M BIOMEDICAL ENGINEERING

FACULTY OF SCIENCE AND ENGINEERING

UNIVERSITY OF GRONINGEN

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CONTENTS

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REPORT ON THE MASTER'S PROGRAMME BIOMEDICAL ENGINEERING OF GRONINGEN UNIVERSITY

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

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

Master's programme 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:	Diagnostic Imaging & Instrumentation (DII) Biomaterial Science & Engineering (BSE) Medical Device Design (MDD) European Master's programme CEMACUBE (double degree)
Location(s):	Groningen
Mode(s) of study:	full time
Language of instruction:	English
Expiration of accreditation:	31/12/2019

The visit of the assessment panel Biomedical Engineering to the Faculty of Science and Engineering of University of Groningen took place on 5 and 6 November 2018.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

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

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO approved the composition of the panel on 27 August 2018. The panel that assessed the master's programme Biomedical Engineering consisted of:

- Prof. J. (Jos) Vander Sloten, full professor at the Faculty of Engineering Science and vice-dean Internationalisation at the Faculty of Engineering Science at the KU 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. S.C.G. (Sander) Leeuwenburgh, full professor Regenerative Biomaterials at Radboud University Medical Center in Nijmegen;
- V. (Vera) Koomen, master's student Biomedical Engineering at the Eindhoven University of Technology.

The panel was supported by drs. R.L. (Renate) Prenen, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The master's programme Biomedical Engineering at the Faculty of Science and Engineering of the University of Groningen was assessed within the cluster assessment Biomedical Engineering. Between October and December 2018 the panel assessed 10 programmes at 5 universities: Vrije Universiteit Amsterdam, Delft University of Technology, University of Groningen, Eindhoven University of Technology and University of Twente.

On behalf of the participating universities, the quality assurance agency QANU was responsible for logistical support, panel guidance and production of the reports. Peter Hildering, MSc, was project coordinator for QANU. Peter Hildering, MSc, and drs. Renate Prenen acted as secretaries during the site visits. [redacted], and [redacted] acted as second secretary during a number of the site visits.

During the site visit at the University of Groningen, the panel was supported by Renate Prenen, a certified NVAO secretary. During the first day of the site visit, the panel was accompanied by NVAO coordinator Irma Franssen for the initial accreditation of the bachelor's programme.

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)

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 Groningen, QANU received the self-evaluation reports of the programmes and forwarded them to the panel. A selection of theses was made by the panel's chair and the project coordinator. The selection consisted of 15 theses and their assessment forms, 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 the framework and working method for the initial accreditation, 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 Groningen took place on 5 and 6 November 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 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 them checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The reports were 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

Intended learning outcomes
The two-years master´s programme Biomedical Engineering (BME) is an interdisciplinary programme offered by the Faculty of Science and Engineering (FSE), the Faculty of Medical Sciences (FMS) and the University Medical Center Groningen (UMCG). The main aim of the programme is to educate students in such a way that they are able to improve the quality of medical care, increase patient safety, and reduce costs and manpower through engineering solutions. The programme includes three tracks: Diagnostic Imaging & Instrumentation (DII), Biomaterial Science & Engineering (BSE) and Medical Device Design (MDD). In addition, a European version is offered, i.e. CEMACUBE (Common European Master's Course in Biomedical Engineering).

The panel is positive about the programme's profile. It approves of the strong design focus and the intertwining of technical and medical disciplines. It also appreciates the ambition to integrate design and research. However, it felt that this intended integration could be reflected more clearly in the programme's aims and learning outcomes to avoid a dichotomy between research and design within the programme. The panel confirmed and appreciated the strong connection to the professional field. Representatives of the field participate in advisory bodies which inform and advise about e.g. developments in the field, experiences with BME graduates and the overall quality of the programme.

The intended learning outcomes of the master's programme BME are in line with the subject-specific reference framework as well as the international Dublin descriptors. However, the panel ascertained that they overlap to a large extent with those of the faculty's bachelor's programme BME, which makes it difficult to indicate the intended master's level. It advises adjusting the outcomes in order to differentiate them from the bachelor's programme and to better reflect the master's level.

Teaching-learning environment
The panel established that the master's programme BME is adequately designed and enables the students to achieve the intended learning outcomes. The content suits a master´s level and is well-aligned with the intended learning outcomes. The panel is satisfied with the academic and professional orientation of the programme. Students have ample opportunities to apply knowledge and insights and to train their academic and design skills. The link to the professional field is established through the use of real-world assignments and projects. It is enhanced by the internship and the various career orientation activities and services.

The curriculum structure with compulsory general courses and track-specific courses, safeguards the programme's coherence. The tracks give students the opportunity to specialize in one of three BME domains. One point of concern is the observation that students within a track hardly intermingle with students from other tracks, mainly caused by the early time point of choosing a track. The panel advises elaborating ways to strengthen the community building. It is positive about the CEMACUBE programme in Groningen. The programme is well-designed and prepares students well for the international BME market.

The programme is feasible, and the success rates are satisfactory. Students are positive about the teaching and guidance provided by the staff. However, attention should be paid to a better spread of the workload over the years. Attention should also be paid to the progress of students who enroll at another time than in September. Because they go through the programme in a different order, this could have an impact on the perceived cohesion. The panel approved the master's project setup and is enthusiastic about the accompanying winter and summer symposia. However, it also ascertained attention should be paid to the further integration of design and research in the various master's projects.

The panel is satisfied with the setup of the individual courses. The teaching methods are in line with the learning outcomes and course contents. The panel considers them to be not very innovative but sufficiently interactive, given the small student groups. Attention should be paid to the scheduling of

lectures and working groups and the low attendance of students during classes. The panel advises exploring ways to make the teaching more active and to increase student attendance.

The panel values the professional, scientific and didactic qualities of the staff and the attention paid to their professionalization. A point of attention is the staff´s English proficiency. As the programme is taught entirely in English, their English language skills should be closely monitored and stimulated. The panel also concludes that the quantity of the staff is sufficient. It considered the student-staff ratio to be acceptable and was pleased to see that investments are being made to recruit more staff. At this moment there is an imbalance in UMCG versus FSE staff. The panel appreciates the management's intention to consciously monitor this balance and take further measures if necessary. The programme committee functions adequately. In the panel's opinion, it is undesirable that the programme coordinator acts as an adviser and formal secretary of the committee because this could influence the committee's independent role. Finally, it ascertained that the programme-specific facilities are adequate. It advises finding a quick solution to the discomfort that students experience due to the absence of a UMCG pass.

Student assessment
The panel is satisfied with the assessment and evaluation system of the master's programme BME. The formal regulations are clearly set out in the Teaching and Examination Regulations and the Rules and Guidelines for Boards of Examiners. It appreciates the various measures that were implemented to promote the reliability, validity and clarity of assessment, such as the overall assessment programme, the CUAOs and the peer-review principle. However, it also established that in daily practice there is a lot of variation, depending on the individual preferences and experiences of lecturers. In its opinion, more consistency should be sought. It advises monitoring and controlling the coherence of the assessment system from a joint vision on testing.

The panel approved the types of assessment used. They are sufficiently varied and suit the content and design of the programme. The thesis evaluation procedure is adequate. There are always two supervisors involved, one of the eight mentors and the daily project supervisor, with the mentors playing an important role in safeguarding the quality of the master's thesis. However, the panel noted some weaknesses in this system with regard to the independence of the assessments, such as the close involvement of mentors in supervising students during their theses. It advises elaborating measures to strengthen the quality assurance of the thesis assessments further, for example by promoting calibration sessions among the mentors. With respect to the CEMACUBE students, the panel strongly advises including a second examiner from within the University of Groningen on all master's projects abroad. It is satisfied with the master's project assessment form. However, it also concluded that the completed assessment forms could become more transparent, particularly with regard to the scores for criteria in relation to the final mark and the written clarification. It is positive about the plan to develop a rubric for the thesis evaluation, as this can have a positive effect on increasing the transparency and reliability of the assessment.

The panel is satisfied with the functioning of the Board of Examiners. It appreciates the various measures that have already been taken to safeguard the quality of the assessment system. However, it also ascertained that there is still work to be done, for example with respect to the quality assurance of external parts of the programme. It encourages the Board to play a more proactive and decisive role. Furthermore, it recommends a change in the position of the programme coordinator as formal secretary to the Board because this could interfere with the independence of this body.

Achieved learning outcomes
The panel studied a selection of theses and found that their overall quality could be considered satisfactory. It advised paying attention to strengthening the academic depth of the theses as well as the further integration of research and design. The interviewed alumni were positive about their programme, and the panel established that they are quite successful in their careers. The field representatives confirmed this positive impression. They are generally very satisfied with the performance of the graduates.

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

Master's programme Biomedical Engineering

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

The chair, prof. Jos Vander Sloten, and the secretary, drs. Renate Prenen, of the panel hereby declare that all panel members have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

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

Introduction
The master´s programme Biomedical Engineering (BME) is an interdisciplinary programme offered by the Faculty of Science and Engineering (FSE), the Faculty of Medical Sciences (FMS) and the University Medical Center Groningen (UMCG). It includes three tracks: Diagnostic Imaging & Instrumentation (DII), Biomaterial Science & Engineering (BSE) and Medical Device Design (MDD). In addition to the standard BME master's programme, a European version exists as well, i.e. CEMACUBE (Common European Master's Course in Biomedical Engineering). The CEMACUBE double degree master's programme is jointly organised by the University of Groningen (the Netherlands), RWTH Aachen (Germany), Trinity College Dublin (Ireland), Czech Technical University Prague (Czech Republic), Ghent University (Belgium) and Vrije Universiteit Brussels (Belgium).

Formal responsibility for the programme rests with the FSE. Within this faculty, all bachelor's programmes are organised in the Undergraduate School of Science and Engineering and all master's degree programmes in the Graduate School of Science and Engineering. The BME master's degree programme is managed by the director of the Graduate School of Science and the deputy director of the programme with the involvement and direction of the Faculty Board. The BME programme's daily affairs are managed via the programme 'triangle', which consists of the deputy director, the programme coordinator and the academic advisor. The content of the BME programme has strong ties with both the FSE and FMS/UMCG research institutes. Staff members are appointed to organisational research groups, which are clustered into several research institutes and schools. The programme has a dedicated programme committee and a board of examiners.

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.

Explanation:
The intended learning outcomes demonstrably describe the level of the programme (Associate Degree, Bachelor's, or Master's) as defined in the Dutch qualifications framework, as well as its orientation (professional or academic). In addition, they tie in with the regional, national or international perspective of the requirements currently set by the professional field and the discipline with regard to the contents of the programme. Insofar as is applicable, the intended learning outcomes are in accordance with relevant legislation and regulations.

Findings
According to the self-evaluation report, the mission of the master's programme BME is to educate students in such a way that they are able to improve the quality of medical care, increase patient safety, and reduce costs and manpower through engineering solutions. At the University of Groningen, teaching is intertwined with academic research, and thus, students are familiarized with academic research skills. In line with this, the programme's vision states that research- and design-based teaching must be grounded in the latest academic theories, research outcomes and design methodologies; they will form an integral part of the programme. Explicit attention will be paid to the introduction, practice and assessment of academic and engineering skills.

The mission is subdivided into several goals for the BME master's programme: (1) to train students to perform scientific research to develop new techniques for diagnosis and therapy, mainly at or in cooperation with universities, University Medical Centres (UMCs) and large companies with distinct research departments; (2) to train students to design new diagnostics and therapies at universities, UMCs and companies; (3) to train students in applying new diagnostics and therapies at UMCs and hospitals. The programme has used its mission, vision and goals to determine and formulate eight

intended learning outcomes (cf. appendix 2). Students can choose between three tracks. The Diagnostic Imaging and Instrumentation (DII) track deals with the underlying principles, the instrumentation used and insights into current imaging and ionizing equipment. The Biomaterials Science and Engineering (BSE) track is concerned with the development, analysis, assessment and application of innovative biomaterials for restoration and regeneration of body function and the enhancement of implant efficacy. The third track, Medical Device Design (MDD), deals with the design of innovative medical devices that contribute to the prevention of health decline by better diagnostics and to ameliorate therapies. The tracks share a common set of learning outcomes, but differ in their specific emphasis within the domain of biomedical engineering.

During the site visit the panel discussed the programme's profile with staff, students and representatives of the field. It ascertained that the master's programme BME at the University of Groningen has a strong focus on the design aspects of biomedical engineering. It can be characterized by its aim to integrate design and research skills. The programme is also distinguished by the fact that engineering and natural sciences expertise from the Faculty of Science and Engineering (FSE) is combined with the medical expertise available from the Faculty of Medical Sciences (FMS)/ the University Medical Center Groningen (UMCG), culminating in a combination of both the technical and medical fields from a research and applications perspective.

In general the panel is positive about the programme's profile. It appreciates the strong design focus, which is in line with the university´s and faculty´s aim to expand its offering of technical and engineering programmes. It is also enthusiastic about the collaboration between the two faculties and the UMCG; it considers the intertwining of technical and medical expertise and practices as a fruitful and distinctive feature of the programme. It approves the programme's ambition to integrate design and research. The panel is convinced that a fusion of both is essential to train BME professionals on an academic level and avoid a dichotomy between design and research. However, it remarked that the mission and vision around the required integration of design and research, as presented in the self-evaluation report, could be expressed more clearly. This mission and vision should ensure a proper balance between research and design in the further composition and organization of the programme's curriculum. The panel advises to re-define the programme´s mission, vision and learning outcomes in such a way that they clearly reflect this intended integration.

The panel remarked that in recent years there have been changes in the track options (one of the two original tracks was split into two) and naming of the tracks. It approves of these changes; the current tracks are well-chosen and provide students with the opportunity to specialize within the broad field of BME. It also appreciates CEMACUBE, which is very attractive for students with ambitions to study abroad. The six participating European universities have good reputations within the field, and after graduation, students receive a double degree. As an added benefit, the CEMACUBE programme introduces four international students per cohort on average into the regular programme, thereby increasing the international character of the faculty's BME programme. Recently, a new and integrated addition was introduced to the CEMACUBE programme, the European Institute of Innovation & Technology (EIT) Entrepreneur specialisation. According to the panel, this programme is highly distinctive. With an emphasis on entrepreneurship, a European intercultural view, and the ability to develop innovative medical devices, it builds a valuable bridge between academia and industry.

The panel appreciates the strong connection to the professional field. To address the fast-paced, ever-changing nature of the BME field, a Curriculum Committee was established consisting of representatives from the field (hospitals as well as industry), current students and teaching staff. This committee informs the programme of new developments in the field and how the professional field values the BME graduates. It also offers suggestions for adapting the curriculum to better prepare students for careers in BME. In addition, an External Advisory Panel has been assembled, composed of senior national and international employees from the field. The aim of this panel is to provide information about the field as well as experiences with BME graduates. Notably, it advises

on the overall quality of the programme, in terms of organization, learning outcomes, preparedness of students for the labour market and the curriculum as a whole.

The panel studied the intended learning outcomes and established that they are in agreement with the domain-specific reference framework (cf. appendix 1) and can be linked to the international Dublin descriptors for the master's level. The outcomes are therefore in accordance with national as well as international standards. The panel noticed that the learning outcomes of the BME master's programme BME are very similar to the learning outcomes of the faculty's proposed bachelor's programme BME, which the panel also assessed. This makes it difficult to interpret the exact distinction between the bachelor's and master's level. In fact, the learning outcomes 1, 2, 3, 4, 6, 7 and 8 are almost identical. The panel recommends revising the outcomes so they are more distinctive from those of the bachelor's programme and clearly reflect the intended master's level. The panel also advises to avoid the suggestion in the intended learning outcomes that students obtain the title 'biomedical engineer' after graduation, as this is not a formal title. According to the panel, the learning outcomes can be adjusted by referring to the competences of the 'master of science in biomedical engineering' instead of those of the 'biomedical engineer'.

Considerations
The panel is positive about the programme's profile. It approves of the strong design focus and the intertwining of technical and medical disciplines. It also appreciates the ambition to integrate design and research. However, it felt that this intended integration could be reflected more clearly in the programme's aims and learning outcomes to avoid a dichotomy between research and design within the programme. The panel confirmed and appreciated the strong connection to the professional field. Representatives of the field participate in advisory bodies which inform and advise about e.g. developments in the field, experiences with BME graduates and the overall quality of the programme.

The intended learning outcomes of the master's programme BME are in line with the subject-specific reference framework as well as the international Dublin descriptors. However, the panel ascertained that they overlap to a large extent with those of the faculty's bachelor's programme BME, which makes it difficult to indicate the intended master's level. It advises adjusting the outcomes in order to differentiate them from the bachelor's programme and to better reflect the master's level.

Conclusion
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.

Explanation:
The intended learning outcomes have been adequately translated into educational objectives of (components of) the curriculum. The diversity of the students admitted is taken into account in this respect. The teachers have sufficient expertise in terms of both subject matter and teaching methods to teach the curriculum, and provide appropriate guidance. The teaching-learning environment encourages students to play an active role in the design of their own learning process (student-centred approach).

Findings

Curriculum content and design
The master's programme BME is a two-year, fulltime programme consisting of 120 EC (cf. appendix 3). Each year is divided into two semesters of 30 EC. All courses are worth 5 EC. The internship is 15 EC and the master's project 35 EC. At the start of the programme, all students must choose one of the three tracks; once chosen, all courses within the track are compulsory. The first semesters of

both the first and the second years are dedicated to track-specific courses. The second semester of the first year consists of general courses for all tracks followed by an industrial internship. The general courses include: Technology and Ethics, Statistical methods in BME, Introduction to MATLAB programming for BME, Biomedical Instrumentation, and the Multidisciplinary Project. The internship is performed in a local or international company or hospital and serves as an introduction to the daily practice of a biomedical engineer in a representative work environment. The programme concludes with a master's project.

The panel is satisfied with the design of the programme. The fixed structure with three tracks and obligatory courses contributes to a clear, well-organized and coherent programme. The tracks give students the opportunity to specialize in a particular BME domain. The content suits a master´s level and is in line with the intended learning outcomes. The programme's academic and scientific orientation is sufficient. In addition to dedicated research components, such as the master's project, students learn and practise academic and research skills during different courses. The panel appreciates the strong connections to the professional field. In various courses, for example the Multidisciplinary Project, students learn to apply their knowledge and skills through real-world assignments and projects. The internship must be done in an industry or hospital outside the University of Groningen and prepares students well for their future working careers.

During the site visit the panel spoke with students and staff about the fact that students have to choose a track right at the start of the programme. It learned from these conversations that in the past, the first year had compulsory general courses for all students. In the second year, students specialized by choosing a track. This approach has been changed because students encountered difficulties in seeing the coherence of the general courses with the overall goals and final learning outcomes of the programme. In addition, the programme has appointed three tracks coordinators responsible for the coherence within and in between the tracks.

Students and staff are satisfied with this alteration, which contributes to the programme´s coherence as well as the students´ overview and motivation. The panel supports the change in curriculum structure and the appointment of the track coordinators. However, it also noted that while students are mixing with students within their track, they hardly interact with students from other tracks in the first half-year and second year of the programme. The programme aims to remedy this, as it is an unintended side effect that does not benefit the general formation of a feeling of community. The panel agrees that a strong shared community is of great importance for a stimulating educational climate. It encourages elaborating on ways to break down barriers, such as a joint introduction week. It also favours the management´s intention to introduce a study association for those programmes lacking one, like the master´s BME.

Students conclude their studies with a master's project. These projects are carried out within departments that conduct research in biomedical engineering in interdisciplinary settings or at various types of organizations. Students can choose to pursue more research-oriented projects at one of the research departments involved in the BME Master's programme at the University of Groningen or the University Medical Center Groningen; students who are attracted to more industrial environments can conduct their master's project work at a company. Going abroad is highly encouraged. The panel approved the master's project design. However, it also noticed that in practice many projects consisted of either scientific research or methodical design, whereas a combination of both components would be expected based on the programme's stated goals (see also standard 4). According to the panel, the programme should strive for an adequate synergy of design and research in *all* master's projects.

The thesis trajectory is accompanied by the winter and summer symposia. During the winter symposium, each student presents his or her thesis topic and planning to other students (from all tracks), teaching staff and two or three alumni from different professional orientations (academic, industry, entrepreneurial). Thus, all students become familiar with their fellow students' topics and strategies and learn from each other's plans. At the end of the second year, the summer symposium

takes place. During this symposium, students present their master's project results to other students, supervisors and teaching staff. They learn from their peers and practice their presentation skills. The panel ascertained that the symposia are greatly appreciated by the students, staff and alumni. The panel strongly supports these initiatives.

The panel studied the information in the self-evaluation report concerning the setup of the CEMACUBE programme and discussed it with the management during the site visit. It ascertained that the consortium of six universities offers students a common curriculum in BME. Students follow a general programme at one of the universities during their first year, and a specialization programme at another CEMACUBE university in the second year. At the end of their programme, they receive a master's degree from both universities. During their stay in Groningen, first-year CEMACUBE students are offered a mix of courses of all three tracks to provide them with more general content, which is the same in all participating universities. Second-year CEMACUBE students generally follow the same programme as non-CEMACUBE BME students. The panel is positive about the CEMACUBE programme in Groningen. It considered it to be adequately designed. The international component is very stimulating for students and prepares them well for the international BME market.

Feasibility
The panel ascertained that the programme is feasible based on the information in the self-evaluation report and on discussions with the students and lecturers. The overall success rates are acceptable. The graduation rate after two years varied between 55% and 71% for the years 2011 to 2015. A graduation rate of 80% within 2 years, the faculty's target, was not attained. However, graduation rates after 3 and 4 years are relatively high. Students with study delays often chose consciously to focus on extracurricular activities or extra courses. Some decided to extend the duration of the master's project with the aim of publishing their research in scientific journals. Others, like those who wish to follow the Clinical Physicist programme after obtaining their master's degree, are required to follow extra courses. Reasons for student dropout were generally due to personal circumstances.

The interviewed students confirmed this impression. They considered the programme to be feasible within two academic years and did not detect any stumbling blocks. However, some mentioned experiencing an imbalance in the workload. In particular, the first semester of the second year is quite demanding. According to the students, there could be a better spread of the workload over the years. They are satisfied with the guidance and support provided by the staff. The lecturers are always available to answer questions or provide help.

The panel noticed that, although the programme's official starting moment is September, students can enrol throughout the year. The interviewed staff explained that they are pleased with this extra service to students and have experienced no adverse effects on feasibility so far. At the same time, they realize that it is not in line with the philosophy of the programme and discourage students from doing so. The panel understands this. It also sees the disadvantages with regard to the programme's cohesion. It therefore advises closely monitoring the progress of the students involved and taking further measures if necessary.

Teaching concept and methods
The panel studied the information in the self-evaluation report and the course materials on the reading table during the site visit. It noted that the programme does not have a distinctive overall didactical vision that underlies the teaching and learning, but rather relies on traditional teaching methods such as lectures, working groups, and practicals. Although these teaching methods are not considered particularly innovative, the panel approves these teaching methods in view of the small-sized student groups which allows for interactive forms.

The panel advises paying attention to the scheduling of the lectures and working groups. As it learned from the students, most working groups are organised immediately after the lectures. Particularly when they are not well prepared, students experience the working groups to be inefficient. According

to them, more time between the lectures and working groups would contribute to better preparation. The panel also advises paying attention to the low student attendance during lectures. It suggests that there might be a connection with the non-obligatory nature of the lectures and the emphasis on knowledge transfer. It suggests exploring alternative teaching methods to stimulate active learning and student attendance.

Teaching staff
The panel studied the composition of the teaching staff involved in the master's programme BME as presented in the self-evaluation report. During the site visit it also discussed the quality and quantity of the staff with the management, lecturers and current students. There are 22 staff members involved. The student to staff ratio was approximately 15:1 in 2016/2017, which is very favorable in the panel's opinion.

The panel is positive about the quality of the staff. It appreciates that almost all staff members have doctorates and engage in original research. They bring their experiences in research, international working environments and professional networks to the BME programme to the students' benefit. Because they integrate the results of their own research into the course units they teach, students learn about the most recent developments in the relevant scientific fields. The panel also appreciates the fact that attention is paid to the staff's didactical expertise. Approximately 75% of the teaching staff had already obtained the University Teaching Qualification ('basiskwalificatie onderwijs'); newly appointed staff members are currently in the process of obtaining their teaching qualification. The interviewed students were in general positive about the staff. They appreciated the staff's expertise as well as their accessibility and involvement. With respect to the lecturers´ English language skills, they mentioned experiencing differences in level. Some lecturers are more skilled than others. According to the panel, the staff´s English proficiency should be closely monitored and stimulated. If necessary, further measures should be taken.

The BME lecturers are employed at one of the research institutes of FSE or UMCG. The panel noticed an imbalance; the majority of the staff involved is appointed by the UMCG. According to the management, this has developed historically and currently is not causing any issues regarding the availability and quality of the staff. In the long term, the balance will be closely monitored and steered, taking into account the required expertise, continuity and developments in the field. The panel supports this vision. It noted that, although the UMCG and FSE staff are located in different places, they regularly meet to discuss the content, setup and quality of the programme. The programme can be congratulated for such a dedicated group of lecturers.

Programme-specific facilities
The panel considered the programme-specific facilities to be adequate. The master's programme uses facilities at both the FSE and FMS/UMCG. General lecture facilities are available at the two locations. A substantial part of the teaching occurs in laboratories and departmental conference rooms, which are distributed over both locations. All laboratories are used by research units or discipline groups from research institutes and contain all basic and specialized equipment necessary for current research. The interviewed students are generally satisfied with the programme's facilities. They follow courses at both faculties, which are well equipped. One inconvenience is that BME students do not have an entrance pass for the UMCG building, so they cannot open doors and make use of the coffee machines, for example. The panel advises resolving this problem quickly.

The panel appreciates the attention paid to the students' preparation for the job market. The Career Services of the University of Groningen collaborates actively with faculties, study and alumni associations, and other institutions in the field of career services. They offer workshops and training courses and give personal career advice. Faculty-wide career events are organized to help students define their career choices better and meet future employers. A fruitful initiative on the programme level is the BME Portal website, set up by several students and alumni in 2017. Its aim is to develop a community of biomedical engineering in Groningen and strengthen the link between BME students, alumni, the University and the BME industry. The aforementioned winter and summer symposia are

also very informative. During these symposia alumni give presentations on their experiences in finding their jobs, what they do, their experiences in the workforce and how their studies prepared them for their jobs. Students react very positively to these events, particularly the contacts with alumni and the preview of post-graduate life.

The master's programme BME has a programme committee composed of 5 lecturers and 5 students, with representatives of all the different tracks. During the site visit, the panel spoke with several members of the programme committee. It ascertained that the committee functions adequately. The committee has a crucial role in the evaluation and adjustment of the curriculum. There are open discussions, and teaching staff and students have an equal say in matters. Recommendations are followed up by the programme's management. A point of attention is the fact that the programme coordinator functions both as an adviser and the formal secretary of the committee. According to the panel, this is undesirable as it could influence the independent position of the committee. It advises changing this situation.

Considerations

The panel established that the master's programme BME is adequately designed and enables the students to achieve the intended learning outcomes. The content suits a master´s level and is well-aligned with the intended learning outcomes. The panel is satisfied with the academic and professional orientation of the programme. Students have ample opportunities to apply knowledge and insights and to train their academic and design skills. The link to the professional field is established through the use of real-world assignments and projects. It is enhanced by the internship and the various career orientation activities and services.

The curriculum structure with compulsory general courses and track-specific courses, safeguards the programme's coherence. The tracks give students the opportunity to specialize in one of three BME domains. One point of concern is the observation that students within a track hardly intermingle with students from other tracks, mainly caused by the early time point of choosing a track. The panel advises elaborating ways to strengthen the community building. It is positive about the CEMACUBE programme in Groningen. The programme is well-designed and prepares students well for the international BME market.

The programme is feasible, and the success rates are satisfactory. Students are positive about the teaching and guidance provided by the staff. However, attention should be paid to a better spread of the workload over the years. Attention should also be paid to the progress of students who enroll at another time than in September. Because they go through the programme in a different order, this could have an impact on the perceived cohesion. The panel approved the master's project setup and is enthusiastic about the accompanying winter and summer symposia. However, it also ascertained attention should be paid to the further integration of design and research in the various master's projects.

The panel is satisfied with the setup of the individual courses. The teaching methods are in line with the learning outcomes and course contents. The panel considers them to be not very innovative but sufficiently interactive, given the small student groups. Attention should be paid to the scheduling of lectures and working groups and the low attendance of students during classes. The panel advises exploring ways to make the teaching more active and to increase student attendance.

The panel values the professional, scientific and didactic qualities of the staff and the attention paid to their professionalization. A point of attention is the staff´s English proficiency. As the programme is taught entirely in English, their English language skills should be closely monitored and stimulated. The panel also concludes that the quantity of the staff is sufficient. It considered the student-staff ratio to be acceptable and was pleased to see that investments are being made to recruit more staff. At this moment there is an imbalance in UMCG versus FSE staff. The panel appreciates the management's intention to consciously monitor this balance and take further measures if necessary. The programme committee functions adequately. In the panel's opinion, it is undesirable that the

programme coordinator acts as an adviser and formal secretary of the committee because this could influence the committee's independent role. Finally, it ascertained that the programme-specific facilities are adequate. It advises finding a quick solution to the discomfort that students experience due to the absence of a UMCG pass.

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

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

Explanation:
The student assessments are valid, reliable and sufficiently independent. The requirements are transparent to the students. The quality of interim and final examinations is sufficiently safeguarded and meets the statutory quality standards. The tests support the students' own learning processes.

Findings

Assessment system
The panel studied the assessment information in the self-evaluation report. During the site visit it also reviewed course and assessment materials and spoke with students and staff about the assessments. It is satisfied with the programme's assessment system. The formal regulations regarding examination registration, terms of assessment, and criteria of validity of results are clearly set out in the Teaching and Examination Regulations and the Rules and Guidelines for Boards of Examiners. The assessment forms are varied and in line with the learning outcomes and type of course elements involved. In general, course units in which knowledge is essential are assessed by written or oral examinations. Course units which train students' scientific and design professional demeanor and skills are assessed by assignments, presentations and reports. Due to the interdisciplinary nature of the master's programme, learning outcomes of most course units refer to both knowledge and academic skills. Hence, the majority of course units are assessed by a combination of assignments and written or oral examinations.

In line with the faculty's assessment policy and protocol, there is an assessment programme, which should guarantee that graduates have attained the learning outcomes. Aside from this plan at the level of the programme as a whole, there is a Course Unit Assessment Overview (CUAO) available for each course unit for the relevant lecturers and committees. The CUAO is composed by the course unit coordinator. It gives a systematic description of the links between learning outcomes, modes of instruction, and modes of assessment and marking, as well as the students' required background knowledge and the position of the course unit within the curriculum. As a rule, examinations and assignments will be drafted and checked by two lecturers (peer review) to ensure that the exam questions are clear and unambiguous and sufficiently assess whether the various learning outcomes have been attained.

The panel is positive about these measures. They encompass strict rules and guidelines that contribute to safeguarding the reliability, validity and clarity of the testing. On the basis of the interviews with staff and students, however, the panel found a lot of variation in practice. This means assessment depends greatly on the individual lecturer, which forms are used and how the grading will take place. It also turned out that not all lecturers apply the peer-review principle properly when designing the examinations and assignments. According to the panel, there should be more consistency on this matter. It advises carefully monitoring and steering the coherence of the assessment system from a joint vision on testing.

Students conclude their studies with the master's project. This culminates in a report and an oral presentation to an audience with relevant expertise, followed by a discussion. The grading of the

master's theses is always based on the assessment of two supervisors: one of the eight mentors of the master's programme and the daily project supervisor, who can be a local supervisor or an external specialist. The CEMACUBE theses conducted at other universities are assessed locally by assessors from the partner universities (see below). The mentors act as the first thesis assessor to safeguard the quality and to make sure that the projects meet academic standards. They also act as a back-up daily supervisor if the relation with the local supervisor is problematic. In particular, for all projects performed outside the university, the role of the mentor is even more important. There are usually weekly contacts between the mentor and the student. The panel appreciates this mentoring system. The mentors have an important part to play in safeguarding the quality of the master's thesis. They assess several master's theses each year, which enables them to compare the quality of different theses. The panel also observed a weakness, however. As a supervisor in a small-scale programme, the mentor usually builds up a relationship with the student. Therefore, both the first (mentor) and second assessor (the daily supervisor) are involved with the students on a personal level. The panel stresses that this weakens the procedure from a quality assurance point of view, as both assessors consult the student during the process. It also remarked that the mentors are not united in some kind of a formal body. They sometimes consult each other, but this happens occasionally and only on an informal basis. Although the panel did not find any indication that the reliability of the thesis assessment is currently under pressure, it is of the opinion that the thesis quality assurance could be further strengthened. It advises the programme to reflect on this, and to consider additional measures such as stimulating formal calibration sessions among the mentors, and/or separating the mentoring and thesis assessor role for external thesis projects.

The panel approved the master's project assessment form. It includes three separate categories for practical work, written report and oral presentation. In order to pass, all three categories must be assessed with a minimum of 5.5. The panel noted that the correspondence between the scores for criteria (indicated with crosses) and the final grade is not very clear and deserves attention. In addition, the completed assessment forms contained little to no written clarification, affecting the transparency of the assessments. As explained by the staff, a rubric will be developed to further elaborate the assessment criteria. The panel supports this plan. The rubric could be an important instrument in enlarging the assessment transparency and reliability. It could also be a useful tool for further calibration of the assessments.

Board of Examiners

The self-evaluation report states that the Board of Examiners is responsible for the quality of examinations and degree certificates. The Board, which is a dedicated board for this master's programme, is appointed by the Faculty Board. Detailed descriptions of the Board of Examiners' specific duties and all legally assigned duties and powers are determined in the protocol for Boards of Examiners and the rules and regulations. The Board, for example, is responsible for the quality control of testing and examinations. It also appoints examiners, handles individual cases of fraud and individual requests from students, awards degree certificates and the accompanying diploma supplements, grants exemptions, and handles appeals and/or complaints about exams. The Board draws up an annual report of activities and gives advice to the Faculty Board on the Teaching and Examination Regulations. The panel remarked that the programme coordinator functions as the formal secretary of the board. In its opinion, this is an undesirable situation as it could influence the independent position of the board. It advises adjusting this situation in the short term.

During the site visit, the panel spoke with representatives of the Board of Examiners about the quality control of testing and examinations. It ascertained that the Board used to focus on the administrative course elements, e.g. checking whether the CUAO's learning outcomes were well described and consistent with the mode of assessment. Recently, they decided to shift their attention more towards the contents of the assessment, particularly the written exam, and the quality of courses. Although the Board members are not experts on all of the course subjects, their experiences so far have enabled them to reach consensus on the quality of the course unit assessments. To assure the quality of the master's project, the Board inspects in detail a number of theses selected randomly from the three different tracks each year. The panel appreciates these initiatives and concludes that the Board

is on the right track. It particularly valued the increased focus on the content of the assessments. However, it feels that the Board can be even more proactive. Points of improvement in the assessment system are currently being identified, but a more active and decisive role is needed from this Board to ensure that its observations and recommendations are followed up.

With regard to the quality control of the CEMACUBE programme, the panel noted that neither the Board of Examiners nor the programme management is involved in the quality assurance of the external study components. In that respect, the Board relies on the local systems of quality assurance at the partner-universities. As emphasized by the Board, the partner-universities have consistently delivered good education, and up to now, there have never been incidents. The panel is also confident about the quality of these institutes. Nevertheless, because CEMACUBE students obtain a degree from the University of Groningen based on their education at the external partners, the panel advises the Board of Examiners and the programme management to elaborate ways to guarantee the quality of the external part of the programme better, for instance by requesting the results of the quality assurance processes at the external partners, and discussing them where necessary. With regard to the master's project, the panel strongly advises including a second examiner from within the University of Groningen on all master's projects conducted by their students at partner universities, and include these theses in the annual review by the Board of Examiners.

Considerations
The panel is satisfied with the assessment and evaluation system of the master's programme BME. The formal regulations are clearly set out in the Teaching and Examination Regulations and the Rules and Guidelines for Boards of Examiners. It appreciates the various measures that were implemented to promote the reliability, validity and clarity of assessment, such as the overall assessment programme, the CUAOs and the peer-review principle. However, it also established that in daily practice there is a lot of variation, depending on the individual preferences and experiences of lecturers. In its opinion, more consistency should be sought. It advises monitoring and controlling the coherence of the assessment system from a joint vision on testing.

The panel approved the types of assessment used. They are sufficiently varied and suit the content and design of the programme. The thesis evaluation procedure is adequate. There are always two supervisors involved, one of the eight mentors and the daily project supervisor, with the mentors playing an important role in safeguarding the quality of the master's thesis. However, the panel noted some weaknesses in this system with regard to the independence of the assessments, such as the close involvement of mentors in supervising students during their theses. It advises elaborating measures to strengthen the quality assurance of the thesis assessments further, for example by promoting calibration sessions among the mentors. With respect to the CEMACUBE students, the panel strongly advises including a second examiner from within the University of Groningen on all master's projects abroad. It is satisfied with the master's project assessment form. However, it also concluded that the completed assessment forms could become more transparent, particularly with regard to the scores for criteria in relation to the final mark and the written clarification. It is positive about the plan to develop a rubric for the thesis evaluation, as this can have a positive effect on increasing the transparency and reliability of the assessment.

The panel is satisfied with the functioning of the Board of Examiners. It appreciates the various measures that have already been taken to safeguard the quality of the assessment system. However, it also ascertained that there is still work to be done, for example with respect to the quality assurance of external parts of the programme. It encourages the Board to play a more proactive and decisive role. Furthermore, it recommends a change in the position of the programme coordinator as formal secretary to the Board because this could interfere with the independence of this body.

Conclusion
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.

Explanation:
The achievement of the intended learning outcomes is demonstrated by the results of tests, the final projects, and the performance of graduates in actual practice or in post-graduate programmes.

Findings
Prior to the site visit, the panel studied a selection of 15 master's theses and the accompanying assessment forms completed by the supervisors. This selection included a wide spread of the marks. The panel was satisfied with the quality of the theses and ascertained that the students successfully achieved the intended learning outcomes covered by the master's theses. In general, it remarked that many theses have an applied character, sometimes at the expense of academic depth. In particular, the attention paid to analysis and interpretation of research data in the theses concerned is relatively limited and could be strengthened. The panel observed that the theses differ considerably in terms of content and structure. These differences are most apparent between theses in the field of design. The design theses follow a template that deviates structurally from the other theses following a more traditional scientific research format. This reflected the dichotomy between design and research within the master's thesis, whereas according to the panel, a more integrated approach is desired.

As mentioned in the self-evaluation report, a LinkedIn profile overview of alumni was used to determine where BME graduates are currently employed. The results showed that in general, the students find employment soon after graduation. They either embark on a PhD or choose a professional career in the industry or in hospitals. During the site visit, the panel spoke with a selection of alumni and representatives from the professional field. It learned that all alumni were enthusiastic about the programme. They felt well prepared for their future careers. The field representatives mentioned they were very satisfied with the quality of the graduates: they work independently, are well trained, have good communication skills, and are used to working in multidisciplinary teams.

Considerations
The panel studied a selection of theses and found that their overall quality could be considered satisfactory. It advised paying attention to strengthening the academic depth of the theses as well as the further integration of research and design. The interviewed alumni were positive about their programme, and the panel established that they are quite successful in their careers. The field representatives confirmed this positive impression. They are generally very satisfied with the performance of the graduates.

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

GENERAL CONCLUSION

The panel assesses Standard 1, 2, 3 and 4 as 'satisfactory'.

According to the decision rules of NVAO's Framework for limited programme assessments, the panel assesses the master's programme Biomedical Engineering as 'satisfactory'.

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

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

A. Domain specific requirements for level and orientation of graduates

Biomedical Engineering (BME) is an engineering discipline focused at the interface of engineering and life sciences. BME education should include basic general engineering requirements (as for example indicated by ABET) and a thorough understanding of life sciences.

BME programs must demonstrate that their students attain, according to the shared Dublin descriptors:

Knowledge and understanding:

- Knowledge of the basic disciplines mathematics, sciences, and engineering (mechanical, electrical, and chemical engineering and applied physics) to be applied in the field of Biomedical Engineering in a broader sense; i.e. including directly adjacent fields.
- Knowledge and understanding of concepts of physiology, (cell-) biology, anatomy, biochemistry, pharmacology and pathology as applicable in the field of Biomedical Engineering.

Applying knowledge and understanding:

- The capability to apply and integrate advanced mathematics, sciences, and engineering to model and solve complex biomedical problems (see also d).

Making judgments:

- An ability to conduct scientific research in areas of biomedical engineering and technology that are relevant to the advancement of knowledge and insight into fundamental and applied aspects of health and disease.
- An ability to make measurements on and interpret data from living systems, addressing problems associated with the interaction between living and non-living materials and systems.
- An ability to translate a clinical or health-relevant problem or question into an experiment, system, component, or process (design) to meet desired needs and, governed by scientific research or modeling, to advise in issues like clinical research in biomedical engineering, diagnosis and therapy.

Communication:

a. A capability to bridge the gap between fundamental and applied research in biomedical engineering and medical (life) sciences by:
  - Demonstrating an ability to communicate effectively in written and verbal form, and
  - Collaboration in a multidisciplinary setting, which may include clinicians, other healthcare workers and industrialists alike.

b. An awareness of potential societal and ethical implications of scientific research in Biomedical Engineering and, in this context, an ability to critically evaluate the effects of his/her research.

Learning skills:

- An ability to develop new concepts within the field of BME.
- An ability to study international scientific research.
- Recognition of the need for, and an ability to engage in life-long learning.

B. Domain specific requirements of the BSc (Cycle 1) and MSc (Cycle 2) programs

The Bachelor's program focuses on general knowledge, based on advanced textbooks and including some aspects informed by knowledge of the forefront of their BME specialization, basic skills and solving recognizable problems.

The Master's program focuses on deepening theoretical knowledge in one or more specific parts of Biomedical Engineering and provides ample experience in setting up, executing and reporting research and design. It leads to an attitude of scientific involvement.

BSc students acquire
Knowledge and understanding in:

- Basic beta disciplines: mathematics, sciences, and engineering (mechanical, electrical, and chemical engineering and applied physics) to be applied in the field of Biomedical Engineering in a broader sense; i.e. including directly adjacent fields.
- Life sciences: physiology, (cell-) biology, anatomy, biochemistry, pharmacology and pathology as applicable in the field of Biomedical Engineering.

BSc students learn to
Apply knowledge and understanding:

- Of mathematics, sciences and engineering to model and solve simple biomedical problems.

Make judgments:

- Involving the making of measurements on and the interpretation of simple data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems at a basic level.
- Involving the ability to translate simple clinical or health-relevant problems or questions into an experiment, system, component, or process to meet desired needs and, governed by scientific research or modeling, to advise in issues like clinical research in biomedical engineering, diagnosis and therapy.

h. By demonstrating an awareness of potential societal and ethical implications of scientific research in Biomedical Engineering and, in this context, an ability to critically evaluate the effects of his/her research.

Communicate:

e. By bridging the gap between fundamental and applied research in biomedical engineering and medical (life) sciences by:

- Demonstrating an ability to communicate effectively in Dutch in written and verbal form, and
- Collaboration in a multidisciplinary setting.

BSc students acquire
Learning skills:

f. As demonstrated in their recognition of the need for, and an ability to engage in lifelong learning at the BSc+ level with a high level of autonomy.

MSc students acquire
Knowledge and understanding:

a. Of in depth biomedical engineering, in a coherent set of specialties, that builds on the basic knowledge acquired in the Bachelor's phase, and that provides a basis or opportunity for originality in developing or applying ideas in this specialization.

MSc students learn to
Apply knowledge and understanding:

a. In order to apply and integrate advanced mathematics, sciences and engineering knowledge as well as specialized knowledge to model and solve complex biomedical problems in new and unfamiliar environments.

Making judgments:

b. In an ability to conduct scientific research in areas of biomedical engineering and technology that are relevant to the advancement of knowledge and insight into fundamental and applied aspects of health and disease.

- An ability to make measurements on and interpret complex data from living systems, addressing the complex problems associated with the interaction between living and non-living materials and systems, and the ability to successfully recognize and address new problems in this field.
- An ability to translate a complex, not well-defined, clinical or health-relevant problem or question into an experiment, system, component, or process to meet desired needs and, governed by scientific research or modelling, to advise in issues like clinical research in biomedical engineering, diagnosis and therapy.

Communicate:

c. With a capability to bridge the gap between complex fundamental and applied research in biomedical engineering and medical (life) sciences by

- Demonstrating the ability to communicate effectively in written and verbal form in Dutch and English, by underpinning knowledge and rationale (restricted scope) to specialist and non-specialist audiences alike, and
- Collaboration in a multidisciplinary setting, which may include clinicians, other healthcare workers and industrialists alike.

d. An awareness of potential societal and ethical implications of scientific research in Biomedical Engineering and, in this context, an ability to critically evaluate the effects of the research carried out under his/her responsibility.

Learning skills

e. An ability to study international scientific research.

f. Recognition of the need for, and an ability to engage in life-long learning at MSc+ level in a manner that may be largely self-directed or autonomous.

C. Description of derivation process of sections A and B

The formulation of the Domain specific requirements have taking into account our mutual aims, requirements, and experiences from other sources. In the past, representatives of the programs participate in international discussions on BME education and accreditation (Europe: the BIOMEDEA project [project leaders: [redacted], [redacted], [redacted], and [redacted]] under the auspices of EAMBES, the European Alliance of Biomedical Engineering and Science; USA: Whitaker BEES I (2000) and BEES II (2005) summit on BME education and accreditation in Lansdowne, Virginia.

The derivation process included the following steps:

- Comparison with standards derived by the academic BME community
  - Netherlands: compilation of the aims of the BME programs, which were based on international surveys (see below). In-line with basic requirements of engineering programs such as Mechanical Engineering, Applied Physics, etc.
  - Europe
    - European BME programs did not serve as reference, since no fully integrated Bachelor/Master's programs were available at the time.
    - EAMBES
      - IFMBE White paper on harmonization and accreditation of European BME programs,
      - BIOMEDEA conferences, papers and discussions
  - USA
    - The IFMBE-White paper
    - Whitaker Foundation:
      - Information on website
      - First and second BEES summit
    - and personal contacts from:
      - Duke University, Durham
      - Marquette University, Milwaukee
      - Northwestern, Evanston
      - University of Illinois, Chicago
      - Case Western Reserve University, Cleveland
      - Rensselaer Polytechnic institute, Troy
      - Massachusetts Institute of Technology, Boston
      - University of Pennsylvania, Philadelphia
      - Drexel University, Philadelphia
      - Johns Hopkins University, Baltimore
      - University of Utah, Salt Lake City

- Comparison with standards of independent bodies

- NL: BME degree program standards were not available. KIVI, the Dutch engineering alumni association has set up a BME branch, but standards for BME still have to be prepared.

- Europe
  - EAMBES-BIOMEDEA: The process of harmonization of accreditation is ongoing. We are actively participating.
  - EURACE: the European Accreditation of Engineers is active in preparing evaluation standards of engineering programs in Europe. The process is rather similar to that of QANU. However, they formulated no BME standards.
- USA
  - ABET: Accreditation Board of Engineering and Technology. ABET has general engineering standards and specific standards for BME.

- Field of employment
  - NL: no representation yet. Each program has its own External Advisory Board or is setting it up. We used their input. The BME-branch of the Royal Institute of Engineers (KIVI/NIRIA) is active in the field of employment.

It is interesting to note that the BME student societies SvBMT Protagoras (TU/e), Idun (RUG) and Paradoks (UT) are actively seeking contacts with the field of employment.

- Europe: ESEM.
- USA: BMES, lead society for BME in ABET. BMES formulates the specific BMES standards for ABET.

APPENDIX 2: INTENDED LEARNING OUTCOMES

Learning Outcomes

The Biomedical Engineer aims to solve health care problems, increase citizens' quality of life, create affordable health care, both in terms of costs and manpower, and increase patient safety. The Biomedical Engineer achieves these aims by:

- preparing and performing Research & Development (R&D);
- disseminating the results of the R&D process;
- using a systematic approach to R&D (as shown in Figure 1).

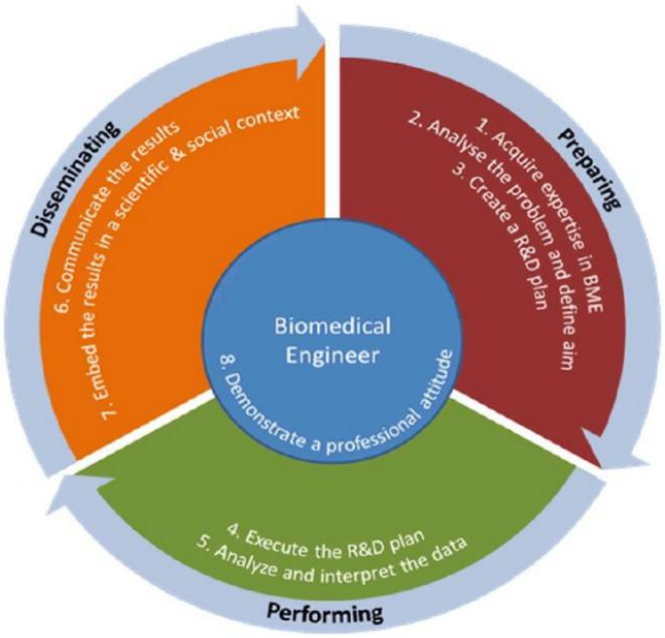

Figure 1. *The R&D cycle in Biomedical Engineering with learning outcomes*

As concerns the learning outcomes, a graduate with a Master of Science in BME can:

1. Acquire expertise in Biomedical Engineering

A Biomedical Engineer is able to continuously improve his/her expertise (knowledge and competences) by building on his/her thorough mastery of a specific field of biomedical engineering. This is demonstrated, not only by the Biomedical Engineer's ability to develop and apply new knowledge based on a self-evaluation report on standard knowledge, but more so by increasing or adapting his/her competences by critically and independently reflecting on his/her own thinking, decision making, and acting.

2. Analyse the problem and define aim

A Biomedical Engineer is able to analyse biomedical problems by (re)formulating ill-structured biomedical problems of a complex nature by choosing the appropriate level of abstraction and by critically examining existing theories, models or interpretations based on the assessment of the scientific value of current research within Biomedical Engineering. The Biomedical Engineer thereby creates a cause-effect model, distinguishes the problems that are fundamental and solvable and defines the aim which has the highest priority.

3. Create an R&D proposal

A Biomedical Engineer is able to design different strategies to obtain the defined aim, and has the skills in, and the affinity with, the use, development and validation of models to allow the Biomedical Engineer to consciously choose the most efficient and effective R&D plan.

4. Execute the R&D plan
A Biomedical Engineer is able to execute an R&D plan and to adapt it when external circumstances or advancing insight requires it. Depending on the project, the focus may be more on the scientific approach to increase knowledge and understanding (research) or on the design of new techniques or systems (development) although both aspects are essential in the R&D cycle of innovative products. Standard 1: Intended learning outcomes

5. Analyse and interpret the data
A Biomedical Engineer is able to formulate adequate questions, and has a critical, yet constructive attitude towards analysing and solving complex real-life biomedical problems. The Biomedical Engineer is able to form a well-reasoned opinion in the case of incomplete or irrelevant data; is able to analyse and interpret the results of R&D in terms of statistics, limitations and the relation to existing literature aiming to contribute to the advancement of knowledge in Biomedical Engineering and beyond the field's bounds.

6. Communicate results
A Biomedical Engineer, as an interdisciplinary specialist, is able to communicate orally and in writing about R&D with colleagues, non-colleagues and other involved parties including health care providers and patients. In addition, the Biomedical Engineer is able to debate about both Biomedical Engineering and the place of Biomedical Engineering in society.

7. Embed the results in scientific and social context
A Biomedical Engineer is able to analyse and to discuss the consequences (economic, social, cultural) of new developments in Biomedical Engineering with colleagues and non-colleagues; has insight into (debates about) scientific practice and is able to analyse and to discuss the ethical and the normative aspects of the consequences and assumptions of the scientific practice with colleagues and non-colleagues. The Biomedical Engineer is able to integrate these ethical and normative aspects in its own work.

8. Demonstrate a professional attitude
A Biomedical Engineer is able to incorporate the knowledge, skills and competences described above and demonstrates a professional attitude by showing a high level of independence, responsibility and commitment. In addition the Biomedical Engineer shows social skills as well as the ability to improve after feedback.

Students are also trained in one particular field of BME to prepare them for careers as specialists. In Groningen, students can choose between three tracks: 1) Diagnostics, Imaging and Instrumentation (DII), 2) Biomaterials Science and Engineering (BSE) and 3) Medical Device Design (MDD). These tracks share a common set of learning outcomes, but differ in the specific area within the domain of Biomedical Engineering that they emphasize.

Table E1 – schematic curriculum overview – Regular Programme starting 2018-2019

Year	Period	Diagnostic Imaging and Instrumentation	Biomaterials Science and Engineering	Medical Device Design
1	1A	Radiation physics	Interface Biology	Control Engineering
		Conventional Imaging Techniques and Ultrasound	Biomaterials 2	
		Introduction to Matlab programming for BME		
	1B	Image Processing	Biofilms	Prosthetics & Orthotics
		Computed Tomography	Engineering & Biotribology	
		Radiation Therapy	Surface Characterisation	Mechatronics
	2A	Statistical Methods in BME		
		Biomedical Instrumentation 2		
		Interdisciplinary project		
	2B	Internship		
2	1A	Physics in Nuclear Medicine	Recent Developments in Biomaterials	Product Design by FEM
		MRI	Integration Labcourse in Biomaterials	Interface Biology
		Microscopy and Imaging		Robotics
	1B	Applied Medical Visualisation	Colloid and and Interface Science	MEMS/NEMS and Nanofabrication
		Technology and Ethics		
		Preparation MSc Project		
	2A	Master Project		
	2B			

Engineering
Physics/Mathematics
Research
Medical/Biological

APPENDIX 4: PROGRAMME OF THE SITE VISIT

Sunday 4 November 2018

18.00 – 19.30	Discussing initial findings

Monday 5 November 2018

09.00 - 09.15	Arrival
09.15 - 09.45	Panel preparation
09.45 - 10.45	Interview management bachelor & master (incl. short presentation)
10.45 - 11.00	Break
11.00 - 11.45	Interview students bachelor
11.45 – 12.00	Break
12.00 - 12.45	Interview staff bachelor
12.45 - 13.30	Lunch break
13.30 - 14.15	Interview Board of Examiners bachelor & master (incl. chair current bachelor's BoE)
14.15 – 14.30	Break
14.15 - 15.00	Interview Programme Committees (incl. chair current bachelor's PC)
15.00 – 15.15	Break
15.15 – 16.00	Interview management bachelor
16.00 - 17.15	Concluding session bachelor's programme
17.15 - 17.45	Interview professional field and alumni master
17.45 – 18.00	Finalizing conclusion bachelor's programme

Tuesday 6 November 2018

09.00 - 09.45	Arrival, preparation panel
09.45 - 10.30	Interview students master
10.30 – 10.45	Break
10.45 - 11.30	Interview staff master
11.30 - 11.45	Break
11.45 - 12.15	Student demonstrations
12.15 - 13.30	Lunch / internal session
13.30 - 14.15	Interview management master programme
14.15 - 15.15	Concluding session master's programme
15.15 - 15.30	Oral presentation panel's findings (open)
15.30 - 15.45	Break
15.45 - 16.30	Development dialogue
16.30 - 16.45	Wrap up

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied fifteen 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):

Folders on the following BME Master courses:
- Biofilms
- Biomaterial 2
- Colloid and Interface Science
- Integrated Lab Course Biomaterials
- MRI
- Neuromechanics
- Physics in Nuclear Medicine
- Product Design by the Finite Element Method
- Prosthetics & Orthotics
- Statistical Methods for BME

Additional materials:
- Education monitor
    - o MSc Biomedical Engineering 2016
    - o Faculty of Science and Engineering (FSE) 2018
    - o Faculty of Science and Engineering (FSE) 2017
- Education Primer
- Teaching and Examination Regulations (Faculty wide part):
    - o Bachelor's degree programmes FSE 2018-2019
    - o Master's degree programmes FSE 2017-2018
    - o Master's degree programmes FSE 2018-2019
- Appendices Teaching and Examination Regulations (programme specific parts):
    - o Master's degree programme Biomedical Engineering 2017-2018
    - o Master's degree programme Biomedical Engineering 2018-2019
    - o Proposed new Bachelor's degree programme Biomedical Engineering
- Assessment plan MSc Biomedical Engineering 2017-2018
- Programme Committee Handbook UG 2017-2018
- Quality Assurance documents for Boards of Examiners FSE
    - o Protocol for the duties and powers
    - o Quality Assurance Guide
    - o Rules and Regulations Board of Examiners
- Quality Assurance Manual for Teaching Staff
- Quality Assurance Manual FSE 2016-2017
- Annual Reports Board of Examiners MSc Biomedical Engineering
- Annual Reports Programme Committee MSc Biomedical Engineering
- Annual Reports Admissions Board MSc Biomedical Engineering
- FSE Manual for quality assurance of education
- Minutes of the Curriculum Committee 2017
- Scores National Student Survey (2017)
- Letters External Advisory Panel
- Guidelines Industrial Internship MSc Biomedical Engineering
- Guidelines Master's Project MSc Biomedical Engineering
- Scores Master Keuzegids 2018