MASTER’S PROGRAMME NANOSCIENCE

FACULTY OF SCIENCE AND ENGINEERING

UNIVERSITY OF GRONINGEN

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This report was finalized on 24 september 2018.

REPORT ON THE MASTER'S PROGRAMME NANOSCIENCE OF THE UNIVERSITY OF GRONINGEN

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 Nanoscience

Name of the programme:	Nanoscience
CROHO number:	60618
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	-
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 to the Faculty of Science and Engineering of the University of Groningen took place on 4 – 5 June 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 has approved the composition of the panel on 26 March 2018. The panel that assessed the master's programme Nanoscience consisted of:

- Prof. J. (Johan) Hofkens, professor at the unit Molecular Imaging and Photonics at the KU Leuven (Belgium) [chair];
- Prof. N. (Nadine) Witkowski, professor of Physics at the Institut des Nanosciences de Paris of Sorbonne Université (France);
- Prof. dr. ir. M.C.M. (Richard) van de Sanden, director of the Dutch Institute for Fundamental Energy Research (DIFFER) and professor of Applied Physics at Eindhoven University of Technology;
- Dr. J.T. (Jan) van der Veen, associate professor and chair of the 4TU Centre for Engineering Education of University of Twente;
- Y. (Yasser) Pordeli Bsc, master's student of Nanotechnology at the University of Twente.

The panel was supported by Peter Hildering MSc, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

Preparation
The assessment of the master's programmes Nanoscience is a stand-alone assessment with a single panel consisting of the members mentioned above. Peter Hildering MSc of QANU was project coordinator and secretary for this assessment.

Before the assessment panel's site visit to the University of Groningen, the secretary received the self-evaluation report that the programme wrote based on the NVAO framework for limited programme assessments. He sent it to the panel after checking it for completeness of information. Upon reading the self-evaluation report, the panel members formulated their preliminary findings. The panel also studied a selection of sixteen theses and the accompanying assessment forms: four theses for each panel member, excluding the student member. This selection was made by the panel's chair, in cooperation with the secretary, from a list of graduates from the past three years. The chair and secretary took care that all specializations within the programmes were covered, and made sure that the distribution of grades in the theses selection matched the distribution of grades over all theses.

The panel chair, secretary and programme jointly composed a schedule for the site visit. Prior to the site visit, the programme selected representative partners for the various interviews. Interviews were planned with students, teaching staff, management, alumni, the programme committee and the board of examiners. See Appendix 3 for the definitive schedule.

Site visit
The site visit to the University of Groningen took place on 4 and 5 June 2018. At the start of the visit, the panel held a preparatory meeting during which it was instructed regarding the assessment framework and procedures. After this, the panel discussed its working method and its preliminary findings for the site visit.

During the site visit, the panel conducted interviews with representatives of the programme, and examined materials provided by the programme. An overview of these materials is given in Appendix 4. The panel used the final part of the visit to discuss its findings in an internal meeting. Afterwards the panel chair gave an oral presentation, in which he expressed the panel's preliminary impressions and general observations. The visit was concluded with a development conversation, in which the panel and the programmes discussed various developments routes for the programmes. The result of this conversation is summarized in a separate report.

Report
After the site visit, the secretary wrote a draft report based on the assessment panel's findings. Subsequently, he sent it to the assessment panel for feedback. After processing the panel members' feedback, the secretary sent the draft report to the university in order to have it checked for factual irregularities. The secretary discussed the ensuing comments with the panel's chair and adapted the report accordingly before its finalisation.

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

Mission and goals
The master's programme Nanoscience is a very ambitious and challenging programme that aims to prepare excellent students for a PhD in nanoscience. It uses a strict selection procedure and an intensive, small-scale, master-apprentice educational approach to get the students to a high level. It is an internationally unique programme in terms of aims, focus and didactic approach. The panel is impressed by the multidisciplinarity of the programme, which trains its students to reach a master's level in physics as well as chemistry in order to become highly skilled in the multidisciplinary field of nanoscience. By focusing on the core fields of nanoscience and using related fields such as computer science and medicine as examples, the programme offers a solid foundation, while retaining the connection to rapid developments in the field.

The intended learning outcomes of the programmes are well formulated and clear in their level and orientation, and form a strong basis. The programme could consider adding an element of simulation and computational skills. Overall, the panel was very impressed by the programme's design and focus, and considers it an internationally unique master's programme.

Teaching
The panel finds that the curriculum, which consists of a short period of guided self-study, followed by theoretical core modules and research projects, is coherent and of high quality. The course goals are clearly related to the intended learning outcomes, leading to a curriculum that thoroughly educates the students on the topics of the intended learning outcomes. The split between the theoretical part (first semester) and practical part (second to fourth semesters) guarantees that all students are well equipped theoretically before starting their research projects, regardless of their undergraduate degree. The programme is challenging yet feasible, which is reflected in the high success rates.

The didactic philosophy of small-scale, intensive teaching by highly qualified staff is very well suited to the programme. The programme maintains a careful balance between group interaction and independent work. The intensive, personal guidance by top researchers gives students a unique opportunity to prepare on a high level for a PhD trajectory in Nanoscience, far beyond that of a regular master's programme. The position of the programme within the university gives it unique opportunities to select the best students and have them work closely together with the best researchers, leading to an atmosphere of excellence rarely found elsewhere in a master’s programme.

Assessment
The programme has a very solid system of assessment in place. The Assessment Plan links the intended learning outcomes to a variety of assessment types. The Board of Examiners is closely involved in the assessment policy of the programme and has put very good procedures and regulations in place in recent years. This includes a very good and insightful assessment form for the individual projects, procedures for implementing a peer review for exams, and an annual quality check on a selected number of projects. The panel encourages the Board to keep up their good work, while remaining aware of the pitfalls of a close student-supervisor relation that is common to this type of small-scale programme. The planned implementation of grading rubrics to align grading between supervisors might be useful to this end. Finally, the panel suggests exploring alternatives to reducing the number of EC for electives offered by other programmes.

Exit level of graduates
The students of the master's programmes convincingly show that they systematically far exceed the expected level for graduates of a master's programme. The theses are of an exceptional quality, revealing in particular excellent research skills and multidisciplinarity. They are often almost of PhD quality, as is reflected in the high number of publishable theses. Almost all of the programme's alumni successfully continue as PhD students and are very well prepared for that position.

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

Master's programme Nanoscience

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

The chair (Prof. Johan Hofkens) and the secretary of the panel (Peter Hildering MSc) declare that all panel members have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 24 September 2018

DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED FRAMEWORK 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

Mission and goals
The master's programme Nanoscience is an internationally oriented, two-year programme aimed at preparing excellent students for a PhD in nanoscience. It was developed by the Zernike Institute for Advanced Materials (ZIAM), in close cooperation with the chemically oriented Stratingh Institute and the Groningen Biomolecular Sciences and Biotechnology Institute (GBB). The programme was set up to guarantee a steady influx of highly qualified PhD candidates to these three research institutes, and aims to give students a high-level and uniquely dedicated master's training.

Nanoscience is a multidisciplinary field, combining insights primarily from physics and chemistry, and to a lesser extent biology. To be prepared for a successful research career in nanoscience, students need to become experts in each of these fields. Therefore, the programme aims for its students to reach full master's level in physics as well as chemistry, regardless of their undergraduate programme. This results in a highly challenging curriculum which is specifically aimed towards very talented and highly motivated students. The programme uses a strict and selective selection procedure to make sure that students are properly equipped to undertake this challenge. Each year, 15 students are admitted to the programme. The didactic philosophy of the programme is reminiscent of a master-apprentice approach: students have frequent personal interaction with experienced researchers in the field, who help and guide them to become masters in nanoscience.

The panel is very positive about the mission and goals of the programme. High-level PhD candidates in nanoscience are in great demand, in the University of Groningen and in other leading research institutes worldwide. Also, the nanotechnology industry is expected to become a major driver of innovation and technological development in the coming decennia. This underlines the importance of educating skilled researchers in nanoscience. The panel praises the high ambitions of the programme to be truly multidisciplinary, requiring its students to reach full proficiency in both physics and chemistry in order to master the topics relevant to nanoscience in these fields. The strict selection procedure combined with the small-scale, intensive didactic approach gives the programme the tools to achieve this very ambitious goal.

According to the panel, the master's programme Nanoscience has no equal in terms of focused effort and educational approach. The programme is among the most ambitious and intensive master's programmes offered worldwide. The programme is also unique in focusing on fundamental research: most programmes within the field at least partly aim for careers in the nanotechnology industry. The overview of related programmes the programme included in its self-evaluation report supports this conclusion.

The majority of students end up in industry after their PhD, and even if they stay in academia, research projects with industry are commonplace in nanoscience. The panel reckons that, without compromising the focus on educating PhD candidates, these aspects could be given a place in the programme. As the panel understood during the site visit, the researchers teaching in the programme have many industry connections themselves and use them in their teaching activities, such as research projects based on real-life problems in the industry. The panel is positive about these initiatives and encourages further exploration of these possibilities.

The field of nanoscience is increasingly reaching out to other disciplines, such as medicine (nanomedicine) and computer science/artificial intelligence (brain-inspired networks). As the programme requires its students to be able to adapt to rapid changes in the field (learning outcome 13), such examples are often used within the courses. During the site visit, the panel discussed with the programme whether content from disciplines such as medicine or computer science should get a permanent place within the programme. The programme indicated that it sees nanoscience as primarily drawing on physics and chemistry (and to a lesser extent biology) with a material science focus, and does not wish to adopt a broader definition to include its many applications. The panel praises the efforts to include new developments in the field within the programme, and fully supports the programme's take on nanoscience. It recommends staying true to this view, and not getting too distracted by new branches in the field of nanoscience until they become firmly established, however tempting this might seem at times.

Intended learning outcomes
The programme's goals are summarized in thirteen intended learning outcomes (ILOs), which are listed in Appendix 1. The panel studied them in terms of level, orientation and content. It concludes that the ILOs are clearly tied to the Dublin descriptors, as demonstrated in an overview presented to the panel in which the two are linked through the course goals. As a result, the master's level and academic orientation are clearly visible in the ILOs. The programme even surpasses the requirements of a master's programme, for instance by requiring students to be able to formulate a research plan (ILO 12) and solve realistic scientific problems on the 'basis of a rudimentary problem specification', (ILO 5), which suits the lofty ambitions of the programme and the aim of preparing students for a PhD programme.

In general, the panel considers the ILOs fitting to the programme and very well formulated. Their formulation is compact and specific regarding the skills the students are expected to achieve. As such, it provides a strong basis for the programme. The panel suggests making an explicit mention of simulation and computational skills, which does play a role within the programme. This aspect could for instance be mentioned under either ILO 4 or 8.

Considerations
The master's programme Nanoscience is a very ambitious and challenging programme that aims to prepare excellent students for a PhD in nanoscience. It uses a strict selection procedure and an intensive, small-scale, master-apprentice educational approach to get the students to a high level. It is an internationally unique programme in terms of aims, focus and didactic approach. The panel is impressed by the multidisciplinarity of the programme, which trains its students to reach a master's level in physics as well as chemistry in order to become highly skilled in the multidisciplinary field of nanoscience. By focusing on the core fields of nanoscience and using related fields such as computer science and medicine as examples, the programme offers a solid foundation, while retaining the connection to rapid developments in the field. The ILOs of the programmes are well formulated and clear in their level and orientation, and form a strong basis. The programme could consider adding an element of simulation and computational skills. Overall, the panel was very impressed by the programme's design and focus, and considers it an internationally unique master's programme.

Conclusion
Master's programme Nanoscience: the panel assesses Standard 1 as 'excellent'.

Standard 2: Teaching-learning environment
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

Findings
The teaching-learning environment of the master's programme Nanoscience is designed around the didactic philosophy of small-scale, intensive teaching. Throughout the curriculum, students work in

small cohorts of 15 for the core modules, where they are trained to do research through one-on-one interaction with leading researchers from the associated research institutes. The programme considers this an excellent learning environment to achieve its goals. It has settled on a group size of 15 students per year as optimal. According to the programme, 15 students is small enough to prevent splitting into smaller groups, and large enough for diversity in interactions.

Curriculum: Guided self-study
The students start off their first year with five weeks (6 EC) of guided self-study aimed at equalizing their background knowledge. Students with a bachelor's degree in Physics acquire knowledge in organic and inorganic chemistry, and those with a bachelor's degree in Chemistry study solid-state physics and quantum physics. A mentor (who remains associated with the student throughout the programme) and a number of tutorial sessions are available for each student. Students with different backgrounds help and train each other. At the end of the self-study period, students are tested on bachelor’s level knowledge of the topics in an exam. Students describe the self-study weeks as very challenging yet fulfilling. In the end, they are all successful in their exams and feel like they are adequately equipped for the rest of the programme. In addition, the five weeks of studying together and helping each other out create a strong community feeling that lasts throughout the programme.

The panel is very positive about this start-up phase of the programme. Equalizing the background knowledge of students is a challenge for multidisciplinary master's programmes, and the programme has found a very successful way of doing so, as confirmed by both students and teachers. The panel is very impressed that students master relevant topics outside their undergraduate field in such a short amount of time with no drop-outs, even when taking into account that they are highly talented. It provides a solid starting point for the rest of the curriculum, with community formation as a nice added bonus. The panel also approves assigning a mentor to each of the students, who helps and advises them throughout the programme.

Curriculum: Core modules
After the self-study weeks, the remainder of the first semester is dedicated to three core modules: Preparation, Characterization, and Fundamental and Functional Properties of Nanomaterials and Devices, for a total of 30 EC. The core modules are split into sub-modules, which are taught by different teachers and assessed separately. These provide the students with a solid basis of the physics, chemistry and to some extent molecular biology relevant to nanoscience. A variety of teaching methods is used that fit the aims of the modules. They include so-called 'chalk and talk' lectures, in which students discuss and solve problems, project-based assignments and reading assignments. Like the guided self-study, students describe the core modules as very challenging yet feasible. Course evaluations reveal very positive feedback on both the content and didactic methods, which was confirmed by the students in the site visit interviews. They need to work hard in the first semester, but they feel that the rapid acquisition of core knowledge really pays off in the remainder of the programme. They also feel strongly guided by the teachers, fellow students and their mentor, which is reflected by the high success rates of the programme (on average 89%).

The panel is very positive about both the content and design of the core modules. It is challenging for the students, but this is deliberate as it allows students to enter the research and skills part of the programme fully equipped with all relevant scientific knowledge. Students are clearly informed about this distribution of workload at the start of the programme, and have shown that they are able of coping with this.

Curriculum: Research projects
The second semester of the first year is reserved for the Research Paper project (6 EC) and a Small Research Project (13 EC). The Research Paper project trains students in academic research skills such as literature research, academic writing and ethics. In the Small Research Project, students do an individual research project under the guidance and supervision of one of the Zernike Institute researchers. At the end of the second semester, they present their research projects to their fellow students and staff in a student-organized symposium. Starting in the second semester, students also

have the opportunity to take electives (14 EC), which runs until the end of the programme. These consist of master's courses in (Applied) Physics, Chemistry or related programmes and are chosen in close consultation with the student's mentor, based on the student's research project interests and requirements.

The second year (third and fourth semesters) is largely dedicated to the Master Thesis Project (45 EC), in which students do research and write their thesis based on the knowledge and skills they acquired in the first year. They do this in one of the Zernike Institute's research groups, and are considered part of this group for that year. In parallel with this project and further electives, they are taught to write a PhD Research Proposal (6 EC). Several of these proposals have actually been submitted and led to funding. The Zernike Institute itself funds one proposal a year on average.

The panel spoke to students and teachers of the programme, and had the opportunity to visit some of the research facilities of the Zernike Institute which are available to the students. It was impressed by the opportunities provided to students of the programme. They are taught how to conduct research in close cooperation with top researchers, and are thoroughly prepared to become academic PhD candidates. In this, the programme goes far beyond regular master's programmes, embedding students in research groups and delivering one-on-one training in research skills, teaching them how to write a PhD proposal, and in many cases to write and submit a research paper based on the master's thesis project. Student satisfaction for these elements is very high, which is reflected in the site visit interviews, the good course evaluations and the high success rates of the programme.

For further development of the research skills part of the programme, the panel wants to point out two minor points of improvement that came up during the student and alumni interviews. First, some students remarked that they would like more opportunities to practice their presentation skills other than at the student symposium, for instance a mid-term student peer review of the master's thesis. Second, other students noted that opportunities for working in the labs could be limited due to the high demand for lab resources within the institute. The panel suggests that the programme try to find spare equipment (for instance older models) for educational purposes in order to give students time to practice with lab equipment and get hands-on experience whenever they want.

Teaching staff

The teaching within the programme is mostly done by top researchers from one of the three associated research institutes, the majority of whom are full professors heading a large (international) research network. All teaching staff members hold a University Teaching Qualification or are enrolled to obtain one. Due to the small-scale, intensive didactic approach, the programme has a very favourable staff-student ratio of 1:11. Teachers frequently embed their own research into their courses and projects, which brings students in touch with state-of-the art research in the field of nanoscience.

The teachers that the panel spoke to during the site visit share the feeling that they are part of something special. The students they work with are very talented, and they have the opportunity to really invest in their development on a personal level. This special atmosphere within the programme is felt by new teachers to the programme, who usually need some time to get used to the teaching style. This is recognized by the programme, which guides new staff to get acquainted with the set-up.

The panel looks very favourably on the teaching staff within the programme. Most of the teachers are high-ranking researchers, who get the opportunity to teach and guide the students closely on their path to becoming high-level PhD candidates. The panel recognizes the feeling of the teaching staff that they are part of something special, and sees that this makes them very committed to the programme and the students and willing to make a special effort to support the success of the programme.

Position of the programme
The master's programme Nanoscience holds a special position within the university. It aims to be an exemplary master's programme, and is given the means to achieve this. It is allowed by the university to implement a strict admissions procedure to select 15 very talented students from the 50-60 applications it receives annually. The Admissions Board, which consists of core teachers in the programme, selects students based on criteria that include top grades in the bachelor's programme (which are usually 8 or higher for students in the programme), proficiency in English, motivation and attitude. The programme aims for a balance of 10 international students and 5 Dutch students, although in recent years it has become challenging to find enough high-level international students, mainly due to international competition.

The selected students receive an allowance from the university over the course of the programme to make sure that they are fully devoted to the programme and do not need to take on part-time jobs. Additionally, the programme can make use of an optimal staff-student ratio of around 1:11, guaranteeing that the teaching staff has enough time to invest in supervising the students.

The panel feels that the programme can be proud of its possibilities and the way these are put to good use. This truly shows how a programme can excel if the necessary amount of resources, energy and dedication is put into it.

Considerations
The panel finds that the guided self-study, core modules and research projects jointly form a coherent, high-level curriculum. The course goals are clearly related to the intended learning outcomes, leading to a curriculum that thoroughly educates the students on the topics of the intended learning outcomes. The split between the theoretical part (first semester) and practical part (second to fourth semesters) guarantees that all students are well equipped theoretically before starting their research projects, regardless of their undergraduate degree. The programme is challenging yet feasible, which is reflected in the high success rates.

The didactic philosophy of small-scale, intensive teaching by highly qualified teachers is very well suited to the programme. The programme maintains a careful balance between group interaction and independent work. The intensive, personal guidance by top researchers gives students a unique opportunity to prepare on a high level for a PhD path in Nanoscience, far beyond that of a regular master's programme. The position of the programme within the university gives the programme unique opportunities to select the best students and have them work closely together with the best researchers, leading to a unique atmosphere of excellence rarely found elsewhere in a master's programme.

Conclusion
Master's programme Nanoscience: the panel assesses Standard 2 as 'excellent'.

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

Findings
The Board of Examiners for Nanoscience is responsible for the examination and assessment quality of the master's programme Nanoscience. It is a dedicated Board that can fully focus on this master's programme. Its main focus is the quality of assessment of course units and projects, monitoring the exit level of individual students through rules and regulations, and the quality assurance of the thesis assessment. It consists of teachers from within the programme and an external member from another department of the faculty.

Assessment policy
The assessment policy within the programme is based on an Assessment Plan drafted annually by the programme's deputy director. This plan maps the intended learning outcomes of the programme to all forms of assessments within the courses and projects, and lists the proposed examiners for each test. The Board of Examiners thoroughly checks this plan to determine whether all learning outcomes are properly assessed, whether the listed examiners are qualified for this role, and whether the various modes of assessment fit the intended learning outcomes of the programme.

To safeguard the quality assurance of the various types of assessment, the Board of Examiners imposes rules and regulations. Every exam is subjected to peer review, in which a second lecturer checks whether the exam questions are clear, unambiguous and properly test the course goals. The assessment procedure of the oral exam, of which there is currently one in the programme, was recently updated to include a written record and the presence of a second examiner. The Board of Examiners annually checks a number of assessments and assessment products from both the core modules and the individual projects to ensure their quality.

The panel has studied the programme's Assessment Plan and interviewed the Board of Examiners, management, lecturers and students on the topic of assessment. It concludes that the programme has a very solid assessment policy in place. The Assessment Plan ensures that all intended learning outcomes are properly assessed throughout the programme. The modes of assessment are varied and include written exams, an oral exam, practical work, reports, papers and presentations. The panel was impressed by the implementation of peer review throughout the programme: every exam is checked in the design phase by another lecturer, and each project has at least two examiners.

Individual project quality assurance
The Board of Examiners pays extra attention to the quality assurance of the individual projects in the programme, and especially the Master Thesis Project as this reflects the exit level of the students. The projects (Research Paper, Small Research Project and PhD Research Proposal) are always assessed by two or more staff members: the individual supervisor and the course coordinator. For the Master Thesis Project, each thesis is assigned a second examiner from another research unit not involved in the project. The second examiner gives an independent second opinion on the quality of the scientific presentation of the student and the thesis.

All individual projects are graded using elaborate assessment forms. These are based on a standard form of the faculty, fine-tuned using the input of the programme' management, staff and Board of Examiners. The forms describe in detail what elements should be checked in the student's work and how they contribute to the final mark. Examiners are asked to provide qualitative feedback on each part of the grade, justifying their mark on that part. The result of a standard check on fraud using anti-plagiarism software is also included, along with the number of feedback cycles between student and supervisors before the final product was submitted.

As part of the quality assurance procedures, the Board of Examiners checks a number of student products each year. They include products that just passed and ones with the highest grades, plus a number of randomly selected ones. During this procedure, the Board checks whether the grade given is appropriate and the assessment forms have been completed correctly and with insight. No major differences between the examiners and the Board have been found in the past years.

The panel studied a number of thesis assessment forms as part of the thesis quality check. It was very impressed by the quality of these forms. They show in an insightful and detailed way how the final grades are built up and the reasoning behind the scores. The extra elements of the plagiarism check and the explicit mention of the number of feedback cycles add to the validity of the assessment. As a result, it is a very good tool to monitor and check the quality of the exit level of students, especially when combined with an independent second examiner and a quality check by the Board as described. Overall, the panel is impressed by the attention paid to the quality assurance of the individual projects, not only the thesis but also the other student projects.

Board of Examiners
Based on the assessment policies and procedures described above, and the interviews during the site visit, the panel judges very positively the position of the Board of Examiners within the programme. The Board is very active and can dedicate all its energy to a single programme. It has implemented quite a few measures in recent years, including the assessment form, the procedure for oral exams, and the extra check on the quality of the individual projects, which were partly based on recommendations from the previous accreditation committee. With this, the Board has strengthened its position as a major player in the programme's quality assurance.

The level of involvement of the Board within the programme can be illustrated by a discussion the panel had with the Board of Examiners concerning the assessment of ILO 13. This ILO assumes students will be able to adapt to the rapid changes in the field of nanoscience. As this is hard to assess, the Board closely monitors the assessment of this learning outcome, which is currently assessed with a literature study, the grant proposal and the thesis, and is actively considering alternative approaches with the programme management.

Although the Board has a good control of the programme in general, the panel wants to keep stressing the risk of too close an involvement of students and teachers in a small-scale, intensive programme. One example is a grade bonus that was awarded to one student for one of the theses that the panel studied. The student received +0.5 on the thesis grade for working hard and exceeding expectations on deadlines for submission. This is not standard procedure and was awarded without informing the Board of Examiners. When asked, the Board indicated that it would probably not have agreed with this bonus. This might very well be a one-off incident, as the Board cannot be expected to catch everything going on in the programme, but it is an indication of the risk associated with a close relation (sometimes informal) between students and supervisors. The panel recommends the Board monitor this and keep up its efforts to align grading procedures between individual supervisors. In this aspect, it fully endorses the planned inclusion of rubric grading to achieve calibration in grading.

Credits for electives
Another discussion on assessment the panel had with various representatives of the programme concerned the number of credits students receive for electives. The programme reasons that, due to the selection process and intensive curriculum, its students are more talented than the average master's students. Therefore, it reduces the number of credits students receive for electives followed in other programmes by 20% (in most cases from 5 to 4 EC). If there is any overlap with the core modules (elements of them), the number of credits received can be reduced further. This is decided per elective by the Board of Examiners.

The panel understands the reasoning behind this, but is not in favour of reducing the number of credits for courses offered by other programmes. It might be hard, if not impossible, to determine for each elective how well a nanoscience student would do compared to regular students (who might be equally talented). The time and resources devoted to this could perhaps be better spent. As it is not against the rules of the university, as was also confirmed by the Board of Examiners, the programme is free to do so. Still, the panel suggests exploring other possibilities to solve this. An option could be to request students to do four electives without adapting the number of EC, and accept that some students will go over the 120 EC for the programme.

Considerations
The programme has a very solid system of assessment in place. The Assessment Plan links the intended learning outcomes to a variety of assessment types. The Board of Examiners is closely involved in the assessment policy of the programme and has put very good procedures and regulations in place in recent years. This includes a very good and insightful assessment form for the individual projects, procedures for implementing peer review for exams, and an annual quality check of a selected number of projects. The panel encourages the Board to keep up their good work while remaining aware of the pitfalls of a close student-supervisor relation that are common to this type

of small-scale programme. The further implementation of grading rubrics to align grading between supervisors might be useful to this end. Finally, the panel suggests exploring alternatives to reducing the number of EC for electives offered by other programmes.

Conclusion
Master's programme Nanoscience: the panel assesses Standard 3 as 'good'.

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

Findings
To assess the achieved learning outcomes of the programmes, the panel studied a sample of 16 theses (four for each panel member, excluding the student member), and interviewed several alumni of the programme. It was very impressed by the quality of the theses. In all cases, the students demonstrated that they far surpass the minimum level required for a master's programme. The theses show high-quality, independent work and a powerful demonstration of a wide variety of research skills that might be considered almost PhD-level quality. This is reflected in the high number of scientific publications in international peer-reviewed journals resulting from or incorporating elements from the master's theses: 23 since 2012. The topics are practically relevant as well as scientifically challenging and are on the cutting edge of new developments in nanoscience due to the embedding of the students in research groups. Additionally, graduates demonstrate that they are able to show true multidisciplinarity: combining topics on physics and chemistry on the master's level, an aim of the programme.

The main goal of the programme (to prepare excellent students for a PhD in nanoscience) is achieved very convincingly: 95% of the programme's graduates since 2012 went on to a PhD degree, either in Groningen (77%) or elsewhere (23%). Only three of the students in the past six years chose a different career path: two in industry and one unknown. The programme indicates that several students of the programme have been offered PhD positions by multiple universities, indicating that the programme's graduates are in high demand. The alumni expressed their satisfaction with the programme, both in the interviews and in evaluations performed by the programme. They feel well prepared for their PhD, and notice their head start in both nanoscience content and research skills compared to other PhD students. The panel is very impressed by the level of the programme's alumni, praising the exceptional percentage of graduates in a PhD programme.

Considerations
The students of the master's programmes convincingly show that they systematically far exceed the expected level for graduates of a master's programme. The theses are of an exceptional quality, and show in particular excellent research skills and multidisciplinarity. They are often of almost PhD-level quality, as is reflected in the high number of publishable theses. Almost all of the programme's alumni successfully continue on as PhD students, and are very well prepared for this.

Conclusion
Master's programme Nanoscience: the panel assesses Standard 4 as 'excellent'.

GENERAL CONCLUSION

The panel assesses Standards 1, 2 and 4 as 'excellent' and Standard 3 as 'good'.

According to the decision rules of NVAO's Framework for limited programme assessments, the panel assesses the master's programme Public Administration as 'excellent'.

Conclusion
The panel assesses the *master's programme Nanoscience* as 'excellent'.

APPENDICES

APPENDIX 1: INTENDED LEARNING OUTCOMES

The graduate of the Master's degree programme in Nanoscience:

LO 1. Has been trained in academic research in Nanoscience;

LO 2. Has the knowledge, skills and attitude that are needed for successful entrance and participation in a PhD programme;

LO 3. Has been trained on the importance of proper scientific conduct and responsible behaviour when performing research, and is aware of the social and ethical ramifications of scientific research and its applications;

LO 4. Has recent and profound knowledge of those parts of the disciplines of physics, chemistry, and mathematics that are relevant to Nanoscience, and has also knowledge of a selection of topics within molecular biology and medicine that are relevant to Nanoscience;

LO 5. Is able to apply this knowledge to solving realistic scientific problems in Nanoscience, even on the basis of a rudimentary problem specification;

LO 6. Is capable of acquiring within a limited time span sufficient knowledge to work in a different speciality within Nanoscience;

LO 7. Is capable of critically using the scientific literature in his/her chosen speciality;

LO 8. Is capable of both performing scientific studies and experiments and of interpreting its results;

LO 9. Can effectively convey results of scientific research, orally and in written form, to specialists as well as non-specialists;

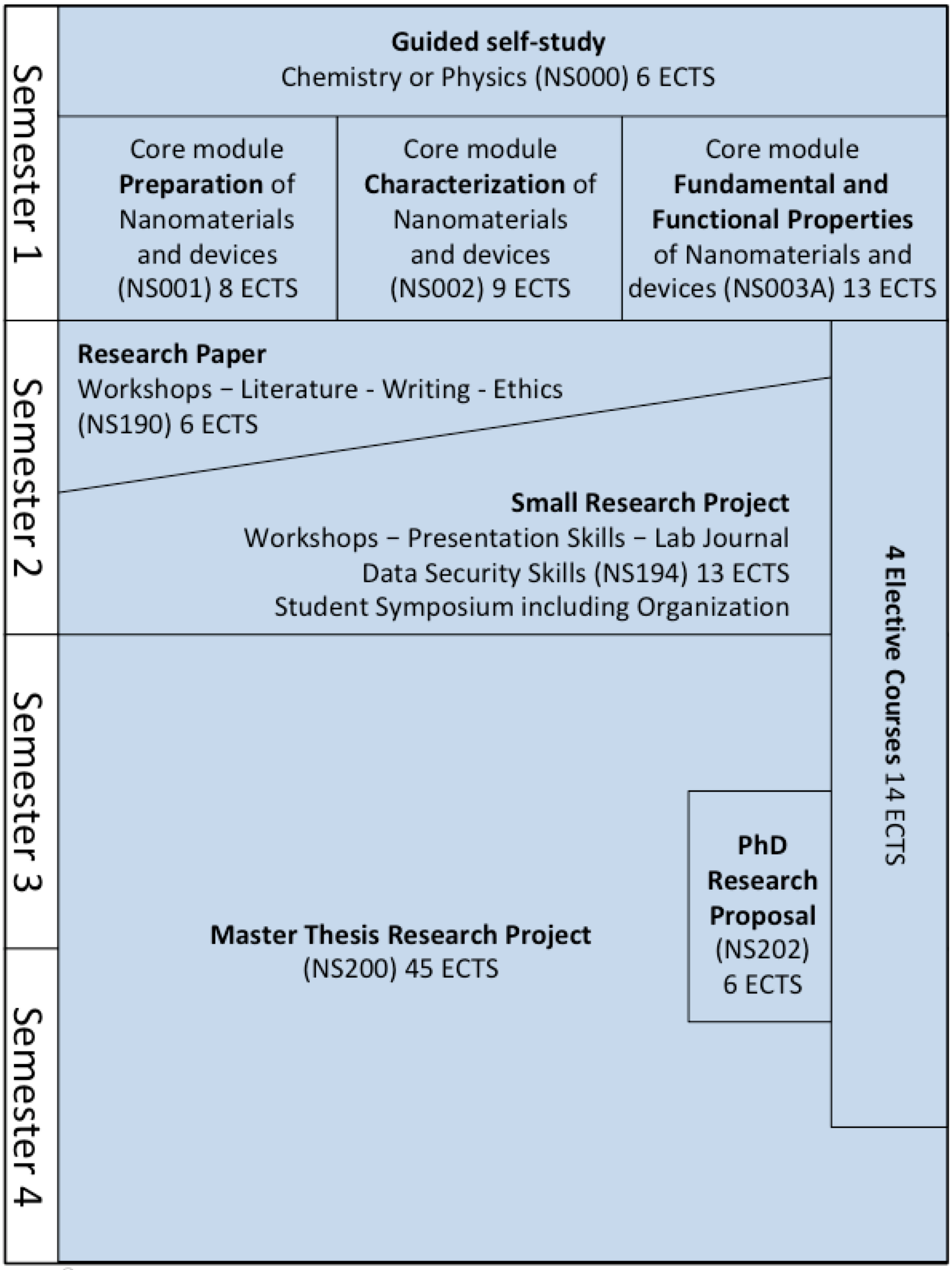
LO 10. Is capable of working independently;

LO 11. Can cooperate in a research team;

LO 12. Can formulate and defend a realistic and well-argued research plan based on a rudimentary problem specification;

LO 13. Is able to adapt to the rapid changes occurring in the field of Nanoscience.

APPENDIX 2: OVERVIEW OF THE CURRICULUM



APPENDIX 3: PROGRAMME OF THE SITE VISIT

Sunday 3 June 2018

17.00 – 19.00	Instructional panel meeting

Monday 4 June 2018

09.00 - 11.00	Arrival and welcome, preparation interviews
11.00 – 11.15	Presentation programme management
11.15 - 12.15	Interview programme management
12.15 - 12.45	Lunch
12.45 - 13.15	Reading documents
13.15 - 13.30	Presentations students
13.30 - 14.15	Interview students
14.15 - 15.00	Tour of the facilities
15.00 - 15.30	Closed meeting
15.30 - 16.15	Interview lecturers
16.15 – 16.20	Break
16.20 - 17.00	Interview programme committee
17.00 - 17.15	Break
17.15 - 18.00	Interview alumni

Tuesday 5 June 2018

09.00 - 09.45	Closed meeting
09.45 - 10.30	Interview board of examiners
10.30 - 11.00	Preparation concluding meeting with management
11.00 - 11.45	Concluding meeting and development dialogue with management
11.45 - 13.30	Drafting final findings (incl. lunch)
13.30 - 13.45	Oral feedback by panel chair

APPENDIX 4: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 16 theses of the master's programme Nanoscience (four for each panel member, excluding the student member). 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 courses:
- Guided-Self Study in Nanoscience
- Preparation of Nanomaterials and Devices
- Characterization of Nanomaterials
- Fundamental and Functional Properties of Nanomaterials
- Research Paper
- Small Research Project and Symposium
- Research Proposal
- Master thesis Nanoscience

Additional materials:
- Annual Reports of, and assessments by Board of Examiners
- Annual Reports Programme Committee
- Annual Reports Admissions Board
- Report External Advisory Panel
- Report staff meeting
- Student Satisfaction Survey (graduates 2017)
- Scores National Student Survey (2017)
- Scores Master Keuzegids 2018
- Education monitor
- Teaching and Examination Regulations
- Assessment plan Nanoscience (and list of examiners) 2017-2018
- Rules of Procedure for the Programme Committee Nanoscience
- Programme Committee Handbook UG 2017-2018
- Quality Assurance documents for Boards of Examiners FSE
- Quality Assurance Manual for Teaching Staff
- Quality Assurance Manual FSE 2016-2017
- Instellingstoets kwaliteitszorg RUG 2014
- Folder Scientific Publications
- Posters of scientific presentations of Nanoscience students