programme

The panel found that the curriculum is adequately linked to its intended learning outcomes. The panel was pleased to see that the programme is actively working on improving the connection between the programme's components and the intended learning outcomes. Also, it was very impressed with the concept of the modules and could see that the programme management was committed to shaping the modules into integrated, coherent units of education. Although it believes that a stronger alignment of the modules could improve the coherence of the programme, the panel was impressed by the large variety of teaching methods in the modules. It is of the opinion that the modules do not only add to the academic and professional skills of students but they also offer them a glimpse of the working field as a biomedical engineer.

The panel is particularly impressed with the programme management's tireless dedication to educational improvement. In this respect, the Quality Assurance Committee deserves special mention: students are asked to evaluate their education and are encouraged to collaborate with their peers and teachers to come up with ideas to improve the content of the programme. The way the committee ensures the programme continues to evolve has made quite an impression on the panel. The staff of the programme has proved to be very knowledgeable and showed admirable dedication to the programme. Students appreciate the informal way in which the staff can be approached. The panel is impressed with how the programme management puts great effort into improving the coherence of the teaching staff. This, in combination with the activities of the *Disciplineraad*, improves the efficiency and effectiveness of the programme even further.

The panel appreciates the fact that the programme management is working on a programme-based assessment policy and would like to see in this document an overview of how the intended learning outcomes connect to the assessment of the programme. The panel appreciates how, over time, the weight of peer review in deciding the grade increases and the lecturers' judgement becomes less decisive. It asks the programme management to examine claims of students on how the amount of group work makes it harder to obtain a cum laude distinction on an individual basis..

The panel appreciates process of the assessment in the programme. It appreciates the commitment of the entire staff to improve and monitor the quality of each assessment. The panel especially admires the assessment of the modules, in which the entire module team is involved. The panel approves of the procedures concerning thesis assessment and concludes that these adequately safeguard a reliable assessment of the programme's theses. Concerning the assessment of the bachelor's theses, the panel had a few remarks. For example, it recommends to develop more detailed assessment forms in which it is easier to recognize the programme's intended learning outcomes. In addition, the panel is of the opinion that the assessment form could be improved in terms of transparency, making it easier to reconstruct how the final grade was determined.

The panel is positive about role of the Examination Board within the programme. It feels that the board is capable of assuring that the assessment in the programme is of decent quality and that all graduates achieve the intended learning outcomes.

The panel ascertained that all bachelor's theses are of an appropriate academic level and demonstrate that students have achieved the intended learning outcomes of the programme. Graduates of the bachelor's programme usually enrol in a master's programme. Although the panel thinks that the programme should step up its efforts to help students select thesis topics that fully reflect the programme's aim, it applauds the overall quality of the theses of the programme.

Master's programme Biomedical Engineering
The panel greatly appreciates the vision and ambition of the programme. It could clearly see both reflected in the stated intended learning outcomes of the master's programme. The intended learning outcomes of the programme reflect the academic level and orientation of each. Overall, the panel is satisfied with the intended learning outcomes of the programme: they are in line with the Dublin descriptors and therefore reflect the academic level and orientation of the programme. The panel does think that the phrasing of the intended learning outcomes could be improved, and advises the programme management to reflect on a phrasing that shows differentiation between the bachelor and master level, makes it easier to verify the achievement of the intended learning outcomes, and is better aligned with the actual high level at which certain topics are taught within the programme Also, the panel advises updating the intended learning outcomes to specifically mention engineering skills.

The panel ascertained that the intended learning outcomes are adequately translated into the components of the programme. It appreciates the effort the programme management has made to reorganize the curriculum into a coherent programme, while at the same time maintaining a sufficient amount of freedom for the student to be able to design his/her own career path. The panel is particularly impressed with the programme management's tireless dedication to educational improvement. In this respect, the Quality Assurance Committee deserves special mention: students are asked to evaluate their education and are encouraged to collaborate with their peers and teachers to come up with ideas to improve the content of the programme. The way the committee ensures the programme continues to evolve has made quite an impression on the panel. The staff of the programme proved to be very knowledgeable and showed admirable dedication to the programme. Students appreciate the informal way in which the staff can be approached. The panel is impressed with how the programme management puts great effort into improving the coherence of the teaching staff. This, in combination with the activities of the *Disciplineraad*, improves the efficiency and effectiveness of the programme even further.

The panel appreciates the fact that the programme management is working on a programme-based assessment policy and would like to see in this document an overview of how the intended learning outcomes connect to the assessment of the programme. The panel appreciates how, over time, the weight of peer review in deciding the grade increases and the lecturers' judgement becomes less decisive. It asks the programme management to examine claims of students on how the amount of group work makes it harder to obtain a cum laude distinction on an individual basis..

The panel appreciates process of the assessment in the programme. It appreciates the commitment of the entire staff to improve and monitor the quality of each assessment. The panel approves of the procedures concerning thesis assessment and concludes that these adequately safeguard a reliable assessment of the programme's theses. Concerning the assessment of the master's theses, the panel had a few remarks. For example, it recommends to develop more detailed assessment forms in which it is easier to recognize the programme's intended learning outcomes. In addition, the panel is of the opinion that the assessment form could be improved in terms of transparency, making it easier to reconstruct how the final grade was determined.

The panel is positive about role of the Examination Board within the programme. It feels that the board is capable of assuring that the assessment in the programme is of decent quality and that all graduates achieve the intended learning outcomes.

The panel ascertained that all master's theses are of an appropriate academic level and demonstrate that students have achieved the intended learning outcomes of each programme. Although the panel thinks that the programme should step up its efforts to help students select thesis topics that fully reflect the programme's aim, it applauds the overall quality of the theses of the programme. Graduates of the master's programme are welcomed across a broad spectrum of employers: industry, research and hospitals.

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

Bachelor's programme Biomedical Engineering

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

Master's programme Biomedical Engineering

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

The chair, prof. J. (Jos) Vander Sloten, and the secretary, P. (Peter) Hildering, MSc., of the panel hereby declare that all panel members have studied this report and that they agree with the judgements laid down in the report. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 5 April 2019

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

Standard 1: Intended learning outcomes
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

Findings

Ambitions
The Faculty of Science and Technology has formulated an ambition for its educational programmes that can be seen as twofold. First, it wants to have programmes with a strong focus on finding solutions to societal issues. Second, the university believes that knowledge generates more value when people across different disciplines work together. The first objective is expressed in the sense that researchers are working more from an applied rather than a fundamental point of view. In relation to the second objective, researchers are expected to work not only with their peers, but also with scholars from other disciplines.

The panel has seen these intentions reflected in various ways throughout the Biomedical Engineering programmes. Students from both programmes are encouraged to derive their research questions not for the pursuit of mere knowledge, but to do experiments that will serve society. In addition, the department aims to have graduates of the programmes working at the intersection of different disciplines in order to solve societal issues efficiently and effectively. In order to achieve this, both programmes continuously involve not only technological knowledge, but also societal knowledge and the search for applicable and useful solutions.

In the bachelor's programme, the aim is not just to give students a profound command of specific biomedical technological knowledge in the various disciplines (mathematics, chemistry, biology, engineering, anatomy, physics); graduates are also expected to be able to act as independent professionals, think from a cross-disciplinary perspective, while taking responsibility for the societal context in which they work.

In the master's programme, graduates are expected to arrive at useful solutions in the world of healthcare based on medical issues of present-day society. The programme wants to educate students to develop the capability to acquire state-of-the-art insights into their subject, mainly through the scientific literature and performing biomedical research. They should be capable of making deliberate choices which they are able to defend. Graduates become application-oriented scientists and engineers, so that the outcomes of research are easily implemented as a result. Competencies revolving around independence and responsibility are considered most important.

The panel appreciates the ambition and vision of the programmes. During interviews with students and alumni, the panel ascertained that, by educating students in a multidisciplinary, society-focused way, the programme will deliver graduates with a large set of skills and abilities, who are attractive to the labour market.

Intended learning outcomes
In 2009, the curriculum committee formulated a competence profile (appendix 1) for the domain of Biomedical Engineering. The committee has tailored this profile to the bachelor's and master's programmes, which resulted in intended learning outcomes (appendix 2). These intended learning outcomes of both programmes largely correspond to the Dublin descriptors in terms of wording and structure. They therefore reflect the academic level and orientation of each programme. The panel is of the opinion that the intended learning outcomes fit the ambitions of the programmes very well: they show its interdisciplinary character and its focus on creating new solutions.

With respect to the bachelor's programme, the panel thinks the intended learning outcomes are somewhat general in their wording. They seem to be an attenuated version of the master's programme's ones, using terms such as 'under supervision' or 'understands', whereas the outcomes for the master's programme use words such as 'independent' and 'has a thorough mastery'. The panel discussed this with the programme management, who agreed that the intended learning outcomes need to be updated. The panel advises the programme management to formulate intended learning outcomes that specifically fit the bachelor's degree. Although many students do enter the Biomedical Engineering master's programme at Twente University after obtaining the related bachelor's degree, the bachelor's degree could also lead to another master's programme, or be a way to find a meaningful job. The panel thinks that, by revising the intended learning outcomes for the bachelor's programme, the possibilities after graduation become more apparent to the students.

With respect to the master's programme, the panel thinks the intended learning outcomes could be updated to fully reflect the engineering focus of the programme. For instance, the second learning outcome states a few research skills: reformulating research problems; creating a research plan; and incorporating other research disciplines. These skills are not specifically connected to biomedical engineering, nor are specific engineering skills listed elsewhere in the intended learning outcomes. The panel recommends updating the intended learning outcomes in order to reinforce the engineering character of the programme. Next, although the master's programme offers several tracks, it took note of the fact that the intended learning outcomes are solely formulated on a master's level, not on a track level. The programme could consider formulating some track-specific intended learning outcomes. By doing so, the differences between the master tracks in terms of content, skills, and career prospects will become more apparent to students.

Considering both programmes, the panel has a few general remarks. The intended learning outcomes of both the bachelor's and the master's degrees seem quite abstractly formulated. This makes it hard to test and verify whether the students have actually accomplished them. For example, a number of learning outcomes are formulated in terms of "has some skills", "has knowledge of", and "is able to debate". It is unclear to the panel which specific skills or knowledge the students need to master and what level a student should be able to achieve. The programme should consider describing the desired level of knowledge and skill in more detail across all intended learning outcomes. In addition, the panel believes the intended learning outcomes could be formulated more confidently. For instance, the fourth competence states: "is able to identify and take in relevant developments", and the fifth competence mentions "basic numerical skills". According to the panel, these statements are too weak, and do not fit the actual level at which these subjects are treated within the programmes. It recommends adapting the intended learning outcomes to show that the graduates are not passive recipients of new developments, but also actively make efforts to create them on their own, and that they master more than mere arithmetic. By formulating the intended learning outcomes more decisively, the way a biomedical engineer is trained will be better reflected.

Considerations
The panel greatly appreciates the vision and ambition of the programmes. It could clearly see both reflected in the stated intended learning outcomes of the bachelor's and the master's programmes. The intended learning outcomes of both programmes reflect the academic level and orientation of each. Concerning the master's programme, the panel advises updating the intended learning outcomes to include specific engineering skills. Overall, the panel is satisfied with the intended learning outcomes of both programmes: they are in line with the Dublin descriptors and therefore reflect the academic level and orientation of each programme. The panel does think that the phrasing of the intended learning outcomes could be improved, and advises the programme management to reflect on a phrasing that shows differentiation between the bachelor and master level, makes it easier to verify the achievement of the intended learning outcomes, and is better aligned with the actual high level at which certain topics are taught within the programme Also, the panel advises updating the intended learning outcomes of the master's programme to specifically mention engineering skills.

Conclusion
Bachelor's programme Biomedical Engineering: the panel assesses Standard 1 as 'satisfactory'.

Master's programme Biomedical 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

Bachelor's programme
The bachelor's programme includes three learning trajectories, or disciplinary learning lines:
- Neural and Motor Systems
- Imaging and Diagnostics
- Bionanotechnology and Advanced Biomanufacturing.

These disciplinary learning lines address the main disciplinary content relevant to biomedical engineering, such as biomedical physics, mechanical engineering, electrotechnology, cell biology, and chemical engineering. In the first and second year, students follow TOM-modules which alternately address the disciplinary learning lines. In the third year, students choose one of the disciplinary learning lines and follow the corresponding module (15 EC). With respect to the bachelor's thesis (15 EC), the student is expected to carry out research on a topic that corresponds with the chosen learning line, write a report and present the findings during a colloquium. Through this, students are taught the knowledge and skills needed to plan and carry out research. They may decide how to spend the remaining 30 EC of the third year. They can choose to follow one of the other third-year modules from the bachelor's programme, or a module or a minor course from another programme (see appendix 4 for an overview of the curriculum). They are expected to hand in their programme plan at the end of their second year, which has to be approved by the Examination Board.

After examining a selection of documents (see appendix 6), including the self-evaluation report, the panel determined that the programme's components adequately address its intended learning outcomes. However, it agrees with the programme management that the learning objectives of the courses/modules are not explicitly linked to the intended learning outcomes of the bachelor's programme. The panel applauds the fact that the Examination Board is already dedicated to mapping out how the content of the programme covers the intended learning outcomes and has begun checking the assessments of the programme and how it addresses all intended learning outcomes (see standard 3). In addition, the panel suggests revising the learning objectives to get them more in line with the intended learning outcomes. It noticed during interviews with bachelor's and master's students that electronic and programming skills seem to be somewhat underrepresented in the bachelor's programme. Therefore, the panel advises the programme management to consider whether these skills deserve more attention in the programme.

Like all bachelor's programmes at the University of Twente, the programme follows the 'Twents Onderwijs Model' (TOM). This is a modular and project-based didactic concept aiming to optimally convey to the students the several disciplines and interdisciplinary nature of biomedical engineering. The programme consists of eleven TOM modules. All modules comprise a 10-week, full-time unit of 15 EC and are built around a theme, for example biorobotics, thermodynamics, or imaging technologies. The aim of each module is to develop a solution to a realistic health care problem. Modules consists of 3-5 courses with associated lectures and a final project. The courses serve as a knowledge base to enable completion of the final project. The modules consist of lectures, tutorials (practicals) and group work to apply the theory in challenges inspired by real-world issues. In some modules, colstructions are used. Colstructions are a mixed version of lectures and tutorials: students follow a brief lecture, put the theory into practice, follow another lecture, and put the newly acquired knowledge into practice. The panel is very positive about the colstructions. This teaching method activates students in applying their knowledge in practice and learning by doing. Every module ends with a final project. In this project, groups of 4-8 students critically reflect on existing theories and develop new designs to invent a solution to a challenge based on a real-world problem that was presented at the start of the module. In this way, students become independent thinkers who can look beyond what is already known in the field and adapt designs to different medical conditions. The group is supervised by a tutor (a teaching staff member who is involved in a research domain that relates to the project theme), who monitors the progress during the final project. The tutor also makes sure that everyone receives feedback on his/her individual contribution. The panel learned through the interview with students that they are positive about the group work and the supervision provided by their tutors. They feel they can easily discuss things with their tutor, such as progress in the group or problems with individual students.

The panel is very enthusiastic about the TOM modules. The way the programme management carefully constructed them so that the courses and (group)assignments form integrated, coherent units of education is appreciated. The panel believes the modules greatly increase the academic and professional skills of students: they build their knowledge and skills, learn to work in teams, challenge themselves, and become independent thinkers. It is very positive about how the programme management has found a way to express the multidisciplinary character of the programme: each module represents one or two disciplinary learning lines, so that students can experience the broad scope of biomedical engineering in a manageable way (see appendix 3). As a result, the more modules the student completes, the more the multidisciplinary character of biomedical engineering emerges. The panel ascertained that students have an excellent opportunity to see how scientific theory is put into practice through the modules. During the interview with the panel, students indicated that they like the fact that they are allowed to actually make and test a tangible product that can provide a solution to a current health care problem. In addition, the modules offer the students a glimpse of the work in the field of biomedical engineering. All in all, the panel thinks that the modules fit well with the programme's objectives and provide a great way to integrate the technical and medical aspects of the domain of biomedical engineering.

Although the panel is positive about each module in itself, it feels there is a large variation between the modules in terms of structure, assignments and learning objectives. Based on the interviews with students, it seems this variation could be confusing, since students do not always know what is expected from them regarding assignments and learning objectives. The panel is of the opinion that, by structuring the manuals for the modules and showing how the learning objectives of one module connect to the other, the coherence in the bachelor's programme as a whole could be improved.

Over the last couple of years, the bachelor's programme has been growing steadily. In 2009, 68 students enrolled in the bachelor's programme; in 2017, 97 students enrolled. The university's ambition is to provide small-scale education, where teachers and students can interact frequently. Therefore, the growing number of students is a point of concern for both the university and the students. For example, some students feel that larger numbers of students who attend tutorials reduce the possibility of having personal contact with the teacher, and they decide to skip the tutorial altogether. These are considerations the panel can relate to. Certainly, when student numbers increase, tutorials may be in danger of being eliminated altogether. The panel would not like to see this happen, since it appreciates the added value of this learning method. It urges the programme management to think about ways to sustain the tutorials and ensure that students feel it is useful to attend them. One potential solution could be to think about how larger groups can yield added value. Larger groups offer the opportunity to introduce peer assisted learning (horizontal and/or vertical). This method of student-to-student support activates students and makes them feel more responsible for their own learning. To make full use of this method, it may be necessary to alter the assignments or change the materials provided in the tutorials. If peer assisted learning proves to be unsuccessful, another option is to offer shorter, but more frequent tutorials, and let students choose a timeslot.

Master's programme
At the start of the two-year, 120 EC master's programme, students choose one of the four tracks: Bioengineering Technologies; Imaging and In Vitro Diagnostics; Physiological Signals and Systems; and Biorobotics (with two variations: design or robotics). Each track has a compulsory part of 30 EC, 15 EC of biomedical courses and 15 EC of electives (see appendix 4 for an overview of the curriculum). Most courses comprise lectures and group assignments. Students choose from a list of research groups linked to their chosen track, preferably in the third year of their bachelor's programme. At the start of the master's programme, they contact a graduation professor from that specific group (usually the leading professor of the group). In consultation with him/her, they draw up a course list that forms a coherent master's programme, reflecting their own personal interests. The second year consists of an internship (15 EC) and the master thesis (45 EC). The internship takes place in a healthcare institution, research institute, university or a biomedical company, preferably abroad. The objective of the internship is to introduce students to the workplace of a biomedical engineer and let them carry out scientific research under supervision. When the internship is completed, students start writing their master thesis. Together with the graduation professor, the student decides on the subject of the thesis, which should show a clear connection to the research group's field of interest. The objective of the thesis is basically the same as for the internship, the only difference being that the students are asked to carry out their research more independently and take more initiative during the design and test phase of their research.

Redesign of the master's programme
The current master's programme is the result of a recent redesign, implemented in 2018-2019. In the previous curriculum, students had a great amount of freedom to compile their own curriculum from a long list of courses offered by the research groups involved in the programme. In 2017, the programme management decided to limit the number of choices the students could make to establish their list of master's courses. The range of electives was extensive, and as a result, it became too challenging for the programme management to monitor quality at the programme level. Furthermore, the new Technical Medical Centre (TMC) of the University of Twente was to open its doors in 2018. This centre merged the MIRA Institute, the Experimental Centre for Technical Medicine and the three health-related educational programmes, including the Biomedical Engineering programmes. The TMC reorganized the research groups which were housed in these communities into new research domains. As a result, the programme management felt the research groups and the organisation of research in the master's programme should be reorganized as well to keep the programme connected to current research.

In anticipation of the TMC, and in response to the long list of electives, the programme management decided to start redesigning the master's programme. Key researchers from the programme advised on the core concepts that students have to master during their training. These served as a point of departure in the reorganization. As of September 2018, the improved master's programme is now active. The tracks were renamed to connect them to the domains of research in the TMC, and the number of electives was reduced (from 25 to 15 EC; the remaining 10 EC went to the compulsory courses specifically set for each track). The programme management feels the resulting programme is not a major renewal, but rather a realignment of the already present courses, with the redesign enabling an irrefutable attainment level for all graduates and a stronger association with the research at the TMC.

The panel read documents concerning the redesign and discussed them with the programme management and lecturers during the site visit. It is positive about the new master's programme and agrees with the management's intention to align the programme with the research themes of the new TMC. This allows the education in the programme to be perfectly tailored to current research. The panel also appreciates the management's decision to make the programme more manageable by reducing the number of electives. Consequently, the management is able to monitor the quality of the master tracks more closely, and the panel is convinced this will guarantee that all graduates achieve the programme's intended learning outcomes.

In the light of the redesign of the master's programme, the panel would like to pass on remarks made by students and alumni. They mentioned that some knowledge and skills were slightly underrepresented in the previous curriculum of the master's programme, such as entrepreneurship, medical device prototyping and regulatory aspects (e.g. standards on certification). The panel recommends that the programme management investigate these remarks and check whether these subjects are adequately incorporated in the newly developed tracks.

Student centered

The panel learned through interviews with bachelor and master students that both programmes are feasible and well organized. When students argue that it is necessary to deviate from the standard procedures in the programme, the programme management is open to such arguments. For instance, the final assignment of the bachelor's or master's programme can be done abroad, and the order of the internship and the final assignment of the master's programme can be changed.

The panel has ascertained that the programme management is genuinely interested in the way the students feel about their education (see also Quality Assurance Committee, below). The staff meets the bachelor and master students every quartile to discuss their opinion on several topics, such as the curriculum or practical matters. The panel is enthusiastic about the work of the student counsellor. During the site visit it learned that bachelor and master students can turn to the student counsellor for more information about things such as choosing the minor, possibilities abroad, and choosing a master's programme after obtaining their bachelor's degree. In the first year of the bachelor's programme, the counsellor invites every student for an introductory meeting. S/he acts as a coach for the students, by monitoring study progress and discussing the student's planning. The student counsellor also advises the Board of Examiners and lecturers about the students' personal circumstances. The panel heard from master students that the student counsellor actively seeks contact with the students, to inquire about their progress and how they feel about the cooperation with their supervisor. This is highly appreciated by the students. The panel is also impressed with the close connection between the programme manager and students. The programme manager informs the bachelor students several times during the academic year about the programme, the different learning lines within the modules, and how students can make programme-related decisions (e.g. choosing a minor or a master track). It feels both the study counsellor and the programme manager are well informed about all possibilities and opportunities for students. The interviews with alumni and students revealed that the programme management also invests a fair amount of effort in providing information about the labour market, which helps graduates to find an appropriate job. Incidentally, graduates of the master's programme are invited to talk to bachelor and master students to inform them about their career as a biomedical engineer. Because more than 50% of graduates end up working in industry, the panel appreciates the fact that the programme management has recently hired a coordinator to focus on providing students with information about how health technology is applied in corporations. It thinks the programme management could consider giving students more practical experience in this field, by allowing students to complete their master's project within a company.

In the bachelor's programme, students have a high degree of control over their education because of the modules. One of the key values of TOM is *student-driven learning*, and the panel sees this clearly reflected in the way students are presented with open-ended problems. Students are invited to shape their own learning path by allowing them enough freedom to think about and design their own solutions to the problem raised.

Concerning the master's programme, students are presented with a variety of choices to design their own learning process. They choose one of the master tracks offered, select courses, decide in which research group they would like to work, and may propose the subject of their thesis. The panel appreciates the fact that students can, to a certain extent, design the master's programme according to their personal interests and their plans for a future career.

Staff
Reflecting the multidisciplinary nature of the domain of biomedical engineering, the lecturers come from various disciplines (e.g. physics, mathematics, robotics, mechanical engineering, neurophysiology). All lecturers have a PhD and conduct scientific research. The programme does not appoint its own lecturers, but mainly uses staff from research departments within the Faculty of Science and Technology. Because the TOM modules in the bachelor's programme are a university-wide method, all lecturers are familiar with this didactical concept. Students indicated that all lecturers have expert knowledge and show good engineering and didactical skills. The panel concluded the same and inferred that both the faculty and the university provide ample guidance on improving didactic quality. The university's Centre of Expertise in Learning and Teaching provides support to teaching staff in designing and implementing lectures and projects. The centre can also help translate student evaluations into new teaching methods. The university-wide policy states that all lecturers must have acquired a University Teaching Qualification (UTQ). In reality, some more experienced lecturers get an exemption or are offered a shorter track to obtain the UTQ. Tutorials in the programme are guided by student assistants (as a second teacher, alongside the lecturer). These assistants are master students and are selected by the lecturer, based on their knowledge about the subject. For all student assistants, the DISA course, a training in didactics especially developed for student assistants, is mandatory.

Since the programme does not employ its own lecturers, the programme management is aware of the necessity of maintaining good working relations with the teaching staff. The panel is very impressed by the way the programme management has put a great deal of effort into increasing the coherence in the team. It tries to establish strong bonds with the lecturers, by supporting them when needed and making clear that their input is appreciated. This is further established through the *Disciplineraad*. This council is a group of full professors affiliated to the programmes who meet every month to discuss the coherence of the programmes and the ambitions of the research groups. Through the interviews with the management and the lecturers, the panel learned that the lecturers are steadfastly involved in the programmes because of their expertise in the field of biomedical engineering and the fact that the students work on research concerning their own subject area. The students have indicated that the lecturers are easily approachable, and that the communication between lecturers and students is of a rather informal character.

Concerning the bachelor's programme, every module has a module coordinator. The module coordinator takes care of the module's organizational aspects and makes sure the learning objectives of the module are assessed. The module coordinator meets with the teaching staff of the module (including the tutors) to clarify the main objectives of the module and to show how courses provided during the module relate to each other and to the overall scheme of the bachelor's programme. Experiences from the past are discussed as well. During the module, the staff meets twice, to see whether there are any new problems that should be dealt with. The panel appreciates the supporting role of the module coordinator and feels this is a good way to ensure that modules form a coherent unit of education and that all learning objectives are addressed.

Quality Assurance Committee
A large part of the quality assurance of both programmes is the responsibility of the Quality Assurance Committee (QAC). In general, the QAC is concerned with anything that has to do with the quality of the education, such as coherence between modules, and the modules' feasibility. The QAC meets every quartile and consists of 18 students and the programme manager, who acts as chair. The student members are responsible for the evaluation of the teaching within their specific year. They organise surveys or assessment interviews with a panel of teachers and student representatives. A strict planning is followed. The bachelor's programme is evaluated on the module level, while the master's programme is evaluated on the course level. After the evaluation, the students of the QAC report to the responsible lecturers. The QAC also reports to the Programme Committee and places the results on Canvas (the online learning platform for students and lecturers). The following year, the QAC presents the feedback of the past year and how this was dealt with to the new students. The panel is enthusiastic about the QAC. The students are taken very seriously as stakeholders and

are encouraged to think about and take responsibility for the quality of the content and the didactics of both programmes. In addition, the panel feels these evaluations are readily used, but reasonably, by the programme management and the lecturers to improve education. For instance, the planning of handing in assignments for module 2 was revised, and the many teachers who were responsible for only parts of module 1 were replaced by just one lecturer for the entire module to make it less complicated for the students.

Considerations
Concerning the bachelor's programme, the panel found that the programme is adequately linked to its intended learning outcomes. The panel was pleased to see that the programme is actively working on improving the connection between the programme's components and the intended learning outcomes. Also, it was very impressed with the concept of the modules and could see that the programme management was committed to shaping the modules into integrated, coherent units of education. Although it believes that a stronger alignment of the modules could improve the coherence of the programme, the panel was impressed by the large variety of teaching methods in the modules. It is of the opinion that the modules do not only add to the academic and professional skills of students but they also offer them a glimpse of the working field as a biomedical engineer.

Concerning the master's programme, the panel ascertained that the intended learning outcomes are adequately translated into the components of the programme. It appreciates the effort the programme management has made to reorganize the curriculum into a coherent programme, while at the same time maintaining a sufficient amount of freedom for the student to be able to design his/her own career path.

The panel is particularly impressed with the programme management's tireless dedication to educational improvement. In this respect, the Quality Assurance Committee deserves special mention: students are asked to evaluate their education and are encouraged to collaborate with their peers and teachers to come up with ideas to improve the content of the programmes. The way the committee ensures the programme continues to evolve has made quite an impression on the panel. The staff of both programmes proved to be very knowledgeable and showed admirable dedication to the programmes. Students appreciate the informal way in which the staff can be approached. The panel is impressed with how the programme management puts great effort into improving the coherence of the teaching staff. This, in combination with the activities of the *Disciplineraad*, improves the efficiency and effectiveness of both programmes even further.

Conclusion
Bachelor's programme Biomedical Engineering: the panel assesses Standard 2 as 'good'.

Master's programme Biomedical Engineering: the panel assesses Standard 2 as 'good'.

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

Findings

Assessment policy
The health-related programmes of the University of Twente (Biomedical Engineering, Health Sciences, and Technical Medicine) share an assessment policy and quality assurance plan. The assessment policy describes what type of graduates the university aims to deliver and what type of skills the students need to master during their education (e.g. 21st century skills, interdisciplinary skills, communication skills). The quality assurance plan describes the plan-do-check-act cycle to maintain and improve the quality of education and assessment. According to the panel, these documents provide insight into the way the faculty handles quality assurance, although on a very general level. It endorses the fact that the programme management has started to formulate its own

assessment plan. The panel would like to ask the management to incorporate in this plan how the intended learning outcomes are reflected in the assessment of the programmes.

The interviews with bachelor's and master's students showed that the philosophy of training students to become independent learners is reflected in the way in which the assessments during both programmes become more self-regulated. In the bachelor's programme, the module courses are graded by the lecturer. In the final project, peer review comes slightly into play. Students are expected to give their opinion on individual presentations of their peers and/or comment on their peers' contribution in group work. In the master's programme, nearly all courses consist of one or more assignments in which peer review and self-assessment are considered important; the lecturer uses the peer review to adjust the final grade upwards or downwards, and thus the lecturers' judgement becomes less decisive. The panel appreciates this form of student-driven learning which makes students actively involved in the training and assessment of their own and their peers' education. Through interviews with master students and lecturers, the panel learned that the large amount of group work in the master's programme can interfere with the student's plan to graduate cum laude. Lower grades on group work can nullify higher grades on individual exams, and so graduation with honour seems to be almost unattainable. The panel advises the programme management to analyse grades which are based on group work and check whether they are systematically lower than those for individual work. If so, the programme management can decide to recalibrate those grades based on group work by, for example, discussing how to decide on those grades with lecturers and perhaps establish rules of thumb, or to have individual grades weigh more heavily than the group work. Nevertheless, the panel welcomes the group work for its contribution to the students' cooperation, communication and presentation skills.

Examination Board

The Examination Board BMT is responsible for both programmes and meets every six weeks. The board consists of nine members, five of whom are lecturers and/or researchers involved in the programmes. One member is not involved in either one of the programmes and serves as an external member. The student counsellor has an advisory role, to ensure that the student perspective is taken into account. Lastly, two members have an administrative role. The panel was able to ascertain that the Examination Board handles all tasks which lawfully belong to it. The board discusses individual requests (e.g. exemptions, resit of a module) and checks whether each student's course list complies with the directives. It checks whether the assessments in both programmes cover the full range of the intended learning outcomes. In the event of a policy change in the Education and Examination Regulations, the board determines its consequences for the education and assessment in the programmes. The panel is very positive about the fact that the external member of the board is an expert in theories of education, which assures the quality of assessment in both programmes even more.

The panel appreciates the proactive stance the board has taken in recent years. Since last year, it has drawn up several documents to get an overview of the assessments in both programmes. For instance, it is enthusiastically assembling an assessment matrix in which all of the modules of the bachelor's programme and their learning objectives are displayed. The board is also in the process of mapping the comments about assessments based on student evaluations. To safeguard the realized learning outcomes of the programme, the board recently examined 20 bachelor theses and 20 master theses to determine whether the graduates achieved the intended learning outcomes. The board also checked for any deviations in the final grading of the theses and whether a trend emerged within one or more research clusters (i.e. more high or low grades), which was not the case. The results of their findings were discussed with the entire teaching staff. The panel is positive about the more active role the Examination Board has adapted. It feels that the board is capable of assuring the assessments in both programmes are of decent quality and that all graduates have achieved the intended learning outcomes.

Assessment process
The organization of assessment for the bachelor's programme and the master's programme is similar in most aspects. Therefore, in this section, the process of developing the exams and tests of both programmes is discussed concurrently. The term 'course' implies both the bachelor's modules and the master's courses.

The panel took note of the PDCA cycle the programmes use to organize their education and assessment. Six months prior to the start of the course, the responsible lecturers gather. For the bachelor's programme, the entire module team (i.e. teaching staff, programme manager, programme director) is involved during this preparatory phase. For the master's programme, the lecturers responsible for the course meet (mostly two). This preparatory phase aims to clarify the learning objectives of the course and its relation to the programme's intended learning outcomes. The target skills and qualities are made explicit, and the way they should be assessed is discussed. The lecturers also examine student evaluations from the previous year. With the UTQ, all lecturers are trained to design a qualitatively good test (e.g. how to test whether learning objectives are achieved; how to formulate a question) and to perform a test analysis (e.g. interpret test outcomes and decide on possible adjustments). The PDCA cycle has been carried out for six years now. At this point, the outlines of all courses have been established; now only minor changes are made.

The panel appreciates the way the teaching staff prepares its assessment. During interviews with the programme management and the lecturers, it became clear that lecturers invest a lot of time in the assessment quality of both programmes: they are engaged in creating a transparent set of assessment(s), which fit the course's learning objectives adequately. At the start of a course, the responsible teaching staff meets regularly. This is especially applicable for the modules, where the module team and the student counsellor meet twice during the module to discuss the progress of all groups and of the individual students. Finally, when a test has been taken, the evaluation phase starts. In this phase, the responsible lecturers perform a test analysis to see whether there is an uneven distribution of scores, or if some questions turned out to be too difficult.

Bachelor's programme: modules
In each module, students are assessed multiple times. Knowledge is assessed through tests with open-ended or multiple-choice questions. The final project is evaluated by means of a report or poster and a presentation or debate. At the end of the presentation or debate, lecturers ask questions of individual students of the group, to test everyone's knowledge. Students also give their opinion by evaluating each other's work. The panel recommends that the programme management carefully monitor how students implement group work throughout the programme. Since all modules have an element of group work, the students could in principle ignore certain tasks they are uncomfortable with throughout the modules. This phenomenon is obviously undesirable, and therefore the panel advises the programme management to insert more individual assessments into the modules, in a way that requires each student to prove their achieved level for all learning objectives.

The module team as a whole decides whether a student passes the module, based on the results of all courses and the final project. The panel appreciates the way the assessment of the modules is organized. Knowledge is tested through exams, and academic and professional skills are assessed through the final project. The panel admires the fact that the entire module team is involved in deciding on final grades. In this way, the students are evaluated equally. In the past, students had to pass every course and assignment of the module in order to pass the module as a whole. The programme management has changed this assessment policy. Currently, the mean of the grades on all parts counts as the final grade. When the mean is 5.0 or higher, the student is allowed one retake on a part of the module. When the mean is lower, the student has to retake the entire module again. However, when a student fails the final project, s/he may not pass the module. The panel thinks this policy change is a good way of making the programme more feasible, by giving the students the opportunity to do certain parts of the module again, while highlighting the important role the final project plays in demonstrating the achieved learning objectives.

Assessment of the theses
Students finish their bachelor's or master's programme with a thesis. The assignment of the theses of both programmes is to independently carry out a research or design project. Students hand in their report and present their thesis during a colloquium. An assignment committee assesses the thesis, which consists of at least three members: the graduation professor, the daily supervisor (usually a PhD student), and a member of the scientific staff of another research group. The subject of both the bachelor's thesis and the master's thesis and the composition of the assignment committee have to be approved by the Examination Board. The panel approves of these procedures and conclude that these adequately safeguard a reliable assessment of the programme's theses.

Both programmes use the same assessment form, in which content, report, presentation and the overall process are graded. The panel studied a number of assessment forms and the accompanying theses. It was pleased to see that the programme management is already working on improving the assessment form, for instance by including descriptions for each aspect to make the form more transparent. The panel is positive about the fact that the assessment form states the intended learning outcomes as a reminder to the student and the assignment committee. Since the programme management is in the process of improving the assessment form, the panel would like to make a few suggestions. First, it recommends differentiating between the assessment of the bachelor's versus the master's programme, which should be reflected in the assessment form. Since the intended learning outcomes differ, the forms can explain in more detail what the programme expects from the student. Second, the panel saw substantial differences in the amount of feedback provided on the forms. Some forms provided a clear explanation as to why that particular grade was awarded. In other cases, feedback on the students' skills and overall work attitude was meagre, to the extent that the results of grading were not reproducible. The panel feels that by not giving the student helpful written feedback, students miss the opportunity to learn from the supervisors' comments. Therefore, it advises the programme to urge the assignment committee to fill in the form completely and provide helpful feedback to the student. Third, no instructions are provided on how assessors should determine the final grade from the way the different aspects (e.g. content, presentation) are scored. In one thesis, the grade for the research content had a heavy influence on the final grade, while in another thesis, the grade for the presentation played a major role. To make the assessment more transparent, the panel advises the programme management to introduce a system to help determine the final grade from the partial scores. Finally, although the panel appreciates the fact that the form not only assesses the thesis as an end product, but also asks the assignment committee to grade several associated factors like the overall process and the presentation, the programme management could consider whether it would be valuable to insert rubrics for these aspects in order to improve transparency and prevent bias during assessment.

Considerations
The panel appreciates the fact that the programme management is working on a programme-based assessment policy and would like to see in this document an overview of how the intended learning outcomes connect to the assessment of the programme. The panel appreciates how, over time, the weight of peer review in deciding the grade increases and the lecturers' judgement becomes less decisive. It asks the programme management to examine claims of students on how the amount of group work makes it harder to obtain a cum laude distinction on an individual basis..

The panel appreciates process of the assessment in the programme. It appreciates the commitment of the entire staff to improve and monitor the quality of each assessment. The panel especially admires the assessment of the modules in the bachelor's programme, in which the entire module team is involved. The panel approves of the procedures concerning thesis assessment and concludes that these adequately safeguard a reliable assessment of the programme's theses. Concerning the assessment of the master's theses, the panel had a few remarks. For example, it recommends to develop more detailed assessment forms in which it is easier to recognize the programme's intended learning outcomes. In addition, the panel is of the opinion that the assessment form could be improved in terms of transparency, making it easier to reconstruct how the final grade was determined.

The panel is positive about role of the Examination Board within the programmes. It feels that the board is capable of assuring that the assessment in both programmes is of decent quality and that all graduates achieve the intended learning outcomes.

Conclusion
Bachelor's programme Biomedical Engineering: the panel assesses Standard 3 as 'satisfactory'.

Master's programme Biomedical Engineering: the panel assesses Standard 3 as 'satisfactory'.

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

Findings
To assess the graduates' achievement of the intended learning outcomes, the panel studied 15 theses of each programme. The performance level of graduates in the professional field and in graduate programmes or post-initial education after graduation was also taken into consideration.

Theses
According to the panel, the theses of the bachelor's and the master's programme attain the appropriate academic level. In fact, two theses from the bachelor's programme which were awarded a high grade were deemed truly outstanding. The range of topics chosen reflects the broad scope of the domain of biomedical engineering. Because the programmes promise to deliver biomedical engineers, the panel believes that engineering, the development of new technologies, should be a prominent component of all theses. In the bachelor's theses, the panel recognized that the engineering component was largely present. In the master's theses, however, the engineering component could not always be easily detected. For example, some theses concerned mainly laboratory research. Other theses concerned topics which the panel thought were not specifically linked to the domain of biomedical engineering (e.g. cellular biology). During interviews with lecturers, students and the programme management, the panel concluded that students have a lot of freedom to determine the subject of their thesis. Although it appreciates the fact that students can choose a topic that fits their personal interests, the panel thinks that stronger guidelines for selecting a subject will produce theses which better fit the programme's aim.

Generally speaking, the panel is positive about the quality of the theses. The students consistently demonstrate they are able to perform research and show a sound understanding of the chosen methodology. Overall, the awareness of the literature is clear, and the methods and analyses are appropriate. The panel would specifically like to mention that it appreciates that the theses are not only scientifically but also practically thorough: they always revolve around a medical issue which needs to be solved. A strong aspect of the theses is the fact they almost always include practical recommendations and advice targeted at the domain of healthcare.

Performance of graduates
The panel concluded that graduates of both programmes demonstrated that they have met the intended learning outcomes at the expected level. During interviews with master's students, the graduates of the bachelor's programme indicated they found it easy to make the transfer to a master's programme, which in this case was the Master Biomedical Engineering. The panel spoke with a number of graduates of the master's programme and ascertained that they are welcomed in all areas of the job market: two of them worked at suppliers of biomedical products and systems, three participated in a training position within a hospital or a university (to obtain a PhD degree or become a certified clinical physicist). Overall, 20% of the graduates of the master's programme has a job in a hospital, 20% is active within a university, and 60% was welcomed in industry.

Considerations
The panel ascertained that all bachelor's and master's theses are of an appropriate academic level and demonstrate that students have achieved the intended learning outcomes of each programme. Although the panel thinks stricter procedures are needed to ensure theses which reflect the programme's aim, it applauds the overall quality of the theses of both programmes. Graduates of the bachelor's programme usually enrol in a master's programme. Graduates of the master's programme are welcomed across a broad spectrum of employers: industry, research and hospitals.

Conclusion
Bachelor's programme Biomedical Engineering: the panel assesses Standard 4 as 'satisfactory'.

Master's programme Biomedical Engineering: the panel assesses Standard 4 as 'satisfactory'.

GENERAL CONCLUSION

The panel assesses standards 1, 3 and 4 of the *bachelor's programme Biomedical Engineering* as 'satisfactory'. It assesses standard 2 as 'good'. According to the NVAO's Assessment Framework 2016, the overall assessment of the programme is therefore 'satisfactory'.

The panel assesses standards 1, 3 and 4 of the *master's programme Biomedical Engineering* as 'satisfactory'. It assesses standard 2 as 'good'. According to the NVAO's Assessment Framework 2016, the overall assessment of the programme is therefore 'satisfactory'.

Conclusion
The panel assesses the *bachelor's programme Biomedical Engineering* as 'satisfactory'.

The panel assesses the *master's programme Biomedical Engineering* as 'satisfactory'.

APPENDICES

APPENDIX 1: COMPETENCE PROFILE BIOMEDICAL ENGINEER

Appendix I. Competence profile Biomedical Engineer

[k = knowledge, s = skill, a = attitude]

A Biomedical Engineer:

1. **Is specialized in a specific field of biomedical technology. A Biomedical Engineer is familiar with existing scientific knowledge and has the competency to expand this knowledge by studying.**

   1a. Has a command of parts of the specific biomedical technological field that lie at the very forefront of the existing knowledge (the latest theories, methods, techniques, current issues). [ks]
   1b. Actively looks for structure and cohesion between biomedical technology and relevant fields such as physics, mathematics, technology, biology, physiology and medicine. [ksa]
   1c. Has knowledge of and some skill regarding the way in which fact-finding, theory formation and scientific model formation are handled in a specific field of biomedical technology. [ks] Has the skills and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
   1d. Has knowledge of and is somewhat skilled regarding the way in which interpretations (of texts, data, problems, results, etc.) are made in the field of biomedical technology. [ks] Has the skills and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
   1e. Has knowledge of and is skilled regarding the way in which experiments, data collection and simulations are performed in the field of biomedical technology and related fields. [ks] Has the skills and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
   1f. Has knowledge of and is skilled regarding the way in which decisions are made in the field of biomedical technology. Has the skills and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
   1g. Can reflect on standard methods and their assumptions; is able to question them; is able to propose changes and estimate the impact thereof. [ksa]
   1h. Is able to notice gaps in their own knowledge and amending or supplementing their knowledge by studying. [ksa]

2. **Has knowledge of and is skilled at doing research. A Biomedical Engineer has the competency to gain new scientific knowledge by doing research. Research here refers to developing new knowledge and insights in specific and methodical ways.**

   2a. Is able to reformulate badly structured research problems. In doing so, also takes into account the system boundaries. Is able to defend the new interpretation to the parties involved. [ksa]
   2b. Is observant and has the creativity and ability to discover certain connections and new points of view in ostensibly trivial matters. [ksa]
   2c. Is able to create and implement a research plan independently. [ks]
   2d. Chooses the right level of abstraction, given the research problem's process stage. [ksa]

- 2e. Is able to and has the necessary attitude to incorporate other disciplines in their own research if needed. [ksa]
- 2f. Is aware of the changeability of the research process due to external circumstances or advancing insights. [ka] Is able to deal with this changeability and adapt the process based on that changeability if needed. [ksa]
- 2g. Is able to accurately assess the scientific value of research in the field of biomedical technology. [ksa]
- 2h. Is able to independently contribute to the development of scientific knowledge in one or more of the subfields within the field of biomedical technology as a whole. [ks]

3. May in some cases have design skills. Apart from research assignments, some Biomedical Engineers will also complete design assignments. These skills are particularly important in the Human Function Technology track, and less so in the Molecular, Cellular and Tissue Engineering track. Designing is a synthetic activity geared towards creating new or altered artefacts or systems, intended to create values in line with previously established requirements and preferences (such as mobility, health, etc.).

- 3a. Is able to reformulate complex, badly structured design problems. In doing so, also takes into account the system barriers. Is able to defend the new interpretation to the parties involved. [ksa]
- 3b. Has the creativity and synthetic skills needed managing biomedical design problems. [ka]
- 3c. Is able to create and implement a design plan independently. [ka]
- 3d. Chooses the right level of abstraction, given the design problem's process stage. [ksa]
- 3e. Is able to and has the necessary attitude to incorporate other disciplines in their own design if needed. [ksa]
- 3f. Is able to deal with the changeability of the design process due to external circumstances or advancing insights, and adapt the process based on that changeability. [ksa]
- 3g. Is able to formulate new research questions based on a design problem. [ks]
- 3h. Is able to make design decisions and justify and assess these systematically. [ks]

4. Has a scientific approach. A Biomedical Engineer has a scientific approach, characterized by the development and the use of theories, models, and interrelated interpretations, has a critical attitude, and has insight into the nature of science and technology.

- 4a. Is able to notice relevant developments and learning about them. [ksa]
- 4b. Is able to critically reflect on existing theories, models, or interpretations in their track's subfield of biomedical technology. [ksa]
- 4c. Is very skilled at and has a propensity for using, developing and validating models; is capable of consciously choosing between modelling methods. [ksa]
- 4d. Has insight into the nature of science and technology (objective, methods, differences and similarities between scientific fields, the nature of laws, theories, explanations, the role of experiments, objectivity, etc.). And is knowledgeable regarding current discussions about these issues. [k]
- 4e. Has insight into the practical side of science (research system, relationships with clients, publication system, the importance of integrity, etc.). And is knowledgeable regarding current discussions about these issues. [k]

4f. Is able to adequately document the results of research and designs with the aim of contributing to knowledge development both within the field of biomedical technology and outside of it. [ksa]

5. **Has intellectual skills. A Biomedical Engineer skilled at reasoning, reflecting, and forming judgements. These are skills that are taught or strengthened in the context of a certain scientific discipline, but are more generally applicable afterwards.**

5a. Is able to critically and independently reflect on their own thinking, decisions and actions and adjust them accordingly. [ksa]
5b. Is able to recognize logical fallacies. [ks]
5c. Is able to recognize and apply modes of reasoning (induction, deduction, analogy, etc.) in the field. [ksa]
5d. Is able to ask satisfactory questions and has a critical/constructive attitude in analysing and solving complex biomedical real-life problems. [ksa]
5e. Is able to form a well-reasoned judgement in the event of incomplete or irrelevant data, taking into account the method used to obtain that data. [ks]
5f. Is able to take a stance regarding a scientific argument in the field of biomedical technology and assess its value critically. [ksa].
5g. Has basic numerical skills and is aware of orders of magnitude. [ksa]

6. **Is able to collaborate with and communicate with specialists in their chosen track and other relevant parties. A Biomedical Engineer is able to work with and for others. This necessitates satisfactory interaction, a sense of responsibility, and leadership skills, but also good communication with both colleagues and non-colleagues. A Biomedical Engineer is also able to participate in a scientific or public debate.**

6a. Is able to communicate in writing about research and problem solutions with colleagues, non- colleagues and other relevant parties (in English). [ksa]
6b. Is able to communicate verbally regarding research and problem solutions with colleagues, non- colleagues and other relevant parties (in English). [ksa]
6c. Is able to debate on biomedical technology and its place in society.
6d. Is characterized by professional behaviour, namely drive, reliability, involvement, diligence, perseverance, and independence. [ksa]
6e. Is able to work in a project-based manner on complex projects; is pragmatic and has a sense of responsibility; is able to deal with limited resources; is able to deal with risks; is able to compromise. [ksa]
6f. Is able to work in a multidisciplinary team, with a very broad disciplinary variety. [ksa]
6g. Is able to be team leader.

7. **Is able to integrate insights regarding medical and social contexts in their work. Life science and technology are not isolated and always exist in a temporal and social context. Opinions and methods have certain origins; decisions have societal consequences in their time. A Biomedical Engineer is aware of these things and is able to integrate these insights in their scientific work.**

7a. Understands relevant (internal and external) developments in the history of biomedical technology, including the interaction between the internal (idea) development and the external (societal) development. [ks] Integrates aspects of this in their scientific work. [ksa]

7b. Is able to analyse the societal consequences (economically, socially, culturally) of new developments in relevant fields and discuss these with both colleagues and non-colleagues. [ks] Integrates these consequences in their scientific work. [ksa]
7c. Is able to analyse the consequences of scientific thinking and acting on the environment and sustainable development. [ks] Integrates these consequences in their scientific work. [ksa]
7d. Is able to analyse the ethical and normative aspects of the consequences and assumptions of scientific thinking and acting and discuss these with both colleagues and non-colleagues (both in research and in designing). [ks] Integrates these ethical and normative aspects in their scientific work. [ksa].
7e. Takes their place as a professional in our society. [ksa]

APPENDIX 2: INTENDED LEARNING OUTCOMES AT BSC AND MSC LEVELS

Competencies and learning outcomes for biomedical engineers at the BSc and MSc levels

A Biomedical Engineer:

1. has expertise in the discipline of biomedical technology

A Biomedical Engineer is familiar with existing scientific knowledge and has the competence to expand this knowledge through study.	
BACHELOR	**MASTER**
Understands the knowledge base of physics, mathematics technology, biology, physiology and medicine (theories, methods, techniques). [ks]	Has a thorough mastery of a specific field of biomedical engineering extending to the forefront of knowledge (latest theories, methods, techniques and topical questions). [ks]
Understands the structure of engineering and life sciences, and the connections between sub-fields. [ks]	Looks actively for structure and connections with biomedical engineering in the relevant fields of physics, mathematics technology, biology, physiology and medicine. [ksa]
Has knowledge of and some skill in the way in which truth-finding and the development of theories and models take place in biomedical engineering. [ks]	Has knowledge of and skill in the way in which truth-finding and the development of theories and models take place in a specific field of biomedical engineering. Has the skill and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
Has knowledge of and some skill in the way in which interpretations (texts, data, problems, results) take place in biomedical engineering. [ks]	Has knowledge of and some skill in the way in which interpretations (texts, data, problems, results) take place in biomedical engineering. Has the skill and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
Has knowledge of and some skill in the way in which experiments, gathering of data and simulations take place in biomedical engineering and its supporting disciplines. [ks]	Has knowledge of and some skill in the way in which experiments, gathering of data and simulations take place in biomedical engineering and its supporting disciplines. [ksa] Has the skill and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
Has knowledge of and some skill in the way in which decision-making takes place in biomedical engineering. [ks]	Has knowledge of and some skill in the way in which decision-making takes place in biomedical engineering. Has the skill and the attitude to apply these methods independently in the context of more advanced ideas or applications. [ksa]
Is aware of both the presuppositions of the standard methods and their importance. [ksa]	Is able to reflect on standard methods and their presuppositions; is able to question these; is able to propose adjustments, and to estimate their implications. [ksa]
Is able (with supervision) to spot gaps in his own knowledge, and to revise and extend knowledge through study. [ks]	Is able to spot gaps in his own knowledge independently, and to revise and extend knowledge through study. [ksa]

k = knowledge, s = skill, a = attitude

2. has expertise in research

A Biomedical Engineer has the competence to acquire new scientific knowledge by research. Research means here: a goal-oriented and methodical increase of new knowledge and insights.	
BACHELOR	***MASTER***
Is under supervision able to reformulate ill-structured biomedical research problems. [ks] Is able to defend the new interpretation against involved parties. [ksa]	Is able to reformulate ill-structured biomedical research problems of a complex nature. Also takes account of the system boundaries. [ksa] Is able to defend the new interpretation against involved parties. [ksa]
Is observant, and has the creativity and the capacity to discover certain connections and new viewpoints. [ksa]	Is observant, and has the creativity and the capacity to discover in apparently trivial matters certain connections and new viewpoints and is able to put these viewpoints into practice for new applications. [ksa]
Is able (with supervision) to produce and execute a research plan. [ks]	Is able independently to produce and execute a research plan. [ks]
Is able to work at different levels of abstraction. [ks]	Given the process stage of the research problem, chooses the appropriate level of abstraction. [ksa]
Understands the importance of other disciplines (interdisciplinarity), especially those of the basic engineering discipline and the life sciences. [ka]	Is able, and has the attitude to draw, where necessary, upon other disciplines in his own research. [ksa]
Is aware of the changeability of the research process through external circumstances or advancing insight. [ka]	Is able to deal with the changeability of the research process through external circumstances or advancing insight. [ksa] Is able to control the process on the basis of this. [ksa]
Is able to assess research within biomedical engineering on its usefulness. [ks]	Is able to assess research within biomedical engineering on its scientific value. [ksa]
Is able (with supervision) to contribute to the development of scientific knowledge in one or more areas of the disciplines involved in biomedical engineering. [ks]	Is able to independently contribute to the development of scientific knowledge in one or more areas of biomedical engineering. [ksa]

3. has expertise in design

Many biomedical engineers will design new products. Designing means here a synthetic activity aimed at the emergence of new or modified artefacts or systems with the intention of creating value in accordance with predefined requirements and needs (e.g. health).	
BACHELOR	***MASTER***
Is able to reformulate simple ill-structured design problems. Also takes account of the system boundaries. [ks] Is able to defend this new interpretation against the parties involved. [ksa]	Is able to reformulate ill-structured biomedical design problems of a complex nature. Also takes account of the system boundaries. Is able to defend this new interpretation against the parties involved. [ksa]
Shows some creativity and skills in synthesis with respect to design problems. [ksa]	Shows creativity and skills in synthesis with respect to biomedical design problems. [ksa]
Is able (with supervision) to produce and execute a design plan. [ks]	Is able independently to produce and execute a design plan. [ks]
Is able to work at different levels of abstraction including the system level. [ks]	Given the process stage of the design problem, chooses the appropriate level of abstraction. [ksa]
Understands the importance of other disciplines (interdisciplinarity) and their contribution to the design process. [ks]	Is able, and has the attitude, where necessary, to draw upon other disciplines in his own design. [ksa]
Is aware of the changeability of the design process through external circumstances or advancing insight. [ka]	Is able to deal with the changeability of the design process through external circumstances or advancing insight. Is able to steer the process on the basis of this. [ksa]
Is able to integrate existing knowledge in a design. [ks]	Is able to formulate new research questions on the basis of a biomedical design problem. [ks]
Has the skill to evaluate design decisions in a systematic manner. [ks]	Has the skill to take design decisions, and to justify and evaluate these in a systematic manner. [ksa]

k = knowledge, s = skill, a = attitude

4. has a scientific approach

A Biomedical Engineer has a systematic approach, characterized by the development and use of theories, models and coherent interpretations, has a critical attitude and understanding of the nature of science and technology.

BACHELOR	***MASTER***
Is inquisitive and has an attitude of lifelong learning. [ka]	Is able to identify and take in relevant developments. [ksa]
Has a systematic approach characterized by the development and use of theories, models and interpretations. [ksa]	Is able to critically examine existing theories, models or interpretations in the area of his or her BME MSc track. [ksa]
Has the knowledge and the skill to use models for research and design and assess their value ('model' is understood broadly: from mathematical model to scale-model). [ks] Is able to adapt models for his own use. [ks]	Has great skill in, and affinity with, the use, development and validation of models; is able consciously to choose between modelling techniques. [ksa]
Has insight into the nature of life sciences and technology (purpose, methods, differences and similarities between scientific fields, nature of laws, theories, explanations, role of the experiment, objectivity etc.) [k]	Has insight into the nature of life sciences and technology (purpose, methods, differences and similarities between scientific fields, nature of laws, theories, explanations, role of the experiment, objectivity etc.) and has some knowledge of current debates about this. [k]
Has some insight into scientific practice (research system, relation with patients and other clients, publication system, importance of integrity etc.) [k]	Has insight into scientific practice (research system, relation with clients, publication system, importance of integrity etc. [ksa]) and has knowledge of current debates about this. [k]
Is able to document adequately the results of research and design. [ksa]	Is able to document and publish adequately the results of research and design with a view to contributing to the development of knowledge in his or her field of biomedical engineering and beyond it. [ksa]

5. possesses basic intellectual skills

A biomedical engineer is competent in reasoning, reflecting, and judgment. These are skills learned or sharpened in the context of a discipline and then generically applicable.

BACHELOR	***MASTER***
Is able (with supervision) critically to reflect on his or her own thinking, decision making and acting, and able to adjust these on the basis of this reflection. [ks]	Is able critically and independently to reflect on his own thinking, decision making, and acting and to adjust these on the basis of this reflection. [ksa]
Is able to reason logically within biomedical engineering and beyond: both 'why' and 'what-if' reasoning. [ks]	Is able to recognize fallacies. [ks]
Is able to recognize modes of reasoning (induction, deduction, analogy etc.) within biomedical engineering. [ks]	Is able to recognize and apply modes of reasoning (induction, deduction, analogy etc. [ksa]) within the field. [ksa]
Is able to ask adequate questions, and has a critical yet constructive attitude towards analysing and solving simple problems in biomedical engineering. [ks]	Is able to ask adequate questions, and has a critical yet constructive attitude towards analysing and solving complex biomedical real-life problems in the field. [ksa]
Is able to form a well-reasoned opinion in the case of incomplete or irrelevant data. [ks]	Is able to form a well-reasoned opinion in the case of incomplete or irrelevant data, taking account of the way in which that data came into being. [ks]
Is able to take a standpoint with regard to a scientific argument in biomedical engineering. [ksa]	Is able to take a standpoint with regard to a scientific argument in his or her area of the biomedical engineering and is able to assess critically its value. [ksa]
Possesses basic numerical skills, and has an understanding of orders of magnitude. [ks]	Possesses basic numerical skills, and has an understanding of orders of magnitude. [ksa]

k = knowledge, s = skill, a = attitude

6. has expertise in cooperation and communication

A Biomedical Engineer has the skills to work with or for others. This competence requires adequate interpersonal skills, responsibility and leadership, but also excellent communication with colleagues and non-specialists. He or she is also able to participate in a scientific or public debate.

BACHELOR	MASTER
Is able to communicate in writing in Dutch about the results of learning, thinking and decision-making with colleagues and non-colleagues including health care providers and patients. [ks]	Is able to communicate in writing about research and solutions to problems with colleagues, non-colleagues and other involved parties including health care providers and patients in English. [ksa]
Is able to communicate verbally in Dutch about the results of learning, thinking and decision making with colleagues and non-colleagues including health care providers and patients. [ks]	Is able to communicate verbally about research and solutions to problems with colleagues, non-colleagues and other involved parties including health care providers and patients in English. [ksa]
Idem to above (verbally and in writing), but in a second language. [ks]	Idem to above (verbally and in writing), but in a second language. [ksa]
Is able to follow debates about both biomedical engineering and the place of biomedical engineering in society. [ks]	Is able to debate about both biomedical engineering and the place of biomedical engineering in society. [ksa]
Is familiar with professional behaviour. This includes: drive, reliability, commitment, accuracy, perseverance and independence. [ksa]	Is characterized by professional behaviour. This includes: drive, reliability, commitment, accuracy, perseverance and independence. [ksa]
Is able to perform project-based work: is pragmatic and has a sense of responsibility; is able to deal with limited sources. [ksa]	Is able to perform project-based work for complex projects: is pragmatic and has a sense of responsibility; is able to deal with limited sources; is able to deal with risks; is able to compromise. [ksa]
Is able to work within an interdisciplinary team of medical and engineering people. [ks]	Is able to work within an interdisciplinary biomedical team having great diversity. [ksa]
Has insight into, and is able to deal with, team roles and social dynamics. [ks]	Is able to assume the role of team leader. [ks]

7. takes into account the temporal and social context

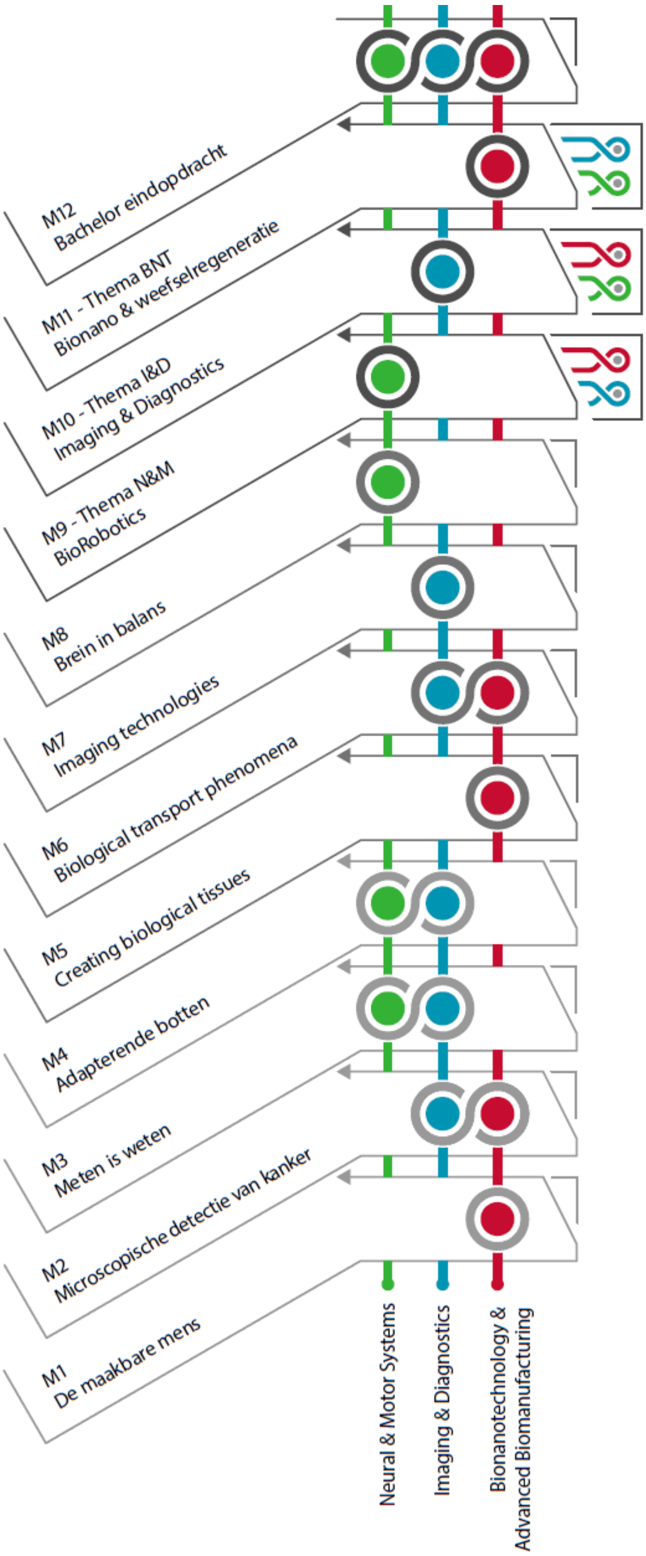
Science and Technology are not isolated and always have a temporal and social context. Ideas and methods have their origins; decisions have social consequences in time. Biomedical Engineers are aware of this and have the competence to integrate these insights into their scientific work.

BACHELOR	MASTER
Is able to analyse and to discuss the social consequences (economic, social, cultural) of new developments in relevant fields with colleagues and non-colleagues. [ks]	Understands relevant (internal and external) developments in the history of biomedical engineering. [ksa] This includes the interaction between the internal developments (of ideas) and the external (social) developments. Integrates aspects of this in scientific work. [ksa]
Is able to analyse and to discuss the ethical and the normative aspects of the consequences and assumptions of scientific thinking and acting with colleagues and non-colleagues (in research, designing and applications). [ks]	Is able to analyse and to discuss the social consequences (economic, social, cultural) of new developments in relevant fields with colleagues and non-colleagues. Integrates aspects of this in scientific work. [ksa]
Has an eye for the different roles of biomedical engineering professionals in society. [ks]	Is able to analyse the consequences of scientific thinking and acting on the environment and sustainable development. Integrates aspects of this in scientific work. [ksa]
Is able to analyse and to discuss the ethical and the normative aspects of the consequences and assumptions of scientific thinking and acting with colleagues and non-colleagues (both in research and in designing). Integrates these ethical and normative aspects in scientific work. [ksa]	Is able to analyse and to discuss the ethical and the normative aspects of the consequences and assumptions of scientific thinking and acting with colleagues and non-colleagues (both in research and in designing). Integrates these ethical and normative aspects in scientific work. [ksa]
Chooses a place in society as a professional person. [ksa]	Chooses a place in society as a professional person. [ksa]

k = knowledge, s = skill, a = attitude

APPENDIX 3: DISCIPLINARY LEARNING LINES OF THE BACHELOR’S PROGRAMME

NB: Each coloured line represents a disciplinary line; the titles above refer to the themes of the bachelor’s modules.



APPENDIX 4: OVERVIEW OF THE CURRICULUM

Bachelor's programme Biomedical Engineering

2018-2019

The B1 program has a study load of 60 EC. The components of the B1 program are:

Name	Content	EC's	Weight	Minimum	Total EC
De maakbare mens, construeren met moleculen, M1	Project	3,00	20%	5,5	15
	Algemene chemie	4,00	33%	5,5	
	Biochemie	2,00	17%	5,5	
	Anatomie	2,00	17%	5,5	
	Introduction to Mathematics + Calculus 1A	4,00	33%	5,5	
Microscopische detectie van kanker, M2	Project	5,00	40%	5,5	15
	Geometrische optica	4,00	24%	5,5	
	Celbiologie	3,00	18%	5,5	
	Calculus 1B	3,00	18%	5,5	
Meten is weten, basisprincipes van medische sensoren, M3	Project	2,50	34%	5,5	15
	Medische sensoren en meetsystemen	5,00	66%	5,5	
	Anatomie en fysiologie	2,50	33%	5,5	
	Optisch meten op weefsel	2,00	27%	5,5	
	Linear Algebra	3,00	40%	5,5	
Adapterende botten, belastingen op en rond implantaten, M4	Project	5,25	30%	5,5	15
	Mechanica	4,49	33%	5,5	
	Harde materialen en beeldvorming	2,24	17%	5,5	
	Calculus 2	3,02	20%	5,5	

The B2 program has a study load of 60 EC. The components of the B2 program are:

Name	Content	EC's	Weight	Minimum	Total EC
Creating biological tissues, M5	Project	6,30	84%	5,5	15
	Structuuranalyse	1,95	26%	5,5	
	Toegepaste celbiologie	4,80	64%	5,5	
	Vector Calculus	1,95	26%	5,5	
Transport phenomena in biological systems, M6	Project	6,00	80%	5,5	15
	Inleiding transportverschijnselen	2,00	25%	5,5	
	Biofysische transportverschijnselen	2,00	25%	5,5	
	Fysische chemie	3,00	45%	5,5	
	Reactiekinetiek	2,00	25%	5,5	
Meten is missen, M7	Project	2,50	17%	5,5	15
	Ultrasound Imaging	2,00	13%	5,5	
	ComputedTomography	2,00	13%	5,5	
	Fysische optica	3,00	20%	5,5	
	Anatomie en fysiologie	2,00	13%	5,5	
	Signalen en systemen	3,50	24%	5,5	
Brein in balans, M8	Project	4,05	54%	5,5	15
	Mechanica	1,95	26%	5,5	
	Biomedische regelsystemen	3,00	40%	5,5	
	Neurofysiologie	3,00	40%	5,5	
	Medische elektronica	3,00	40%	5,5	

The modules offered by BMT for the B3 program are:

Name	Content	EC's	Weight	Minimum	Total EC
BioRobotics, M9	Project	6,50	43%	5,5	15
	Control of Robotic Systems	3,00	20%	5,5	
	Robot Kinematics	2,50	17%	5,5	
	Biomedical Signal Analysis	3,00	20%	5,5	
Imaging & Diagnostics, M10	Project	3,00	20%	5,5	15
	Molecular Spectroscopy for Imaging	3,00	20%	5,5	
	Magnetic Resonance Imaging	6,00	40%	5,5	
	Tissue imaging	3,00	20%	5,5	
Bionanotechnology en weefselregeneratie, M11	Project	5,00	40%	5,5	15
	Cel-materiaalinteracties	2,50	15%	5,5	
	Bio-organische chemie	3,00	18%	5,5	
	Polymeerchemie & Biomaterialen	4,50	27%	5,5	
Bacheloropdracht, M12					

A more detailed description of the bachelor curriculum can be found in Osiris Course Information `https://osiris.utwente.nl/student/OnderwijsCatalogus.do`

Master's programme Biomedical Engineering

Per track, six courses are mandatory (green squares), three elective courses can be chosen (blue squares).

Bioengineering Technologies track

Quartile 1A	1B	2A	2B	Course
green				201400285 Biostatistics (Poortema)
	green			201500222 Technology for Health (Buitenweg)
	green			201400330 Applied Cell biology (Post)
		green		201400284 Biomedical Membranes & Artificial Organs (Stamatialis)
			green	201600327 Tissue Engineering (Leijten)
		green	green	(code t.b.a.) Biological Chemistry (Jonkheijm)
blue				201700040 In Vitro Molecular Diagnostics (Beck)
blue				193740010 Controlled Drug and Gene Delivery (Bansal)
blue				193640020 Biophysical Techniques & Molecular Imaging (Otto)
	blue			201400283 Biomedical Materials Engineering (Poot)
	blue			201200220 Nanomedicine (Prakash)
	blue			193640080 Biophysics (Claessens)
	blue			191211120 Lab-on-a-chip (Eijkel)
		blue		193400111 Bionanotechnology (Bennink)
		blue		193700050 AMM-project Organic Materials (Hempenius)
		blue		191210720 Biomedical Signal Acquisition (Olthuis)
			blue	193640050 Clinical Chemistry (max. 15 participants) (Kemna)
			blue	200900040 Topics in Human Anatomy & Sports Physiology (Reenalda)
green				Introduction to Bioengineering Technologies *(note: only for students who didn't follow B-BMT)*

Physiological Signals and Systems track

Quartile 1A	1B	2A	2B	Course
	green			201500222 Technology for Health (Buitenweg)
green				201400285 Biostatistics (Poortema)
green				201400286 Clinical Research Methods (van Manen)
		green		193810020 Advanced Techniques for Signal Analysis (Heida)
green				191150700 Integrative Design of Biomedical Products (Verkerke)
			green	201700071 Identification of Human Physiological Systems (van Asseldonk)
blue				193810010 Biological Control Systems (Zwart)
		blue		201800156 Biomechanics of human movement (Massimo Sartori)
		blue		191210720 Biomedical Signal Acquisition (Olthuis)
			blue	201400282 Bio-electromagnetics (Heida)
		blue		191150480 Human Movement Control (van Asseldonk)
	blue			201500132 Remote Monitoring and Coaching (Vollenbroek)
			blue	193810100 Dynamic Behavior of Neuronal Networks (van Putten)
	blue			191506001 Mathematical Methods (Meijer)
blue				191560430 Nonlinear Dynamics (Meijer)
			blue	191210920 Optimal Estimation in Dynamic Systems (van der Heijden)
		blue		191131700 System Identification and Parameter Estimation (Aarts)
blue				201600070 Basic Machine Learning (Englebienne)
blue				191154740 Biophysical Fluid Dyn.: The Resp. Syst.

Biorobotics track (Robotics variant)

Quartile 1A	1B	2A	2B	Course
■				201400285 Biostatistics (Poortema, 5 EC)
	■			201300004 Robotics for Medical Applications (5EC, Misra et al)
	■			201500222 Technology for Health (Buitenweg 5EC)
	★			201400040 Dynamics & Control (5EC, Jurnan Schilder et al)
		■		201800335 Programming 2
			★	191211060 Modern Robotics (5EC, Folkertsma) alternative for Dynamics& Control
			■	201700071 Identification of human physiological systems (5E, van Asseldonk et al)
			■	201200133 Biomechatronics (5EC, BE, van der Kooij et al)
		■		91210910 Image Processing and Computer Vision (5EC, vd Heijden)
	✣			191561620 Optimal Control (5EC, Meinsma)
			■	191210920 Optimal Estimation in Dynamic Systems (5EC, van der Heijden)
		■	■	191131360 Design Principles for Precision Mechanisms (5EC, D. Brouwer et al)
		■		191150480 Human Movement Control (5EC, Asseldonk et al)
		■		201800156 Biomechanics of human movement (Massimo Sartori)
■				201400286 Clinical Research Methods (Doggen, 5EC, 1A
■				191150700 Integrative Design of Biomedical Products (Verkerke / Hekman, 5EC)
		■		193810020 Advanced Techniques for Signal Analysis (Heida, 5EC)
■				191210770 Digital control engineering (1A, Theo de Vries)

★alternatief voor verplicht vak; ✣aanbeveling voor de vrije ruimte

Biorobotics track (Design variant)

Quartile 1A	1B	2A	2B	Course
■				191150700 Integrative Design of Biomedical Products (Verkerke/Hekman 5EC)
★				201400286 Clinical Research Methods (alternative Ergonomics dif. content)
■				201400285 Biostatistics
	■			201500222 Technology for Health
	★			201400287 Ergonomics
		■		201800156 Biomechanics of human movement (Massimo Sartori)
			■	200900040 Topics in Human Anatomy & Sports Physiology
	★			201400040 Dynamics & Control (prerequisite knowledge for Rob. For Med. Appl. & Human Mov. Contrl.)
			★	191211060 Modern Robotics (alternative for Dynamics& Control)
	■			201400283 Biomedical Materials Engineering
			■	201600327 Tissue Engineering
	■			201300004 Robotics for Medical Applications
		■		191150480 Human Movement Control
		■	■	201400046 Experimental Methods
		■	■	191155730 Tribology
		✣	✣	201400048 Moulding Technology
		■		91210910 Image Processing and Computer Vision
		■	■	191131360 Design Principles for Precision Mechanisms
✣	✣			191157710 Numerical Methods in Mechanical Engineering
		✣	✣	201400267 Capita Selecta CTW-BW

★alternatief vak; ✣aanbeveling voor de vrije ruimte

Imaging en In Vitro Diagnostics track

Quartile				
1A	1B	2A	2B	Course
■				201700040 In Vitro Diagnostics (Beck)
■				201400285 Biostatistics (Poortema)
■				193640020 Biophysical Techniques and Molecular Imaging (Otto)
			■	Imaging in Radiology (Simonis) (code volgt , q4 onder voorbehoud)
	■			201500222 Technology for Health (Buitenweg)
	■			191506001 Mathematical Methods (Meijer)
■	■			193640060 Radiation Expertise (extern docent)
	■			193572010 Physics of Bubbles (Versluis)
	■			191551150 Numerical Techniques for PDE (Schlottbom)
		■		193542070 Medical Acoustics (Versluis)
		■		193530050 Magnetic Methods for (Neuro) Imaging (ten Haken)
		■		193810020 Advanced Techniques for Signal Analysis (Heida)
		■		191210910 Image Processing and Computer Vision (van der Heijden)
			■	193500000 Biomedical Optics (Vellekoop)

A more detailed description of the master curriculum can be found in Osiris Course Information `https://osiris.utwente.nl/student/OnderwijsCatalogus.do`

APPENDIX 5: PROGRAMME OF THE SITE VISIT

MONDAY 10 DECEMBER 2018

11.00	11.15	Welcome
11.15	13.00	Closed meeting panel (incl. lunch)
13.00	13.45	Interview with management
13.45	14.15	Closed meeting panel (incl. reading documentation)
14.15	15.00	Interview with students: bachelor
15.00	15.45	Interview with teachers: bachelor
15.45	16.15	Break
16.15	17.00	Interview Examination Board
17.00	17.45	Interview with alumni of the master's programme

TUESDAY 11 DECEMBER 2018

09.00	09.45	Closed meeting panel
09.45	10.30	Interview with students: master
10.30	11.15	Interview with teachers: master
11.15	11.45	Break
11.45	12.30	Interview with management
12.30	14.30	Evaluation, mapping opinions (incl. lunch)
14.30	14.45	Reporting provisional findings
14.45	15.00	Break
15.00	15.45	Development interview
15.45	16.00	End

APPENDIX 6: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the bachelor's programme Biomedical Engineering and 15 theses of the master's programme Biomedical 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; all documents apply for both programmes):

- Self-evaluation report
- Overview of the curriculum (descriptions of courses and modules, overview of the planning of all courses throughout the academic years of the programme; overview of the disciplinary learning lines)
- Information on specific disciplinary learning lines *("BMT Leerlijn Anatomie & Fysiologie")*
- Overview of how the core concepts of the curriculum of Biomedical Engineering are covered throughout the bachelor's and master's programme (*"Kernbegrippen Curriculum Biomedische Technologie april 2011")*
- Internship Guide 2018-2019
- Revised assessment form of the bachelor's programme
- Education and Examination Regulations
- Assessment Policy of the Health Programmes
- Annual report Examination Board 2016/2017
- Assessment report accreditation 2012 and decision NVAO